LIGO VACUUM EQUIPMENT

FINAL DESIGN REPORT

CDRL 03

VOLUME TABLE OF CONTENT

VOLUME	TITLE
Volume I	Project Management Plan
Volume II	Design
Volume II Attachment 1	Calculations
Volume II Attachment 2	Calculations
Volume II Attachment 3	Calculations
Volume II Attachment 4	Calculations
Volume II Attachment 5	Specifications/Misc.
Volume III	Fabrication
Volume IV	Installation/Commissioning
Volume V	
Book 1	Mechanical Drawing
Book 2	Electrical Drawing

LIGO VACUUM EQUIPMENT

FINAL DESIGN REPORT

CDRL 03

VOLUME III
FABRICATION

1.0 FABRICATION PLAN

- 1.1 General
- 1.2 Material Control
- 1.3 Control of Special Processes
- 1.4 Change Control
- 1.5 Quality Assurance Program
- 1.6 Safety Program
- 1.7 Contamination Control
- 1.8 Training
- 1.9 Schedule

2.0 BEAM SPLITTER (BSC)

- 2.1 BSC Fabrication Plan V049-2-080
- 2.2 BSC Fabrication Specification V049-2-117
- 2.3 BSC Quality Plan V049-2-048
- 2.4 BSC Testing / Inspections

3.0 HORIZONTAL ACCESS MODULE (HAM)

- 3.1 HAM Fabrication Plan V049-2-081
- 3.2 HAM Fabrication Specification V049-2-078
- 3.3 HAM Quality Plan V049-2-087
- 3.4 HAM Testing / Inspections

4.0 80K PUMPS

- 4.1 80K Pump Fabrication Plan V049-2-082
- 4.2 80K Pump Fabrication Specification V049-2-096
- 4.3 80K Pump Quality Plan V049-2-098
- 4.4 80K Pump Testing / Inspections

5.0 SPOOLS/MODE CLEANERS/BEAM TUBE MANIFOLDS

- 5.1 Spool/Manifold Fabrication Plan V049-2-083
- 5.2 Spool/Manifold Fabrication Specification V049-2-097
- 5.3 Spool/Manifold Quality Plan V049-2-099
- 5.4 Spool/Manifold Testing / Inspections

6.0 MISC COMPONENTS

- 6.1 General
- 6.2 Manufacturing Documentation/Q.A.
- 6.3 Testing

7.0 SPECIAL EQUIPMENT REQUIREMENTS

- 7.1 General
- 7.2 Vessel Fixtures
- 7.3 Washing System
- 7.4 Clean Manufacturing Space

FDR VOLUME III
ATTACHMENTS

1.	Raw Material Handling Procedure	V049-2-120
2.	Control Of Non-Conformance	V049-2-124
3.	Weld Data Specifications	V049-2-084
4.	Weld Procedures	V049-2-070 V049-2-071 V049-2-072 V049-2-073
5.	Cleaning Procedures	V049-2-015
6.	Stress Relief Procedure (304 S.S.)	V049-2-046
7.	Component Bakeout Procedure	V049-2-019
8.	Leak Testing Procedure	V049-2-014
9.	Clean Room Activities	V049-2-118
10.	Dimensional Verification Procedure	V049-2-121
11.	Component Packaging, Handling and Shipping Procedure	V049-2-123
12.	Project Q.A. Plan	V049-2-029
13.	Project Safety Plan	V049-2-023
14.	Viton O-Ring Bakeout Procedure	V049-2-122
15.	Component Shop Conditioning/Test Plan	V049-2-047
16.	Contamination Control Plan	V049-2-119
17.	Material Control Procedure	V048-2-125

FDR VOLUME III
ATTACHMENTS

1.	Raw Material Handling Procedure	V049-2-120
2.	Control Of Non-Conformance	V049-2-124
3.	Weld Data Specifications	V049-2-084
4.	Weld Procedures	V049-2-070 V049-2-071 V049-2-072 V049-2-073
5.	Cleaning Procedures	V049-2-015
6.	Stress Relief Procedure (304 S.S.)	V049-2-046
7.	Component Bakeout Procedure	V049-2-019
8.	Leak Testing Procedure	V049-2-014
9.	Clean Room Activities	V049-2-118
10.	Dimensional Verification Procedure	V049-2-121
11.	Component Packaging, Handling and Shipping Procedure	V049-2-123
12.	Project Q.A. Plan	V049-2-029
13.	Project Safety Plan	V049-2-023
14.	Viton O-Ring Bakeout Procedure	V049-2-122
15.	Component Shop Conditioning/Test Plan	V049-2-047
16.	Contamination Control Plan	V049-2-119
17.	Material Control Procedure	V048-2-125

1.0 FABRICATION PLAN

1.1 General

The Fabrication Plan has been developed to efficiently execute the fabrication of LIGO Vacuum Equipment with minimum risk to project performance goals, project schedule and personnel safety.

The entire fabrication/testing program will be executed under strict quality assurance and safety requirements. Raw materials and finished components will be protected from contamination throughout the fabrication process.

Extensive testing has been conducted during the final design phase to validate manufacturing, ultra high vacuum (UHV) cleaning and testing techniques prior to releasing the main vacuum equipment for fabrication. Additional proactive risk management techniques will continue to be used during the entire fabrication program.

As part of the Final Design Effort, PSI has reviewed the manufacturing options for the vacuum equipment system. PSI has decided to manufacture and process all components from its Westborough, MA facility. Some components (BSC & HAM chambers) will be mechanically fabricated by outside machine shop/fabrication contractors. Components fabricated by outside vendors will be shipped to PSI for final cleaning, leak checking, bakeout and preparation for shipment.

PSI is currently modifying its Westborough Manufacturing Facility to provide clean manufacturing space for the LIGO project. In addition, 10,000 sq. ft. of clean room/UHV test space has been leased 1/4 mile from the Westborough Manufacturing shop.

PSI is also building an automated UHV cleaning system to perform the final wash of the LIGO components. This automated system will ensure consistent cleaning to the required UHV levels.

As a final step in the fabrication process, LIGO components will be evacuated and wrapped for shipment to the site.

The remainder of this volume details the systems, procedures and resources that will be used to fabricate the LIGO Vacuum Equipment.

1.2 Material Control

Materials and items are inspected against the requirements of the purchase order during receipt inspections. Material identification and traceability 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 Material Control Department and maintained under their control until released to Manufacturing. All rejected material is marked and returned to the vendor. It is not stored with the accepted project material.

Where it is necessary to maintain permanent markings or identification on materials or components, they 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.

All components will be assigned a unique mark number and a serial number. See “Material Control Procedure” V049-2-125 for additional details.

1.3 Control Of Special Processes

All manufacturing special processes (welding, heat treating, 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 traceability to recognized National Standards.

1.4 Change Control

Controlled documents and drawings are issued to the Manufacturing Department. They are controlled (issued and recalled) by the Material Control Department. The documents and/or drawings issued are recorded on a log sheet maintained by the Material Control Department. When a new revision is issued, it is their responsibility to remove 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 Quality Assurance Department to check the issued documents and drawings in the manufacturing area to confirm that the latest revision of each is in use.

All requests for change initiated after the Final Design approval by LIGO will be controlled by PSI procedure SOP-006-001. This involves a formal "Request for Change" document with controlled review and approvals.

All outside fabrication vendors will be issued drawings and other engineering documents via the PSI Document Control Department. All transmittals are logged into the document control department data base which is available to PSI LIGO team members thru the PSI engineering network.

1.5 Project Quality Assurance Program

1.5.1 Q.A. Organization

The PSI Q.A. organization will monitor both in-house fabrication activities and outside fabrication contractors.

The quality assurance organization is headed by the PSI Quality Assurance Manager, who has a staff of Quality Assurance Engineers/Inspectors. The Receiving Inspection Department is made up of full-time inspectors also reporting to the QA Manager. The QA Manager has the authority and is responsible for implementing the quality program. In addition, he provides policy administrative guidance to the QA and Inspection Departments.

A lead Q.A. engineer has been assigned to the project for the life of the project. Other engineers and inspectors will be utilized as required.

1.5.2 Project Q.A. Plan

The LIGO Q.A. plan is detailed in V049-2-029. (See Attachment 12).

1.5.3 Supplier Q.A.

Suppliers of LIGO equipment and materials will be monitored for quality and technical performance by a combination of engineering and quality assurance personnel. For major equipment purchases, vendor kickoff meetings, in progress reviews and witnessed performance testing will be conducted.

1.5.4 Training/Qualification Program

The Q.A. department will ensure that all personnel performing special skill tasks (TIG welding, leak checks, etc.) on the LIGO project have been trained and qualified to perform their assigned duties.

1.6 Safety Program

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

The Project Safety Plan V049-2-023 (Attachment 13) details the safety organization, objectives of the safety program and plans for project execution.

"Confined Space" entry procedures will be strictly enforced at all times.

1.7 Contamination Control

LIGO components must be cleaned and maintained at UHV cleanliness levels to achieve vacuum equipment performance goals.

Each step in the manufacturing process has been designed to minimize contamination of raw materials, contamination of finished assemblies after cleaning and contamination during shipping. (See "Contamination Control Plan" V049-2-119 for additional details).

1.8 Training/Qualification

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

PAW Welding Process

GTAW Welding Process

UHV Manufacturing

Cleanroom Protocol

UHV Cleaning

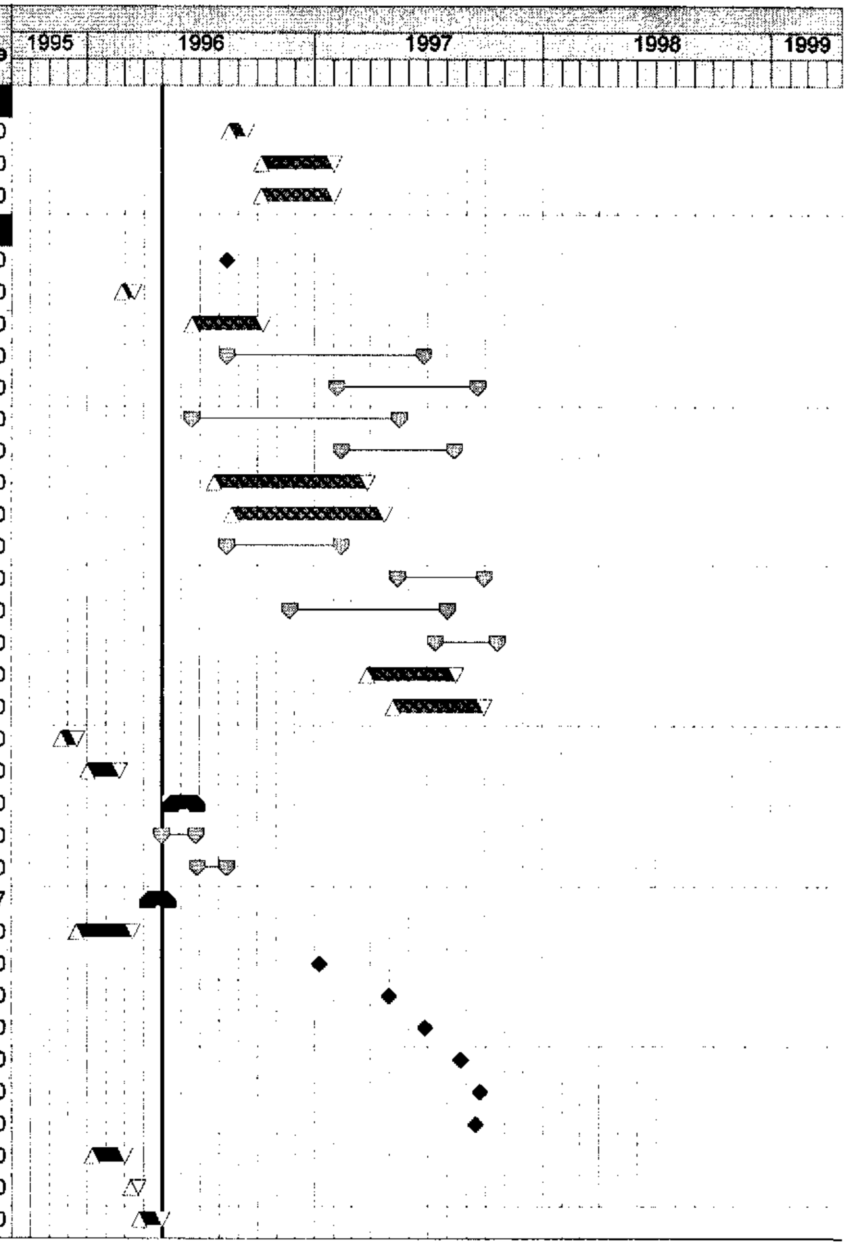
1.9 Schedule

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

MANUFACTURING SCHEDULE

(Sorted by System / Activity ID)

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
SAME - Common Engineering / Design Activities					
181	Prepare cut sheets from piping isometrics	20	16AUG96	13SEP96	0
182	Fab/deliver WA pipe spools	80	07OCT96	31JAN97	0
183	Fab/deliver LA pipe spools	80	07OCT96	31JAN97	0
VACE - Vacuum Envelope					
19	Complete Prototype Vessel Tests	0		13AUG96	0
203	Design BSC chamber fab fixtures	15	26FEB96 A	15MAR96 A	100
229	Order mat'l & fab test/shipping covers	80	18JUN96	09OCT96	0
244	BSC's - Fab and test WA vessels (10)	218 *	14AUG96	24JUN97	0
245	BSC's - Fab and test LA vessels (5)	158 *	06FEB97	18SEP97	0
246	HAM's - Fab and test WA vessels (12)	232 *	18JUN96	16MAY97	0
247	HAM's - Fab and test LA vessels (6)	127 *	13FEB97	12AUG97	0
248	WA Beam Tube Manifolds / Spools / Adapters - Fab	170	24JUL96	26MAR97	0
249	WA BTM/Spools/Adapters - Clean/test/prep to ship	170	21AUG96	23APR97	0
250	Long 80K Cryopumps - Fab & test WA pumps (2)	125 *	14AUG96	12FEB97	0
251	Long 80K Cryopumps - Fab & test LA pumps (2)	95 *	15MAY97	29SEP97	0
252	Short 80K Cryopumps - Fab & test WA pumps (6)	175 *	22NOV96	01AUG97	0
253	Short 80K Cryopumps - Fab & test LA pumps (2)	70 *	14JUL97	20OCT97	0
254	LA Beam Tube Manifolds / Spools / Adapters - Fab	100	27MAR97	15AUG97	0
255	LA BTM/Spools/Adapters - Clean/test/prep to ship	100	08MAY97	29SEP97	0
280	Procure a plasma welding machine	20	20NOV95 A	15DEC95 A	100
281	Qualify Welding Procedure for Plasma Welding	10	02JAN96 A	22FEB96 A	100
290	Short 80K Cryopump - Fab shroud for prototype	30	15MAY96	26JUN96	0
295	Fabricate Prototype BSC Vessel	38 *	01MAY96	24JUN96	0
296	Test program for Prototype vessel	33 *	27JUN96	13AUG96	0
297	Fabricate chamber fab fixtures	15	08APR96 A	10MAY96	47
298	Order mat'l for test/ship covers for prototype	40	15DEC95 A	13MAR96 A	100
13A	Complete fab on 1/3 of WA vessels	0		08JAN97	0
13B	Complete fab on 2/3 of WA vessels	0		30APR97	0
13C	Complete fab of all WA vessels	0		26JUN97	0
14A	Complete fab on 1/3 of LA vessels	0		22AUG97	0
14B	Complete fab on 2/3 of LA vessels	0		22SEP97	0
14C	Complete fab of all LA vessels	0		15SEP97	0
260B	10" Benchscale Vessel - Procure materials	30	09JAN96 A	01MAR96 A	100
260C	10" Benchscale Vessel - Fabricate vessel	10	11MAR96 A	22MAR96 A	100
260E	10" Benchscale Vessel - Order matl/fab new sectn	15	25MAR96 A	30APR96 A	100



PSI

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

Process Systems International, Inc.

LIGO Vacuum System Project

Manufacturing Schedule 1Aof5A

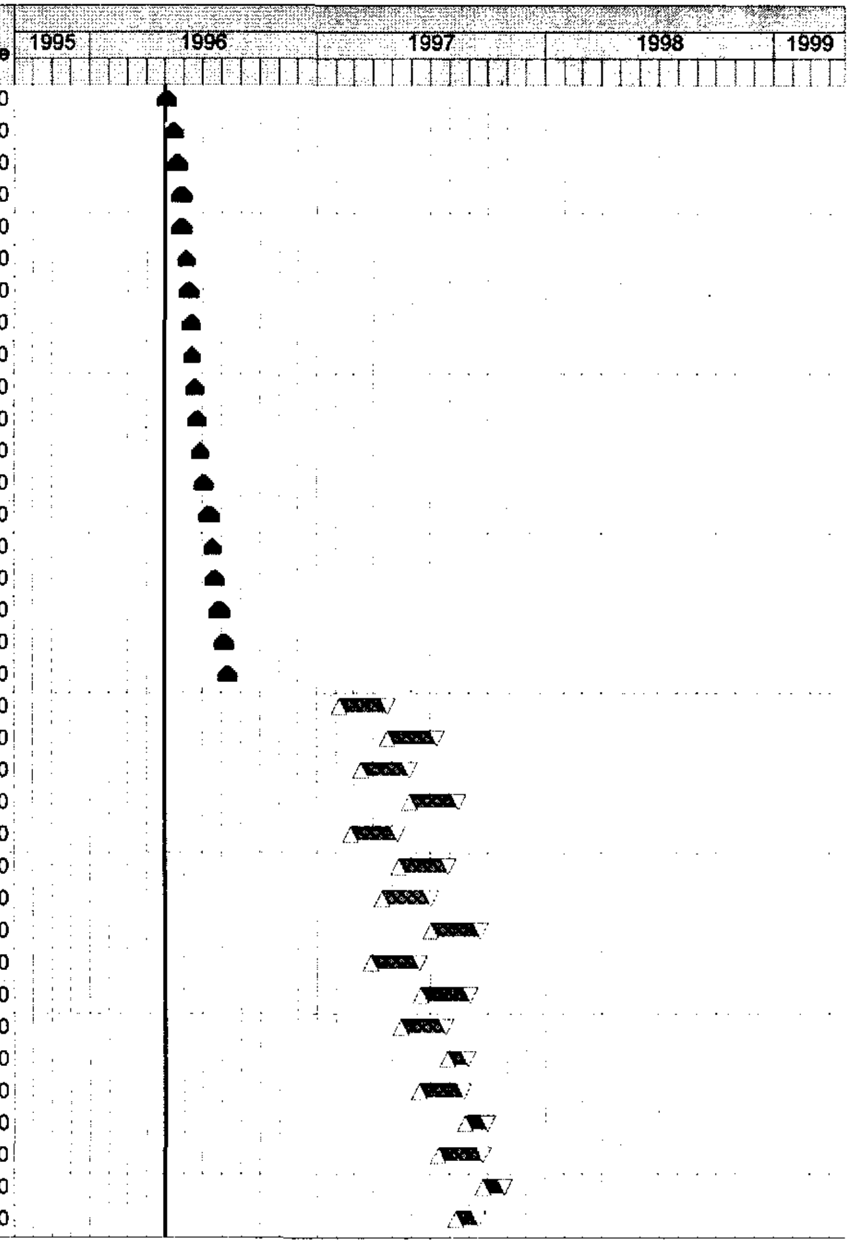
Data date 01MAY96

Run date 03MAY96

Filter Manufacturing Activities Only
Layout System

Date	Revision	Checked	Approved
03MAY96	Final Design Pkg	PFH	REB

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
295A	Prototype BSC Fab - Roll/weld shell (outside)	4	01MAY96	06MAY96	0
295B	Prototype BSC Fab - Weld on heads (outside)	4	13MAY96	16MAY96	0
295C	Prototype BSC Fab - Cut/weld nozzle necks	5	17MAY96	23MAY96	0
295D	Prototype BSC Fab - Machine flanges/blinds (out)	5	24MAY96	31MAY96	0
295E	Prototype BSC Fab - Stress relieve (outside)	5	24MAY96	31MAY96	0
295F	Prototype BSC Fab - Square off nozzles (outside)	2	03JUN96	04JUN96	0
295G	Prototype BSC Fab - Weld on flanges	4	05JUN96	10JUN96	0
295H	Prototype BSC Fab - Install welded attachments	3	11JUN96	13JUN96	0
295I	Prototype BSC Fab - Install internal floor suppt	1	14JUN96	14JUN96	0
295J	Prototype BSC Fab - Install annulus tubing & pmp	3	17JUN96	19JUN96	0
295K	Prototype BSC Fab - Clean chamber to spec	3	20JUN96	24JUN96	0
296A	Start prototype testing program	2	27JUN96	28JUN96	0
296B	Prototype Test - Rough leak check	4	01JUL96	05JUL96	0
296C	Prototype Test - Bakeout	7	08JUL96	16JUL96	0
296D	Prototype Test - Perform dimensional check	1	17JUL96	17JUL96	0
296E	Prototype Test - Final leak check	4	18JUL96	23JUL96	0
296F	Prototype Test - Ultimate pressure test	7	24JUL96	01AUG96	0
296G	Prototype Test - Install cryopump shroud	4	02AUG96	07AUG96	0
296H	Prototype Test - Vibration/boiloff test	4	08AUG96	13AUG96	0
LBSC01F	LBSC1 - Outside fabrication	55	06FEB97	23APR97	0
LBSC01T	LBSC1 - Final fab/clean/test/prep for ship	55	24APR97	11JUL97	0
LBSC02F	LBSC2 - Outside fabrication	55	12MAR97	28MAY97	0
LBSC02T	LBSC2 - Final fab/clean/test/prep for ship	55	29MAY97	14AUG97	0
LBSC03F	LBSC3 - Outside fabrication	55	24FEB97	09MAY97	0
LBSC03T	LBSC3 - Final fab/clean/test/prep for ship	55	12MAY97	29JUL97	0
LBSC04F	LBSC4 - Outside fabrication	55	15APR97	01JUL97	0
LBSC04T	LBSC4 - Final fab/clean/test/prep for ship	55	02JUL97	18SEP97	0
LBSC05F	LBSC5 - Outside fabrication	55	28MAR97	13JUN97	0
LBSC05T	LBSC5 - Final fab/clean/test/prep for ship	55	16JUN97	02SEP97	0
LCP1F	LCP1 - Fabricate long 80K cryopump	50	15MAY97	25JUL97	0
LCP1T	LCP1 - Final clean/test/prep to ship long pump	25	28JUL97	29AUG97	0
LCP2F	LCP2 - Fabricate long 80K cryopump	50	13JUN97	22AUG97	0
LCP2T	LCP2 - Final clean/test/prep to ship long pump	25	25AUG97	29SEP97	0
LCP3F	LCP3 - Fabricate short 80K cryopump	50	14JUL97	22SEP97	0
LCP3T	LCP3 - Final clean/test/prep to ship short pump	25	23SEP97	27OCT97	0
LCP4F	LCP4 - Fabricate short 80K cryopump	25	11AUG97	15SEP97	0



PSI

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

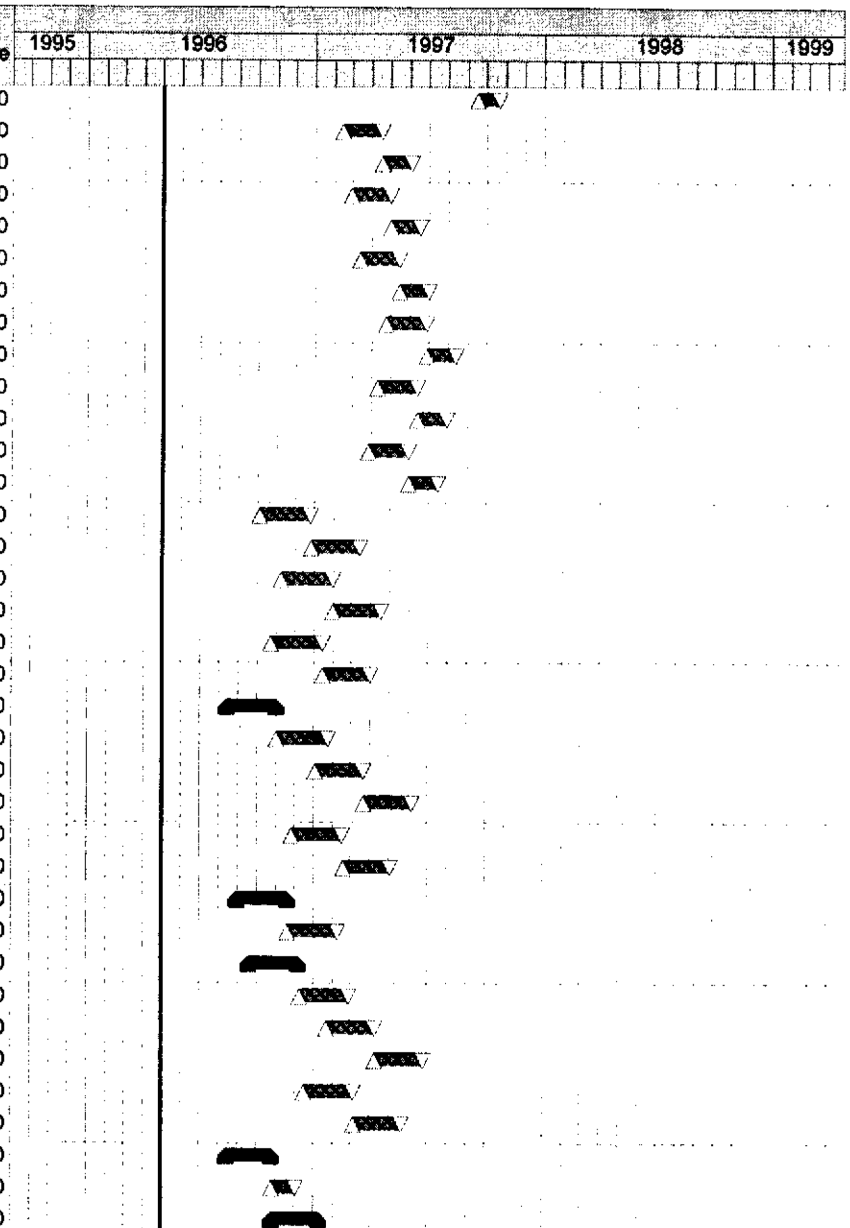
Process Systems International, Inc.

LIGO Vacuum System Project

Manufacturing Schedule 2Aof5A

Data date	01MAY96	Date	Revision	Checked	Approved
Run date	03MAY96	03MAY96	Final Design Pkg	PFH	REB
Filter	Manufacturing Activities Only				
Layout	System				

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
LCP4T	LCP4 - Final clean/test/prep to ship short pump	25	16SEP97	20OCT97	0
LHAM01F	LHAM1 - Outside fabrication	45	13FEB97	16APR97	0
LHAM01T	LHAM1 - Final fab/clean/test/prep for ship	32	17APR97	02JUN97	0
LHAM02F	LHAM2 - Outside fabrication	45	27FEB97	30APR97	0
LHAM02T	LHAM2 - Final fab/clean/test/prep for ship	32	01MAY97	16JUN97	0
LHAM03F	LHAM3 - Outside fabrication	45	13MAR97	14MAY97	0
LHAM03T	LHAM3 - Final fab/clean/test/prep for ship	32	15MAY97	30JUN97	0
LHAM04F	LHAM4 - Outside fabrication	45	24APR97	26JUN97	0
LHAM04T	LHAM4 - Final fab/clean/test/prep for ship	32	27JUN97	12AUG97	0
LHAM05F	LHAM5 - Outside fabrication	45	10APR97	12JUN97	0
LHAM05T	LHAM5 - Final fab/clean/test/prep for ship	32	13JUN97	29JUL97	0
LHAM06F	LHAM6 - Outside fabrication	45	27MAR97	29MAY97	0
LHAM06T	LHAM6 - Final fab/clean/test/prep for ship	32	30MAY97	15JUL97	0
WBSC01F	WBSC1 - Outside fabrication	55	04OCT96	24DEC96	0
WBSC01T	WBSC1 - Final fab/clean/test/prep for ship	55	26DEC96	13MAR97	0
WBSC02F	WBSC2 - Outside fabrication	55	08NOV96	29JAN97	0
WBSC02T	WBSC2 - Final fab/clean/test/prep for ship	55	30JAN97	16APR97	0
WBSC03F	WBSC3 - Outside fabrication	55	23OCT96	13JAN97	0
WBSC03T	WBSC3 - Final fab/clean/test/prep for ship	55	14JAN97	31MAR97	0
WBSC04F	WBSC4 - Outside fabrication	55	14AUG96	31OCT96	0
WBSC04T	WBSC4 - Final fab/clean/test/prep for ship	55	01NOV96	22JAN97	0
WBSC05F	WBSC5 - Outside fabrication	55	03JAN97	20MAR97	0
WBSC05T	WBSC5 - Final fab/clean/test/prep for ship	55	21MAR97	06JUN97	0
WBSC06F	WBSC6 - Outside fabrication	55	26NOV96	14FEB97	0
WBSC06T	WBSC6 - Final fab/clean/test/prep for ship	55	17FEB97	02MAY97	0
WBSC07F	WBSC7 - Outside fabrication	55	30AUG96	18NOV96	0
WBSC07T	WBSC7 - Final fab/clean/test/prep for ship	55	19NOV96	07FEB97	0
WBSC08F	WBSC8 - Outside fabrication	55	18SEP96	06DEC96	0
WBSC08T	WBSC8 - Final fab/clean/test/prep for ship	55	09DEC96	25FEB97	0
WBSC09F	WBSC9 - Outside fabrication	55	21JAN97	07APR97	0
WBSC09T	WBSC9 - Final fab/clean/test/prep for ship	55	08APR97	24JUN97	0
WBSC10F	WBSC10 - Outside fabrication	55	16DEC96	04MAR97	0
WBSC10T	WBSC10 - Final fab/clean/test/prep for ship	55	05MAR97	20MAY97	0
WCP1F	WCP1 - Fabricate long 80k cryopump	50	14AUG96	24OCT96	0
WCP1T	WCP1 - Final clean/test/prep for ship long pump	25	25OCT96	02DEC96	0
WCP2F	WCP2 - Fabricate long 80K cryopump	50	25OCT96	08JAN97	0



PSI

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

Process Systems International, Inc.

LIGO Vacuum System Project

Manufacturing Schedule 3Aof5A

Data date 01MAY96
Run date 03MAY96
Filter Manufacturing Activities Only
Layout System

Date	Revision	Checked	Approved
03MAY96	Final Design Pkg	PFH	REB

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
WHAM12T	WHAM12 - Final fab/clean/test/prep for ship	32	25OCT96	11DEC96	0
WHAM13F	WHAM13 - Outside fabrication	45	30JAN97	02APR97	0
WHAM13T	WHAM13 - Final fab/clean/test/prep for ship	32	03APR97	16MAY97	0
CTRL - Instrumentation and Controls					
515	Ion Pump Controller Cabinets - Size and specify	20	26FEB96 A	24APR96 A	100
599	LIGO Test Eqt & Cleanroom Training	40	18MAR96 A	13MAY96	78
BAKE - Bakeout Subsystem					
720	Bakeout Carts - Assemble 1st cart	31	04APR96 A	17MAY96	58
730	Bakeout Carts - Test 1st bakeout cart	20	29MAY96	25JUN96	0
732	Bakeout Carts - Assemble 5 carts	60	25JUL96	18OCT96	0
733	Bakeout Carts - Test 5 carts	60	21OCT96	16JAN97	0

1995 1996 1997 1998 1999

PSI

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

Process Systems International, Inc.

LIGO Vacuum System Project

Manufacturing Schedule 5Aof5A

Data date	01MAY96	Date	Revision	Checked	Approved
Run date	03MAY96	03MAY96	Final Design Pkg	PFH	REB
Filter	Manufacturing Activities Only				
Layout	System				

Act ID	Description	Orig Dur	Early Start	Early Finish	Percent Complete
WCP2T	WCP2 - Final clean/test/prep to ship long pump	25	09JAN97	12FEB97	0
WCP3F	WCP3F - Fabricate short 80K cryopump	50	22NOV96	05FEB97	0
WCP3T	WCP3 - Final clean/test/prep to ship short pump	25	06FEB97	12MAR97	0
WCP4F	WCP4 - Fabricate short 80K cryopump	50	24DEC96	05MAR97	0
WCP4T	WCP4 - Final clean/test/prep to ship short pump	25	06MAR97	09APR97	0
WCP5F	WCP5 - Fabricate short 80K cryopump	50	20FEB97	30APR97	0
WCP5T	WCP5 - Final clean/test/prep to ship short pump	25	01MAY97	05JUN97	0
WCP6F	WCP6 - Fabricate short 80K cryopump	50	20MAR97	29MAY97	0
WCP6T	WCP6 - Final clean/test/prep to ship short pump	25	30MAY97	03JUL97	0
WCP7F	WCP7 - Fabricate short 80K cryopump	50	23JAN97	02APR97	0
WCP7T	WCP7 - Final clean/test/prep to ship short pump	25	03APR97	07MAY97	0
WCP8F	WCP8 - Fabricate short 80K cryopump	50	17APR97	26JUN97	0
WCP8T	WCP8 - Final clean/test/prep to ship short pump	25	27JUN97	01AUG97	0
WHAM01F	WHAM1 - Outside fabrication	45	18JUN96	20AUG96	0
WHAM01T	WHAM01 - Final fab/clean/test/prep for ship	32	21AUG96	04OCT96	0
WHAM02F	WHAM2 - Outside fabrication	45	15NOV96	22JAN97	0
WHAM02T	WHAM2 - Final fab/clean/test/prep for ship	32	23JAN97	07MAR97	0
WHAM03F	WHAM3 - Outside fabrication	45	03DEC96	05FEB97	0
WHAM03T	WHAM3 - Final fab/clean/test/prep for ship	32	06FEB97	21MAR97	0
WHAM04F	WHAM4 - Outside fabrication	45	16JAN97	19MAR97	0
WHAM04T	WHAM4 - Final fab/clean/test/prep for ship	32	20MAR97	02MAY97	0
WHAM05F	WHAM5 - Outside fabrication	45	02JAN97	05MAR97	0
WHAM05T	WHAM5 - Final fab/clean/test/prep for ship	32	06MAR97	18APR97	0
WHAM06F	WHAM6 - Outside fabrication	45	17DEC96	19FEB97	0
WHAM06T	WHAM6 - Final fab/clean/test/prep for ship	32	20FEB97	04APR97	0
WHAM07F	WHAM7 - Outside fabrication	45	03OCT96	09DEC96	0
WHAM07T	WHAM7 - Final fab/clean/test/prep for ship	32	10DEC96	24JAN97	0
WHAM08F	WHAM8 - Outside fabrication	45	18OCT96	23DEC96	0
WHAM08T	WHAM8 - Final fab/clean/test/prep for ship	32	24DEC96	07FEB97	0
WHAM09F	WHAM9 - Outside fabrication	45	01NOV96	08JAN97	0
WHAM09T	WHAM9 - Final fab/clean/test/prep for ship	32	09JAN97	21FEB97	0
WHAM10F	WHAM10 - Outside fabrication	45	19SEP96	21NOV96	0
WHAM10T	WHAM10 - Final fab/clean/test/prep for ship	32	22NOV96	10JAN97	0
WHAM11F	WHAM11 - Outside fabrication	45	05SEP96	07NOV96	0
WHAM11T	WHAM11 - Final fab/clean/test/prep for ship	32	08NOV96	26DEC96	0
WHAM12F	WHAM12 - Outside fabrication	45	21AUG96	24OCT96	0

1995 1996 1997 1998 1999

PSI

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

Process Systems International, Inc.

LIGO Vacuum System Project

Manufacturing Schedule 4Aof5A

Data date 01MAY96

Run date 03MAY96

Filter Manufacturing Activities Only
Layout System

Date	Revision	Checked	Approved
03MAY96	Final Design Pkg	PFH	REB

2.1 BSC Fabrication Plan V049-2-080

FABRICATION PLAN

FOR

BEAM SPLITTER CHAMBERS (BSC)

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Phillip Farland

QUALITY ASSURANCE: Alan L. Bradbrook

MANUFACTURING ENGINEER: Phillip Farland

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayley

Ø	PEF 5/1/96	DMW	ISSUE PER DEO 0161 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED PEF	DATE 5/1/96	APPROVED REB	DATE 5/2/96	Number A V049-2-080	Rev. Ø

Title FABRICATION PLAN FOR BEAM SPLITTER CHAMBERS (BSC)

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibility

4.0 Fabrication Plan

ATTACHMENTS:

1. BSC Fabrication Documents

2. Fabrication Flow Chart

3. Fabrication Priority List

Number

Rev.

1.0 PURPOSE

The purpose of this procedure is to define design guidelines, specifications, and procedures to enable PSI to specify, purchase, inspect, fabricate, test and ship the BSC chambers per LIGO requirements.

2.0 GENERAL

All Beam Splitter Chambers (BSC) shall be fabricated per this fabrication plan. Each fabrication process shall be controlled via a written procedure. A "first article" approach will be used to validate all fabrication processes prior to release of the full vessel lot.

All vessels will be fabricated in accordance with the Quality Plan. Key points in the fabrication process shall be verified to ensure consistent results.

All vacuum equipment shall be fabricated in accordance with LIGO Project Contract PC175730 dated September 12, 1995, and subsequent change orders.

3.0 RESPONSIBILITY

The Manufacturing Department is responsible for the execution of this procedure, with input and monitoring by the Project Engineer, the Quality Assurance Department, and the Project Manager.

4.0 FABRICATION PLAN

4.1 A first article approach (i.e. BSC prototype) will be used to start the BSC manufacturing cycle to validate the manufacturing procedures and technique prior to the full production release.

4.2 The BSC chambers will be fabricated using an outside manufacturing shop. PSI will perform vessel cleaning, leak checking, bakeout and preparation for shipment.

4.3 All BSC will be fabricated and tested per documents listed in Attachment I "Fabrication Documents".

4.4 The BSC will be fabricated and tested per Attachment 2 BSC Fabrication Flow Chart.

4.5 The BSC Chambers will be fabricated according to the Fabrication Priority List Attachment 3.

4.6 Procurement

PSI will procure all S.S. plate and flange material and supply it with the selected fabrication vendor.

PSI will purchase vessel heads and supply them to the selected fabrication vendor.

4.7 Quality Assurance

The BSC Fabrication Process shall be monitored and control via the Quality Plan.

Outisde fabrication vendors will perform the quality plan inspections for their portion of the work. PSI will witness critical process inspections as detailed in the Quality Plan.

PSI will audit each major fabrication vendor's Q.A. Program after P.O. awards.

PSI and fabrication vendors will inspect all incoming materials to purchase documents.

4.8 Shop Conditioning/Testing

The Beam Splitter Chambers will be shop conditioned (cleaned, bakeout, etc.) per PSI Procedure V049-2-047.

4.9 Preparation For Shipment

The Beam Splitter Chambers will be prepared and shipped per PSI Procedure V049-2-123.

ATTACHMENT 1

BSC FABRICATION DOCUMENTS

1.	Spec. For Beam Splitter Chamber (BSC)	V049-2-117
2.	Spec. For Beam Splitter Chamber Quality Plan	V049-2-048
3.	Bill of Material	V049-4-001
4.	Flanges	V049-2-040 & V049-2-042
5.	Heads	V049-2-039
6.	Raw Material Handling Procedure	V049-2-120
7.	Weld Data Sheet Spec.	V049-2-084
8.	Weld Procedures	V049-2-070, V049-2-071, V049-2-072, V049-2-073
9.	Weld Repair Procedure	V049-2-074
10.	Cleaning Procedures	V049-2-015
11.	Painting Procedures	V049-2-077
12.	Stress Relief Procedures	V049-2-046
13.	Bakeout Procedure	V049-2-019
14.	Leak Test Procedure	V049-2-014
15.	Components Shop Conditioning/Test Plan	V049-2-047
16.	Dimensional Verification Procedure	V049-2-121
17.	Component Packing, Handling, and Shipping Procedure	V049-2-123
18.	PSI Drawings	
	BSC Assembly	V049-4-001
	Chamber Supports	V049-4-023
	60" Port Cover	V049-4-014
	60 1/2" ID Flange (Grooved)	V049-4-019
	104.5" ID Flange	V049-4-022
	Floor Assembly	V049-4-036

BSC FABRICATION PROCESS

SHT. 1 OF 2

LOWER SHELL

REF. DWG. V049-4-001 (5 SHTS)

LEGEND
NUMBERS=PSI MANUFACTURING ACTIVITY
LETTERS=MACHINE SHOP ACTIVITY (VENDOR)

- PSI FINALIZES MACHINING DWGS. & ISSUES WITH SPECS. TO MACHINE SHOP
- A — CHECK/VERIFY MACH. SHOP NOZZLE LOCATIONS
- 5 — • PSI FIXTURE-DESIGN/FAB. SHIP FIXTURE TO VENDOR • PLATE/FORGINGS DROP SHIPPED TO MACHINE SHOP • HEADS SHIP TO VENDOR
- B — SPECIAL HANDLING/LIFTING REQUIREMENTS USED TO PREVENT SS/CS CONTACT (NO CONTAMINATES)
- C — STITCH CUT 60"ø PORTS ON FLAT PLATE BEFORE ROLLING INTO SHELL
- D — MEASURE PLATE THICKNESS BEFORE ROLLING SHELLS-CIRCUM. TOL.
- E — • PREP LONG. SEAM AND ONE END FOR HEAD WELD • PREBEND SEAM EDGES • ROLL SHELL • ROLL 60" NOZZLES WITH PROFILED ENDS
- F — • INSTALL 104.5" SHELL FIXTURES
- G — • TACK WELD SHELL • WELD LONGITUDINAL SEAM • INSPECT WELDS
- H — • REROLL FOR ROUNDNESS ? • ADD INTERNAL FIXTURES
- I — • WELD ON HEAD • WELD ON UPPER STIFFENING RING • INSPECT HEAD WELD
- J — • WELD ON SUPPORT LEG REPADS • ADD TEMP. LIFTING LUGS
- K — STRESS RELIEF SHELL WITH INTERNAL S/S FIXTURES
- L — • STABILIZE WITH INTERNAL BRACES • CUTOUT 60"ø PORTS
- M — ASSEMBLE FIXTURES FOR NOZZLE WELDING
- N — • WELD 60" NOZZLE NECKS TO SHELL WITH PLAZMA ARC & VIBRATORY STRESS RELIEF
- O — WELD ON STIFFENING RINGS BETWEEN 60" NOZZLES
- P — VERIFY NOZ. ALIGNMENT ±3mm.
- Q — • CUTOUT NON CRITICAL PORTS
- R — WELD ALL SMALL NOZZLES EXCEPT "D" NOZZLES
- S — THERMAL STRESS RELIEF WITH INTERNAL S/S FIXTURES
- T — MACHINE SQUARE & PREP ENDS OF 60"ø NOZZLES, PREP FLANGE END OF SHELL
- U — CUTOUT 4 CRITICAL "D" NOZZLES
  - STEAM CLEAN
- V — ASSEMBLE LOWER SHELL INTO FIXTURE
  - UPPER SHELL POINT "A" FROM SHT. 2 OF
- W — • FIT UPPER AND LOWER FLANGES FOR ALIGNMENT WITH LOWER SHELL • JOIN UPPER SHELL TO LOWER SHELL
- X — • WELD 104" FLANGES TO SHELLS
- Y — • FIT & WELD 60" FLANGES TO NOZZLES
- Z — WELD INTERNAL SUPPORT MEMBERS AND LEG REPADS TO LOWER SHELL (PLAZMA ARC)
- AA — • WELD NON CRITICAL FLANGES
- BB — • FIT & WELD "D" NOZZLES & FLANGES WITH FIXTURE
- CC — • INSPECT WELDS DIM/FLATNESS ETC.
- GG — STEAM CLEAN & SEAL UNIT SHIP TO PSI
- 180 — RECEIVE FROM MACH. SHOP
- 290 — • TEST ALIGNMENT JACK DEVICES
- 300 — • FIT FLOOR ASS'Y TO VESSEL
- 310 — • ADD 60" COVERS & TEST BLINDS • ADD ALL REMAINING CF FLANGES
- 320 — • INSTALL ANNULUS TUBING SUPPORTS MANIFOLD & AUX ION PUMP
- 325 — • PRELIMINARY He LEAK CHECK
- 330 — • CLEAN CHAMBER TO SPEC
  - LEG ASSEMBLY POINT "B"
- 332 — • TACK LEG ASSY TO SHELL • WELD ON BASE PLATES USING HOLE LOCATION TEMPLATE
- 334 — • CHECK ALIGNMENT OF ALL NOZZLES WITH LASER LEVEL/TRANSIT
- 336 — • FINAL WELD LEG ASSY.
- 340 HE LEAK TEST
- 350 BAKE OUT
- 360 FINAL VAC TEST
- 370 RECLEAN/PREP FOR SHIP

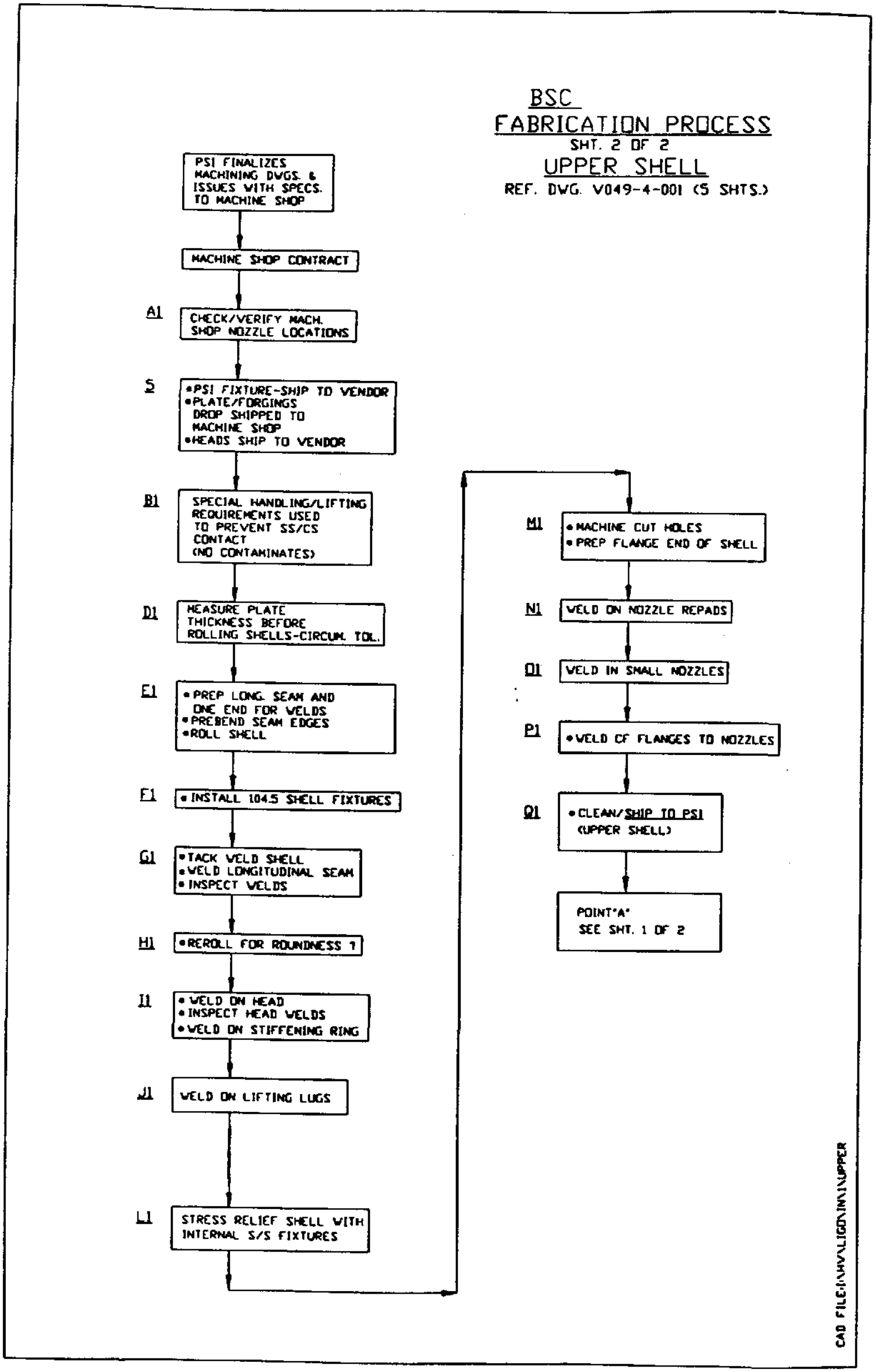
PRE FAB AUX. ION PUMP SUPPORT & MANIFOLD

OTHER MACHINE ITEMS: (INCLUDES TEST CHAMBER)

- I — • MACHINE 104.5" I.D. FLANGES 1-GROOVED 1-FLAT FACED
- II — • MACHINE 60.5" I.D. FLANGES W/ GROOVES 6 REQ'D. • MACHINE HOLES IN (4) 60" HEADS • MACHINE 60" FLGS. ON HEADS F.F. 4 REQ'D. • MACHINE/DEVELOP 14" CF NOZZLE NECKS • MACHINE/PROFILE 8"&10" CF NOZZLES
- III — • MACHINE 60"ø TEST BLINDS-2 REQ'D. • MACHINE 60" NOZZLE FIXTURE FOR PSI
- IV — • ROLL STIFFENING RINGS
- V — • CUTOUT SUPPORT REPADS FROM DROPOUTS • CUTOUT LIFTING LUGS FROM DROPOUTS • CUTOUT "E" PORTS FROM DROPOUTS
- VI — • BASE PLATES-MACHINE HOLES
- VII — • PREFAB LEG ASSEMBLY • BLAST & PAINT

CAD FILE: I:\HVALIGO\NVN\LOWER1

REV Ø
PG. 6 OF 8



BSC
FABRICATION PROCESS
SHT. 2 OF 2
UPPER SHELL
REF. DWG. V049-4-001 (5 SHTS.)
PSI FINALIZES MACHINING DWGS. & ISSUES WITH SPECS. TO MACHINE SHOP
MACHINE SHOP CONTRACT
A1
CHECK/VERIFY MACH. SHOP NOZZLE LOCATIONS
S
•PSI FIXTURE-SHIP TO VENDOR
•PLATE/FORGINGS DROP SHIPPED TO MACHINE SHOP
•HEADS SHIP TO VENDOR
B1
SPECIAL HANDLING/LIFTING REQUIREMENTS USED TO PREVENT SS/CS CONTACT (NO CONTAMINATES)
D1
MEASURE PLATE THICKNESS BEFORE ROLLING SHELLS-CIRCUM. TOL.
E1
•PREP LONG. SEAM AND ONE END FOR WELDS
•PREBEND SEAM EDGES
•ROLL SHELL
F1
•INSTALL 104.5 SHELL FIXTURES
G1
•TACK WELD SHELL
•WELD LONGITUDINAL SEAM
•INSPECT WELDS
H1
•REROLL FOR ROUNDNESS ?
I1
•WELD ON HEAD
•INSPECT HEAD WELDS
•WELD ON STIFFENING RING
J1
WELD ON LIFTING LUGS
L1
STRESS RELIEF SHELL WITH INTERNAL S/S FIXTURES
M1
•MACHINE CUT HOLES
•PREP FLANGE END OF SHELL
N1
WELD ON NOZZLE REPADS
O1
WELD IN SMALL NOZZLES
P1
•WELD CF FLANGES TO NOZZLES
Q1
•CLEAN/SHIP TO PSI (UPPER SHELL)
POINT "A" SEE SHT. 1 OF 2
CAD FILE:\HV\LIGO\IN\UPPER

ATTACHMENT 3

BSC FABRICATION PRIORITY LIST

Prototype (Spare)	
WBSC4	(CS)
WBSC7	(CS)
WBSC8	(CS)
WBSC1	(CS)
WBSC3	(CS)
WBSC2	(CS)
WBSC6	(LMS)
WBSC10	(LES)
WBSC5	(RMS)
WBSC9	(RES)
LBSC1	(CS)
LBSC3	(CS)
LBSC2	(CS)
LBSC5	(LES)
LBSC4	(RES)

2.2 BSC Fabrication Specification V049-2-117

Title: SPECIFICATION FOR BSC FABRICATION

SPECIFICATION FOR

BSC FABRICATION

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Phillip Fulford

PROJECT ENGINEER: N/A

QUALITY ASSURANCE: Alan Bradbrook

MANUFACTURING ENGR: Phillip Fulford

TECHNICAL DIRECTOR: D.O. McWilliams

PROJECT MANAGER: Richard Bayer

ϕ	PEF 5/2/96	DMW 5-2-96	ISSUED PER DPO 0161 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED PEF	DATE 5/2/96	APPROVED KEB	DATE 5/2/96	Number A V049-2-117	Rev. ϕ

TABLE OF CONTENTS

1.0 Scope

2.0 General Requirements

3.0 Codes And Standards

4.0 Fabrication Requirements

5.0 Materials

6.0 Identification

7.0 Required Documentation

8.0 Shop Testing

9.0 Cleaning & Painting

10.0 Storing And Shipping

11.0 Inspection And Quality Requirements

12.0 Non-Escort Privileges And Inspection Right

ATTACHMENTS:

1. BSC Fabrication Documents
2. BSC Fabrication Flow Chart
3. Fabrication Priority List

1.0 SCOPE

1.1 This specification covers the minimum requirements of the manufacturing engineering, materials, fabrication, assembly, inspection, testing preparation for shipping, shipment and delivery of vacuum vessels for the LIGO vacuum system.

1.2 All attachments are incorporated herein by reference and made a part of this specification.

1.3 The specified equipment is intended 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 Richmond, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system of the sensitive interferometer components and optical beams, and other support facilities.

1.4 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.

1.5 The <u>Buyer</u> is defined as Process Systems International, Inc. The Vendor/Seller is the successful bidder.

1 6 The Vendor shall be responsible for coordination of all their subsuppliers and for overall guarantees relating to mechanical or material compatibility. It is the specific responsibility of the vendor to invoke all reference specifications as applicable on each subsupplier purchase order.

1.7 The Vendor may not subcontract any part of the work required herein without approval of the Buyer.

1.8 The Buyer will supply all flanges, 304/304L plate and heads. The Buyer shall also perform all vacuum boundry welds.

2.0 GENERAL REQUIREMENTS

2.1 The design and materials of fabrication shall be as shown on the Buyer's vessel weldment drawings.

2.2 The vessels shall be fabricated and tested in accordance with drawings, standards, and specifications referred to or attached as part of this specification.

2.3 It shall be the responsibility of the Seller to call attention to any apparent conflicts between specifications, the Purchase Order, or Buyer's drawings and request an interpretation from the Buyer. The Seller is not to assume which instruction shall govern. In no case is the Seller to fabricate any component on the basis of Buyer's drawings or calculations if such drawings or calculations are in conflict with applicable code requirements.

2.4 If the Vendor uses PSI's design CAD files to program computer driven equipment, a final check and approval by PSI must be made prior to the fabrication process.

2.5 The vessels covered by this specification are to be used in ultra-high vacuum service and require strict cleanliness and contamination prevention throughout the material handling, fabrication and shipping process. All storage and fabrication for this vessel shall be done in the area isolated (plastic room or equal) from other manufacturing areas. The area shall be purged with clean air to prevent contamination and adjacent areas.

2.6 Fixtures (spiders, roundup rings, etc.) shall be used to maintain vessel and nozzle roundness during fabrication.

3.0 CODES AND STANDARDS

3.1 Priority Of Codes And Documents

1. This Specification
2. Fabrication drawings
3. Codes (highest priority - where applicable)

3.2 The following codes and standards shall be applicable to the fabrication of the equipment:

3.2.1 <u>American Society of Mechanical Engineers (ASME)</u>

a. ASME Boiler and Pressure Vessel Code, 1992 Edition Through 1994 Addenda.

Section II	Material Specifications
	Part A, Ferrous
	Part B, Nonferrous
	Part C, Welding Rods, Electrodes and Filler Metals
Section VIII	Pressure Vessels, Division I
Section IX	Welding and Brazing Qualification

3.3 Any apparent conflicts between the requirements given herein and the applicable ASME Specification shall be brought to the attention of PSI for clarification.

4.0 FABRICATION REQUIREMENTS

4.1 General

4.1.1 Mechanical design of the vessels shall be as shown on the Buyer's fabrication drawings. If additional drawing details are required, the vendor shall submit such details for approval prior to fabrication.

4.1.2 Vessels do not require ASME Code stamping or code inspection.

4.1.3 All vessels shall be furnished complete as shown on the Buyer's drawings, as required by the Purchase Order and as herein noted, and shall include all necessary hardware, such as bolts, washers, and nuts. Tolerances shall be adhered to as specified on the detail drawings.

4.2 Rolling Of Shells

4.2.1 Carbon steel rollers shall be covered with heavy (paper or carpet) or S/S during the rolling process to prevent carbon steel contamination of the stainless steel.

4.2.2 The seam edges of plates to be rolled are to be preworked to assure roundness of the final cylinder.

4.3 Cleanliness

No grinding with abrasive wheels, cloth or stones is allowed on the internal vacuum surface unless specified in this specification. This material is intended for use in a high vacuum application. Potential hydrocarbon contamination shall be prevented. Also, the material shall be wrapped and covered at all times the material is not being processed to minimize possible exposure to contaminants. The shells shall be cleaned (per 9.1) prior to shipment.

No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) are to come in contact with the vessel interior surfaces during material handling and assembly. Machining fluids shall be water soluble and free of oil and sulfur.

4.4 Welding

4.4.1 All welding shall be performed in accordance with the applicable codes (Para. 3.2.1) and PSI procedures for design and fabrication.

4.4.2 The Seller's fitup tack welding procedures and procedure qualifications shall be submitted to the Buyer for approval. Approval must be obtained prior to use.

4.4.3 All metal weld preparation shall be done by cutting machinery lathes if possible and by cutting with light pressure if necessary.

4.4.4 Welding Process

1. Vacuum boundary and attachment welds be made with the Plasma Arc process per PSI weld procedure WPS151 PAW. Shielding gas shall be a 75% Argon/25% Helium mixture, backing gas shall be 100% Argon and Plasma gas shall be 100% Argon. Hydrogen gas is not permitted. GTAW welds are acceptable for minor welds per PSI procedure WPS153 GTAW.

2. All weld repairs shall be performed per PSI procedure V049-2-071.

3. External support structures may be welded using GMAW process. All attachments to the vessel shall be by plasma arc or GTAW.

4. All weld wire and weld preparation areas shall be cleaned with CO_2 scrubbing prior to welding per PSI procedure V049-2-070.

4.4.5 All penetrations in the chamber shall be continuously welded on the inside per drawing details. Welds to be smooth but NOT FLUSH & NOT GROUND.

4.4.6 All welds at vacuum boundaries to be vacuum tight with a helium leak rate equivalent to a total of 1×10^{-9} torr liters/sec/chamber. PSI will leak test all vessel welds with a helium mass spectrometer. Vendor will repair all leak areas identified by PSI.

4.5 Backing strips or rings shall not be used.

4.6 Longitudinal seams shall be positioned as shown on detail drawings.

4.7 Sharp edges are to be removed from all carbon steel areas where external painting is to be applied.

4.8 Post Weld Heat Treatment

Post weld heat treatment shall be performed as stated below per Specification V049-2-046. Furnace shall be adjusted to provide furnace atmospheres of at least 5% excess oxygen.

5.0 MATERIALS

5.1 All vacuum boundary shell material shall meet the requirement of SA240 for both grades 304 and 304L. Vessel head and flange material shall be type 304L. All materials listed on the PSI bill of material will be provided by the buyer, exceptions, shipping covers, paint, etc.

5.2 Any damaged material will be replaced by the Buyer. The cost of this material will be charged to the vendor.

5.3 The Seller shall issue PSI receiving reports for all material received direct from PSI suppliers.

6.0 IDENTIFICATION

6.1 Identification of the material shall be maintained through all manufacturing processes. All cutoff parts shall be marked with the heat number of the parent part as indicated below.

6.2 If material identity is lost, the plate shall be requalified by making all tests that were required by the material specification or as indicated in this specification at the sellers expense. CMTRS have been provided to PSI for the above material, traceability of all materials must be maintained.

6.3 Marking the finished materials with marking fluids, die stamps, and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of .005" is acceptable for marking the <u>outside only</u> of the finished shell. All other marking methods must be approved by the purchaser prior to use. <u>All parts shall be marked on outside surface only</u>. Marking on interior boundary vacuum boundary surfaces is <u>not allowed</u>. The minimum marking is to be the <u>heat/lot number</u>.

7.0 REQUIRED DOCUMENTATION

Vendor shall furnish documentation in accordance with purchase order requirements. The following is a list of minimum documentation required.

7.1 General Requirements

7.1.1 Upon acceptance of the purchase order, the Vendor shall prepare any shop and working drawings in addition to the contract drawings, which are required by the seller to fabricate this equipment. These drawings shall be submitted to the Buyer for approval prior to the start of fabrication. All weld seams other than those shown on the drawing, are to be identified and submitted to the Buyer for approval.

7.1.2 Manufacturing and test data which shall include the following:

1. Details of all weld preparations, welding processes, and welding materials. Welding symbols shall conform to AWS A2.4-79 "Symbols for Welding and Nondestructive Testing."
2. Heat treatment details, including temperature of PWHT and time at temperature, and furnace charts to be supplied, when applicable.
3. General remarks on fabrication, assembly, and testing.
4. Extent and location of all nondestructive examination (NDE).
5. Complete identification and materials used, including gaskets.

7.1.3 Drawings which will supplement the general assembly or arrangement drawings shall contain the following information:

a. Full dimensions of all parts and subassemblies and, where applicable, the tolerances and finishing required.

b. Complete identification of materials used.

7.1.4 The Buyer's equipment number shall appear prominently in all drawing title blocks.

7.1.5 Two (2) copies shall be submitted to the Buyer for approval.

7.2 Drawing Approval

Drawing approval must be obtained from the Buyer before starting fabrication. The Buyer's review of the fabricator's drawings is of a general nature. Approval of any drawings and/or calculations by the Buyer does not serve as approval of any errors or as approval of any deviation from these specifications, the Procurement Document, or instructions relating to the work. The fabricator shall call attention to any such deviations by a separate written notice when submitting the drawings for approval. Unless specific written approval is obtained from the Buyer, any such deviations are not acceptable. Conformance to the applicable codes and legal requirements is the responsibility of the Seller.

7.3 Changes

If changes are made to any drawings after drawing approval has been given, the fabricator shall furnish new copies to the Buyer showing all changes clearly identified on the drawing.

7.4 Test And Quality Assurance Documentation

Buyer requires two (2) copies of the following documentation for each vessel. This documentation shall be submitted by the Seller for the Buyer's review prior to shipment of the equipment.

1. Mill Test Reports (MTRS) for all vacuum boundary shell material purchased by the seller and certificates of compliance (C of Cs) for small stock pressure items purchased by the Seller.
2. Nondestructive test reports on all applicable NDE.
3. Dimensional check report verifying vessel dimensions are within tolerance.

8.0 SHOP TESTING

8.1 The Vendor shall submit, for approval by the Buyer, a detailed procedure for shop testing each vessel. This shall include examination of welds, and all nondestructive tests.

8.2 Leak testing shall be accomplished using the system vacuum pumping equipment (supplied by PSI) per specification V049-2-014 (by PSI).

9.0 CLEANING AND PAINTING

9.1 Cleaning before shipment to PSI shall be per vendor's standard detergent steam cleaning procedure. (Buyer approved.)

9.2 Final cleaning prior to testing at PSI shall be per specification V049-2-015.

9.3 Only carbon steel members are to be painted per specification V049-2-077 later.

10.0 STORING AND SHIPPING

10.1 All bolted connections shall be made up before final shipment to site, with gaskets.

10.2 Shipping covers shall be installed before final shipment to site, with double Viton o-rings.

10.3 Shipping covers shall be used on all double o-ring grooved flanged connections which do not have access covers. Covers shall be suitable for protecting the connections from mechanical damage and preventing the entry of dirt into the equipment. The use of tape or plastic as a shipping cover is not acceptable.

10.4 The vessels shall be wrapped in waterproof polyethylene and covered with a tarp immediately after cleaning operations have been completed to minimize contamination.

10.5 Finished flange surfaces must be covered and protected during all fabrication steps and during shipment to PSI.

11.0 INSPECTION AND QUALITY REQUIREMENTS

11.1 The Seller shall have in effect in their shops at all times, an inspection, testing and documentation program that will ensure that the equipment furnished under the specification will meet in all respects the requirements of the specification. The responsibility for inspection rests with the Seller. However, the Buyer reserves the right to inspect equipment at any time during fabrication to assure that the materials and workmanship are in accordance with this specification. The Buyer's inspector will need to personally witness that certain critical dimensions are within the specified tolerances while the fabricated parts are set-up and indexed in the vendor's computer controlled equipment.

11.2 The Seller shall notify PSI on the day of arrival of materials, so that PSI can inspect the items in a timely manner materials shall be stored indoors in a clean dry storage space after delivery.

12.0 NON-ESCORT PRIVILEGES AND INSPECTION RIGHT

Non-escort privileges for Buyer, Owner, Government and Owner representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to all areas where material is being processed and stored.

The Seller shall cooperate with the Buyer's shop inspectors in establishing when the various inspections or tests will be performed during manufacture, testing, cleaning, and preparation for shipment. The Quality Plan designates which operations require to witness or verification The Seller will furnish an agreed upon amount of notification prior to the start of each. The shop inspector will warn the Seller at any time that he notices anything that may lead to rejection of the equipment or material when it is presented later for inspection and acceptance.

It is not intended that the Buyer's shop inspection shall relieve the Seller in any way whatsoever of his obligation to maintain an adequate test inspection and documentation program of his own, or of any other obligation under the specification. Furthermore, the fact that Buyer's shop inspector may inadvertently overlook a deviation from some requirement of this specification shall not constitute a waiver of that requirement or of the Seller's obligation to correct the condition when it is discovered, or any other obligation under the specification.

ATTACHMENT 1

BSC FABRICATION DOCUMENTS

1.	Spec. For Beam Splitter Chamber Quality Plan	V049-2-048
2.	Bill of Material	V049-4-001
3.	Flanges	V049-2-040 & V049-2-042
4.	Heads	V049-2-039
5.	Raw Material Handling Procedure	V049-2-120
6.	Weld Data Sheet Spec.	V049-2-084
7.	Weld Procedures	V049-2-070, V049-2-071, V049-2-072, V049-2-073
8.	Weld Repair Procedure	V049-2-074
9.	Cleaning Procedures	V049-2-015
10.	Painting Procedures	V049-2-077
11.	Stress Relief Procedures	V049-2-046
12.	Bakeout Procedure	V049-2-019
13.	Leak Test Procedure	V049-2-014
14.	Components Shop Conditioning/Test Plan	V049-2-047
15.	Dimensional Verification Procedure	V049-2-121
16.	Component Packing, Handling, and Shipping Procedure	V049-2-123
17.	PSI Drawings	
	BSC Assembly	V049-4-001
	Chamber Supports	V049-4-023
	60" Port Cover	V049-4-014
	60 1/2" ID Flange (Grooved)	V049-4-019
	104.5" ID Flange	V049-4-022
	Floor Assembly	V049-4-036

LEGEND

NUMBERS=PSI MANUFACTURING ACTIVITY
LETTERS=MACHINE SHOP ACTIVITY (VENDOR)

BSC FABRICATION PROCESS

SHT. 1 OF 2

LOWER SHELL

REF. DWG. V049-4-001 (5 SHTS)

- PSI FINALIZES MACHINING DWGS. & ISSUES WITH SPECS. TO MACHINE SHOP
- A — CHECK/VERIFY MACH. SHOP NOZZLE LOCATIONS
- 5 — •PSI FIXTURE-DESIGN/FAB. SHIP FIXTURE TO VENDOR •PLATE/FORGINGS DROP SHIPPED TO MACHINE SHOP •HEADS SHIP TO VENDOR
- B — SPECIAL HANDLING/LIFTING REQUIREMENTS USED TO PREVENT SS/CS CONTACT (NO CONTAMINATES)
- C — STITCH CUT 60"ø PORTS ON FLAT PLATE BEFORE ROLLING INTO SHELL
- D — MEASURE PLATE THICKNESS BEFORE ROLLING SHELLS-CIRCUM. TOL.
- E — • PREP LONG. SEAM AND ONE END FOR HEAD WELD •PREBEND SEAM EDGES •ROLL SHELL •ROLL 60" NOZZLES WITH PROFILED ENDS
- F — • INSTALL 104.5" SHELL FIXTURES
- G — •TACK WELD SHELL •WELD LONGITUDINAL SEAM •INSPECT WELDS
- H — •REROLL FOR ROUNDNESS ? •ADD INTERNAL FIXTURES
- I — • WELD ON HEAD • WELD ON UPPER STIFFENING RING •INSPECT HEAD WELD
- J — •WELD ON SUPPORT LEG REPADS •ADD TEMP. LIFTING LUGS
- K — STRESS RELIEF SHELL WITH INTERNAL S/S FIXTURES
- L — • STABILIZE WITH INTERNAL BRACES •CUTOUT 60"ø PORTS
- ASSEMBLE FIXTURES FOR NOZZLE WELDING
- M
- N — • WELD 60" NOZZLE NECKS TO SHELL WITH PLAZMA ARC & VIBRATORY STRESS RELIEF
- O — WELD ON STIFFENING RINGS BETWEEN 60" NOZZLES
- P — VERIFY NOZ. ALIGNMENT ±3mm.

- Q — •CUTOUT NON CRITICAL PORTS
- R — WELD ALL SMALL NOZZLES EXCEPT "D" NOZZLES
- S — THERMAL STRESS RELIEF WITH INTERNAL S/S FIXTURES
- T — MACHINE SQUARE & PREP ENDS OF 60"ø NOZZLES, PREP FLANGE END OF SHELL
- U — CUTOUT 4 CRITICAL "D" NOZZLES
- STEAM CLEAN
- V — ASSEMBLE LOWER SHELL INTO FIXTURE
- UPPER SHELL POINT "A" FROM SHT. 2 OF
- W — •FIT UPPER AND LOWER FLANGES FOR ALIGNMENT WITH LOWER SHELL •JOIN UPPER SHELL TO LOWER SHELL
- X — • WELD 104" FLANGES TO SHELLS
- Y — • FIT & WELD 60" FLANGES TO NOZZLES
- Z — WELD INTERNAL SUPPORT MEMBERS AND LEG REPADS TO LOWER SHELL (PLAZMA ARC)
- AA — • WELD NON CRITICAL FLANGES
- BB — • FIT & WELD "D" NOZZLES & FLANGES WITH FIXTURE
- CC — • INSPECT WELDS DIM/FLATNESS ETC.
- GG — STEAM CLEAN & SEAL UNIT SHIP TO PSI
- 180 — RECEIVE FROM MACH. SHOP
- 290 — •TEST ALIGNMENT JACK DEVICES
- 300 — •FIT FLOOR ASS'Y TO VESSEL
- 310 — • ADD 60" COVERS & TEST BLINDS • ADD ALL REMAINING CF FLANGES

OTHER MACHINE ITEMS: (INCLUDES TEST CHAMBER)

- I — •MACHINE 104.5" I.D. FLANGES 1-GROOVED 1-FLAT FACED
- II — • MACHINE 60.5" I.D. FLANGES W/ GROOVES 6 REQ'D. • MACHINE HOLES IN (4) 60" HEADS • MACHINE 60" FLGS. ON HEADS F.F. 4 REQ'D. • MACHINE/DEVELOP 14" CF NOZZLE NECKS • MACHINE/PROFILE 8"&10" CF NOZZLES
- III — • MACHINE 60"ø TEST BLINDS-2 REQ'D. • MACHINE 60" NOZZLE FIXTURE FOR PSI
- IV — • ROLL STIFFENING RINGS
- V — • CUTOUT SUPPORT REPADS FROM DROPOUTS • CUTOUT LIFTING LUGS FROM DROPOUTS • CUTOUT "E" PORTS FROM DROPOUTS
- VI — • BASE PLATES-MACHINE HOLES
- VII — • PREFAB LEG ASSEMBLY • BLAST & PAINT

- 320 — • INSTALL ANNULUS TUBING, SUPPORTS MANIFOLD & AUX ION PUMP
- 325 — • PRELIMINARY He LEAK CHECK
- 330 — • CLEAN CHAMBER TO SPEC
- LEG ASSEMBLY POINT "B"
- 332 — •TACK LEG ASSY TO SHELL •WELD ON BASE PLATES USING HOLE LOCATION TEMPLATE
- 334 — •CHECK ALIGNMENT OF ALL NOZZLES WITH LASER LEVEL/TRANSIT
- 336 — •FINAL WELD LEG ASSY.
- 340 — HE LEAK TEST
- 350 — BAKE OUT
- 360 — FINAL VAC TEST
- 370 — RECLEAN/PREP FOR SHIP
- PRE FAB AUX. ION PUMP SUPPORT & MANIFOLD

CAD FILE: [illegible]

REV
Ø
PG. 12 OF 14

BSC
FABRICATION PROCESS
SHT. 2 OF 2
UPPER SHELL
REF. DWG. V049-4-001 (5 SHTS.)

- PSI FINALIZES MACHINING DWGS. & ISSUES WITH SPECS. TO MACHINE SHOP
- ↓ MACHINE SHOP CONTRACT
- ↓ **A1** CHECK/VERIFY MACH. SHOP NOZZLE LOCATIONS
- ↓ **S**
  - PSI FIXTURE-SHIP TO VENDOR
  - PLATE/FORGINGS DROP SHIPPED TO MACHINE SHOP
  - HEADS SHIP TO VENDOR
- ↓ **B1** SPECIAL HANDLING/LIFTING REQUIREMENTS USED TO PREVENT SS/CS CONTACT (NO CONTAMINATES)
- ↓ **D1** MEASURE PLATE THICKNESS BEFORE ROLLING SHELLS-CIRCUM. TOL.
- ↓ **E1**
  - PREP LONG. SEAM AND ONE END FOR WELDS
  - PREBEND SEAM EDGES
  - ROLL SHELL
- ↓ **F1**
  - INSTALL 104.5 SHELL FIXTURES
- ↓ **G1**
  - TACK WELD SHELL
  - WELD LONGITUDINAL SEAM
  - INSPECT WELDS
- ↓ **H1**
  - REROLL FOR ROUNDNESS ?
- ↓ **I1**
  - WELD ON HEAD
  - INSPECT HEAD WELDS
  - WELD ON STIFFENING RING
- ↓ **J1** WELD ON LIFTING LUGS
- ↓ **L1** STRESS RELIEF SHELL WITH INTERNAL S/S FIXTURES
- ↓ **M1**
  - MACHINE CUT HOLES
  - PREP FLANGE END OF SHELL
- ↓ **N1** WELD ON NOZZLE REPADS
- ↓ **O1** WELD IN SMALL NOZZLES
- ↓ **P1**
  - WELD CF FLANGES TO NOZZLES
- ↓ **Q1**
  - CLEAN/SHIP TO PSI (UPPER SHELL)
- ↓ POINT "A" SEE SHT. 1 OF 2

CAD FILE:\HV\LIGO\INV\UPPER

REV
Ø

ATTACHMENT 3

BSC FABRICATION PRIORITY LIST

Prototype (Spare)

WBSC4	(CS)
WBSC7	(CS)
WBSC8	(CS)
WBSC1	(CS)
WBSC3	(CS)
WBSC2	(CS)
WBSC6	(LMS)
WBSC10	(LES)
WBSC5	(RMS)
WBSC9	(RES)
LBSC1	(CS)
LBSC3	(CS)
LBSC2	(CS)
LBSC5	(LES)
LBSC4	(RES)

2.3 BSC Quality Plan V049-2-048

Title: **QUALITY PLAN FOR LIGO**
BEAM SPLITTER CHAMBER (BSC) - PROTOTYPE

QUALITY PLAN

FOR

LIGO

BEAM SPLITTER CHAMBER (BSC)

PROTOTYPE

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	ALB 4/25/96	REB 4/25/96	REVISED PER DEO 0140
0	ALB 3/1/96	REB 3/14/96	RELEASED PER DEO 0091

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

INITIAL APPROVALS	PREPARED ALB	DATE 2/24/96	APPROVED REB	DATE 3/12/96	Number A V049-2-048	Rev 1

APPLICABLE DRAWINGS

V049-4-001	Beam Splitter Chamber Assembly
V049-4-019	60-1/2" I.D. Flange Details
V049-4-022	104-1/2" I.D. Flange Details

APPLICABLE PROCEDURES

V049-2-071	Welding Plasma-Arc	P8-P8
V049-2-072	Welding GTAW	P8-P8
V049-2-046	Thermal Stress Relief	
V049-2-015	Cleaning	
V049-2-019	Bake-out	
V049-2-044	Vacuum Chamber Fabrication	
V049-2-047	Final Vacuum Test	
V049-2-014	Helium Leak Test	

(RANOR) **SPECIFICATION** V049-2-048 **REV.** 1

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581-5003
(508) 366-9111 Fax (508) 870-5930

PROJECT LIGO – PROTOTYPE JOB NO. V59049-
ITEM BEAM SPLITTER CHAMBER (BSC) DWG NO. V049-4-001
APPLICABLE CODE ASME VIII DIV.1 (WHERE APPLICABLE) PG 3 OF 9

ASME CODE QUALITY PLAN

LEGEND: **D** = DIMENSIONAL, **V** = VISIUAL, **RT** = RATIOGRAPHY, **PT** = LIQUID PENETRANT, **MT** = MAGNETIC PARTICLE, **ET** = EDDY CURRENT, **LT** = LEAK TEST, **UT** = ULTRASONIC, **W** = WITNESS, **X** = HOLD POINT, √ = APPROVED, **R** = REVIEW

	QUALITY PLAN REVIEWED QA ARS AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-LOWER ASSEMBLY-							VENDOR SURVEY PERFORMED 4/11/96
	VERIFY SHELL FIXTURES	V-D			X			
G	INSPECT FIT-UP LOWER ASSEMBLY LONG SEAM	V-D	V049-4-001		X			
G	INSPECT WELDING LONG SEAM	V-D	V049-4-001			X		
H	VERIFY ROUNDNESS OF SHELL	V-D	V049-4-001		X			
I	INSPECT FIT-UP LOWER ASSEMBLY HEAD TO SHELL JOINT	V-D	V049-4-001		X			
I	INSPECT WELDING ON STIFFENING RING AND	V-D	V049-4-001			X		
J	SUPPORT LEG PADS AND LUGS	V-D	V049-4-001			X X		

FILED F TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 **REV.** 1

	QUALITY PLAN REVIEWED QA ARS AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-LOWER ASS'Y CONT-							
K	STRESS RELIEF LOWER ASSEMBLY			V049-2-046	X	X		PSI TO VERIFY HEAT CHARTS. AND OVEN CALIBRATION CERTS.
L	INSPECT	V-D	V049-4-001		X			REF. V049-4-019
	CUTOUT 60" PORTS							
	60" NOZZLE NECKS				X			
	4-60" FLGS. (MACH)		V049-4-019		X			
N	INSPECT WELDING OF 60" NOZZLE NECKS TO SHELL	V-D	V049-4-001			X		
O	INSPECT WELDING OF STIFFENING RINGS	V-D	V049-4-001			X		
N	VIBRATORY STRESS RELIEF				X			
P	VERIFY NOZZLE ALIGNMENT	D	V049-4-001		X			
Q	VERIFY CUT OUTS OF NON-CRITICAL NOZZLE PORTS.	D	V049-4-001		X			
R	INSPECT WELDING ON NON-CRITICAL PORTS	V-D	V049-4-001			X		

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 **REV.** 1

QUALITY PLAN REVIEWED QA [initials] AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
-LOWER ASS'Y CONT.							
S THERMAL							
STRESS RELIEF		V049-2-046		X	X		PSI TO VERIFY HEAT CHARTS
							AND OVEN CALIBRATION CERT.
T INSPECT	D	V049-4-001					
60" NOZ. (MACH)				X			
SHELL FLG. (MACH)				X			
U NOZ "D" CUTOUTS				X			

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 REV. 1

	QUALITY PLAN REVIEWED QA ans AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-UPPER ASSEMBLY-							
	VERIFY SHELL FIXTURES	D			X			
G1	INSPECT FITUP UPPER ASSEMBLY LONG SEAM	V-D	V049-4-001		X			
G1	INSPECT WELDING LONG SEAM	V-D	V049-4-001			X		
H1	VERIFY ROUNDNESS OF SHELL	D			X			
I1	INSPECT FITUP UPPER ASSEMBLY HEAD TO SHELL JOINT	V-D	V049-4-001		X			
I1	INSPECT WELDING ON STIFFENING RING AND	V-D	V049-4-001			X		
J1	LIFTING LUGS				X			
L1	STRESS RELIEF UPPER ASSEMBLY		V049-2-046		X	X		PSI TO VERIFY HEAT CHARTS AND OVEN CALIBRATION CERT.

FILED F TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 REV. 1

	QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-UPPER ASSEMBLY-							
	(CONT.)							
M1	INSPECT MACHINING	D	V049-4-001		X			
	NOZZLE CUTOUTS							
	FLANGE END OF							
	SHELL							
	INSPECT WELDING	V-D	V049-4-001			X		
	OF NOZZLE							
N1	REPADS AND							
O1	NOZZLE WELDS					X		
P1	FLANGES TO							
	NOZZLES					X		

FILED F TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 REV. 1

	QUALITY PLAN REVIEWED QA CRB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-UPPER/LOWER- ASSEMBLY							
W	VERIFY SHELL FLANGE ALIGNMENT BETWEEN UPPER AND LOWER SHELL SECTIONS	D	V049-4-001		X			
X	INSPECT WELDING OF 104" FLANGE TO SHELL	V-D	V049-4-001			X		
Y	60" FLANGE TO NOZZLE					X		
AA	REMAINING FLANGES					X		
BB	NOZZLE "D". INSPECT MACHINING		V049-4-019		X			V049-4-022
Z	VERIFY WELDING ON LEG ASSEMBLY	V-D	V049-4-001			X		
EE	VERIFY ALIGNMENT OF ALL NOZZLES WITH LASER LEVEL / TRANSIT.	V-D	V049-4-001		X			
290	VERIFY TEST ON ALIGNMENT JACK DEVICES				X			

FILED F TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-048 REV. 1

	QUALITY PLAN REVIEWED QA ARS AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	VENDOR INSPECTION SIGN/DATE	PSI INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
	-UPPER / LOWER - ASSEMBLY (CONT.)							
300	VERIFY FLOOR ASSEMBLY IN VESSEL	D	V049-4-001			X		
330	VERIFY FINAL CLEANING AT PSI	V	V049-2-015			X		
350	VERIFY BAKE OUT AT PSI	W	V049-2-019			X		
360	VERIFY FINAL VACUUM TEST AT PSI	W	V049-2-047			X		
380	VERIFY FINAL TESTING ON ALL EQUIPT. AT PSI	W				X		
390	VERIFY CLEANLINESS AND PREP FOR SHIPMENT	V				X		

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

2.4 BSC Testing/Inspections

Each BSC will be inspected at the Mechanical Fabrication contractor prior to release for shipment to PSI (see "Dimensional fabrication procedure V049-2-121 for additional details).

After shipment to PSI, the BSC will be leak checked, cleaned, baked out and prepared for shipment. (See "Component Shop Conditioning/Test Procedure" V049-2-047 and "Component Packaging, Handling and Preparation For Shipment" V049-2-123 for additional details).

3.1 HAM Fabrication Plan V049-2-081

Title: FABRICATION PLAN FOR HORIZONTAL ACCESS MODULES (HAM)

FABRICATION PLAN

FOR

HORIZONTAL ACCESS MODULES (HAM)

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Phillip Falcone

QUALITY ASSURANCE: Alan R Bradbrooke

MANUFACTURING ENGINEER: Phillip Falcone

TECHNICAL DIRECTOR: D.O. McWilliams

PROJECT MANAGER: Richard Bayley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	PF 5/1/96	REB 5/2/96	ISSUED PER DEO 0161 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED PEF	DATE 5/1/96	APPROVED REB	DATE 5/2/96	Number A V049-2-081	Rev. Ø

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibility

4.0 Fabrication Plan

ATTACHMENTS:

1. HAM Fabrication Documents
2. Fabrication Flow Chart
3. Fabrication Priority List

Number

Rev.

1.0 PURPOSE

The purpose of this procedure is to define design guidelines, specifications, and procedures to enable PSI to specify, purchase, inspect, fabricate, test and ship the HAM per LIGO requirements.

2.0 GENERAL

All Horizontal Access Modules (HAM) shall be fabricated per this fabrication plan. Each fabrication process shall be controlled via a written procedure. A "first article" approach will be used to validate all fabrication processes prior to release of the full vessel lot.

All vessels will be fabricated in accordance with the Quality Plan. Key points in the fabrication process shall be verified to ensure consistent results.

All vacuum equipment shall be fabricated in accordance with LIGO Project Contract PC175730 dated September 12, 1995, and subsequent change orders.

3.0 RESPONSIBILITY

The Manufacturing Department is responsible for the execution of this procedure, with input and monitoring by the Project Engineer, the Quality Assurance Department, and the Project Manager.

4.0 FABRICATION PLAN

4.1 A first article approach will be used to start the HAM manufacturing cycle to validate the manufacturing procedures and technique prior to the full production release.

4.2 The HAM chambers will be fabricated using an outside manufacturing shop. PSI will perform vessel cleaning, leak checking, bakeout and preparation for shipment.

4.3 The HAM will be fabricated and tested per documents listed in Attachment I "Fabrication Documents".

4.4 The HAM will be fabricated and tested per Attachment 2 HAM Fabrication Flow Chart.

Number

Rev.

4.5 The HAM vessels will be fabricted according to the Fabrication Priority List, Attachment 3.

4.6 Procurement

PSI will procure all S.S. plate and flange material and supply it with the selected fabrication vendor.

PSI will purchase vessel heads and supply them to the selected fabrication vendor.

4.7 Quality Assurance

The HAM Fabrication Process shall be monitored and control via the Quality Plan.

Outside fabrication vendors will perform the quality plan inspections for their portion of the work. PSI will witness critical process inspections as detailed in the Quality Plan.

PSI will audit each major fabrication vendor's Q.A.Program after P.O. awards.

PSI and fabrication vendors will inspect all incoming materials to purchase documents.

4.8 Shop Conditioning/Testing

The HAM Vessels will be shop conditioned (cleaned, bakeout, etc.) per PSI Procedure V049-2-047.

4.9 Preparation For Shipment

The HAM Vessels will be prepared and shipped per PSI Procedure V049-2-123.

ATTACHMENT 1

HAM FABRICATION DOCUMENTS

1.	Spec. For HAM Fabrication	V049-2-078
2.	HAM Quality Plan	V049-2-087
3.	Bill of Material	V049-4-002
4.	Flanges	V049-2-040 & V049-2-042
5.	Heads	V049-2-039
6.	Raw Material Handling Procedure	V049-2-120
7.	Weld Data Sheet Spec.	V049-2-084
8.	Weld Procedures	V049-2-070, V049-2-071, V049-2-072, V049-2-073
9.	Weld Repair Procedure	V049-2-074
10.	Cleaning Procedures	V049-2-015
11.	Painting Procedures	V049-2-077
12.	Stress Relief Procedures	V049-2-046
13.	Bakeout Procedure	V049-2-019
14.	Leak Test Procedure	V049-2-014
15.	Components Shop Conditioning/Testing Plan	V049-2-047
16.	Dimensional Verification Procedure	V049-2-121
17.	Component Packaging, Handling, and Shipping Procedure	V049-2-123
18.	PSI Drawings	
	HAM Assembly	V049-4-002
	Vessel Supports	V049-4-052
	60" Expansion Joint	V049-4-053
	Bellows Tie Rod Assembly	V049-4-040
	84 1/4" ID Flange (Grooved)	V049-4-021
	60 1/2" ID Flange (FF)	V049-4-032
	60 1/2" ID Flange (Grooved)	V049-4-031

HAM FABRICATION PROCESS DIAGRAM

SHT 1 OF 2

REF. DWG. V049-4-002 (5 S-TS)
REF. DWG V049-4-021, 052, 053

LEGEND

NUMBERS=PSI MANUFACTURING ACTIVITY
LETTERS=MACHINE SHOP ACTIVITY (VENDOR)

- PSI FINALIZES MACHINING DWGS. & ISSUES WITH SPECS. TO MACHINE SHOP
- A — CHECK/VERIFY MACH. SHOP NOZZLE LOCATIONS
- 5 — •PSI FIXTURE-DESIGN/FAB. SHIP FIXTURE TO VENDOR •PLATE/FORGINGS DROP SHIPPED TO MACHINE SHOP •HEADS SHIP TO VENDOR
- B — SPECIAL HANDLING/LIFTING REQUIREMENTS USED TO PREVENT SS/CS CONTACT (NO CONTAMINATES)
- C — STITCH CUT 60"ø PORTS ON FLAT PLATE BEFORE ROLLING INTO SHELL
- D — MEASURE PLATE THICKNESS BEFORE ROLLING SHELLS-CIRCUM. TOL.
- E — •PREP LONG. SEAM AND ENDS FOR FLANGE WELD •PREBEND SEAM EDGES •ROLL SHELL-84.25" I.D. •ROLL 60.5" I.D. NOZZLES WITH PROFILED ENDS
- F — INSTALL 84.25" SHELL FIXTURES
- G — •TACK WELD SHELL •WELD LONGITUDINAL SEAM •INSPECT WELDS
- H — •REROLL FOR ROUNDNESS ? •ADD INTERNAL FIXTURES
- I — •WELD ON SUPPORT LEG REPADS •ADD TEMP. LIFTING LUGS/SUPPORTS
- J — STRESS RELIEF SHELL & 60" NOZZLES W/INT. S/S FIXTURES
- K — •STABILIZE 84.75 I.D. SHELL WITH INTERNAL BRACES •CUTOUT 60"ø PORTS
- L — ASSEMBLE FIXTURES FOR NOZZLE WELDING
- M — •WELD 60" NOZZLE NECKS TO SHELL WITH PLAZMA ARC & VIBRATORY STRESS RELIEF
- N — WELD ON STIFFENING RINGS BETWEEN 60" NOZZLES
- O — VERIFY NOZ. ALIGNMENT 60.5 I.D.
- P — •CUTOUT NON CRITICAL PORTS
- Q — WELD ALL SMALL NOZZLES EXCEPT "E" NOZZLES
- R — STEAM CLEAN
- S — THERMAL STRESS RELIEF WITH INTERNAL S/S FIXTURES
- T — MACHINE SQUARE & PREP ENDS OF 60"ø NOZZLES, PREP FLANGE END OF SHELL
- U — CUTOUT 4 CRITICAL "E" NOZZLES
- V — •WELD 60.5" I.D. HEADS TO FLANGES •WELD 84.25" I.D. HEADS TO FLANGES
- W — •FIT 84.25"ID END FLANGES FOR ALIGNMENT WITH EACH OTHER
- X — •WELD 84.25" FLANGES TO SHELLS
- Y — •FIT & WELD 60" FLANGES TO NOZZLES
- •FIT & WELD EXPAN. JOINT SPOOL AND TIE ROD LUGS TO 60" NOZZLE & FLANGE
- Z — WELD INTERNAL SUPPORT MEMBERS TO SHELL (PLAZMA ARC)
- AA — •WELD NON CRITICAL FLANGES
- BB — •FIT & WELD "E" NOZZLES & FLANGES WITH FIXTURE
- CC — •INSPECT WELDS DIM/FLATNESS ETC.
- EE — •CHECK ALIGNMENT OF ALL NOZZLES WITH HIGH TOL. EQUIPMENT
- GG — STEAM CLEAN & INSTALL TEMP NOZZLE COVERS <u>SHIP TO PSI</u>
- 180 — RECEIVE FROM MACH. SHOP

SEE SHT. 2 OF 2

OTHER MACHINE ITEMS

- I — •MACHINE 84.25" I.D. FLANGES 2-GROOVED 2-FLAT FACED
- III — •MACHINE HOLES IN (2)) 84.25" HEADS •
- II — •MACHINE 60.5" I.D. FLANGES ON HEADS 1-GROOVED 1-FLAT FACED •MACHINE HOLES IN (2) 60" HEADS •MACHINE/DEVELOP 12"/14" OF NOZZ NECKS •MACHINE/PROFILE 8"&10" OF NOZZLES
- IV — •ROLL STIFFENING RINGS & SUPT REPADS
- VI — •BASE PLATES-MACHINE HOLES
- VII — •PREFAB LEG ASSEMBLY •BLAST & PAINT

REV Ø

CAD FILE HAMFABDIAGRAM

LEGEND
NUMBERS=PSI MANUFACTURING ACTIVITY
LETTERS=MACHINE SHOP ACTIVITY (VENDOR)

HAM FABRICATION PROCESS DIAGRAM

SHT 2 OF 2

REF. DWG. V049-4-002 (5 SHTS)
REF. DWG. V049-4-021, 052, 053

100 RECEIVE FROM MACH. SHOP

1 INSTALL ANNULUS TUBING

2
- REMOVE TEMP SHIPPING COVERS
- CLEAN ALL CHAMBER FLANGE SEAL SURFACES
- CLEAN AND PROTECT ALL DOOR COVERS

3
- ADD 60" & 84" COVERS WITH TEST O-RINGS
- INSTALL C.F. FLANGES
- INSTALL 6" G.V. FOR TURBO PUMP

4
- He LEAK TEST ANNULUS TUBING AND CHAMBER

5 FINAL CLEANING

6 MOVE INTO CLEAN ROOM

7
- FINAL ASSEMBLY
- INSTALL TEST/SHIPPING COVERS

8 WELD ON SUPPORT SADDLES

9 BAKE OUT UNDER VACUUM

10 FINAL VACUUM TEST

11
- REMOVE TURBO COMM G.V.
- INSTALL VALVES FOR SHIPPING VACUUM

12 PREP. FOR SHIPMENT UNDER VACUUM

REV. Ø

ATTACHMENT 3

HAM FABRICATION PRIORITY LIST

WHAM1	(CS)
WHAM22	(CS)
WHAM11	(CS)
WHAM10	(CS)
WHAM7	(CS)
WHAM8	(CS)
WHAM9	(CS)
WHAM2	(CS)
WHAM3	
WHAM6	(CS)
WHAM5	(CS)
WHAM4	(CS)
WHAM13	(Spare)
LHAM1	(CS)
LHAM2	(CS)
LHAM3	(CS)
LHAM6	(CS)
LHAM5	(CS)
LHAM4	(CS)

3.2 HAM Fabrication Specification V049-2-078

Title: **SPECIFICATION FOR HAM CHAMBER FABRICATION**

SPECIFICATION FOR
HAM CHAMBER FABRICATION

PREPARED BY:	R.E. Curtis
STRUCTURAL ENGINEER:	R. D. Catto
QUALITY ASSURANCE:	
MANUFACTURING ENGR:	
TECHNICAL DIRECTOR:	D.A. McWilliams
PROJECT MANAGER:	[illegible]

P1	REC 4-2-96		ISSUED FOR QUOTES DEO 0098
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number A **V049-2-078**	Rev.
	R. Curtis	4-2-96	REB	4/3/96		P1

TABLE OF CONTENTS

1.0 Scope

2.0 Schedule

3.0 General Requirements

4.0 Codes And Standards

5.0 Fabrication Requirements

6.0 Materials

7.0 Identification

8.0 Required Documentation

9.0 Shop Testing

10.0 Cleaning & Painting

11.0 Storing And Shipping

12.0 Inspection And Quality Requirements

13.0 Non-Escort Privileges And Inspection Right

ATTACHMENTS:

A. LIGO Quality Assurance Requirements Summary

B. HAM Fabrication Process Diagram

C. Quality Plan A V049-2-087, Rev. 0

D. Weld Repair Procedure V049-2-074

~~E. Weld Cleaning Procedure V049-2-070~~

F. Post Weld Heat Treatment V049-2-046

G. PSI Drawings:

V049-4-002 (5 Sheets) Horiz. Access Module & Bill of Material

V049-4-031 60 1/2" ID Flg. Det. (Grooved)

V049-4-032 60 1/2" ID Flg. Det. (Flat Faced)

V049-4-021 84 1/4" I.D. Flange Detail (Grooved)

V049-4-027 60 1/2" ID Flg. Det. (Flat Faced)

V049-4-0A4 60" End Cover (2 Sheets)

V049-4-052 HAM Chamber Support Saddle

V049-4-053 60 1/2" I.D. Expan. Joint

V049-4-014 60" Type II Cover

1.0 SCOPE

1.1 This specification covers the minimum requirements of the manufacturing engineering, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of vacuum vessels for the LIGO vacuum system.

1.2 All attachments are incorporated herein by reference and made a part of this specification.

1.3 The specified equipment is intended 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 Richmond, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system of the sensitive interferometer components and optical beams, and other support facilities.

1.4 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.

1.5 The Buyer is defined as Process Systems International, Inc. The Vendor/Seller is the successful bidder.

1 6 The Vendor shall be responsible for coordination of all their subsuppliers and for overall guarantees relating to mechanical or material compatibility. It is the specific responsibility of the vendor to invoke all reference specifications as applicable on each subsupplier purchase order.

1.7 The Vendor may not subcontract any part of the work required herein without approval of the Buyer.

1.8 The Buyer will supply all flanges, 304/304L plate and heads. The Buyer shall also perform all vacuum boundary welds on the first article only (lot 1). The vendor shall perform Plasma and TIG welding for lots 2 thru 7.

2.0 SCHEDULE

2.1 Chamber delivery shall be as follows:

Quantity	Delivery Site	Dates	Production Lots
1	PSI, Westborough	1 Aug. 1996	1 (First Article)
3	PSI, Westborough	1 Nov. 1996	2
3	PSI, Westborough	1 Feb. 1997	3
3	PSI, Westborough	15 April 1997	4
3	PSI, Westborough	15 June 1997	5
3	PSI, Westborough	1 Oct. 1997	6
3	PSI, Westborough	1 Dec. 1997	7
19 Total			

2.2 A "first article" chamber shall be manufactured and tested (per Section 8 of this specification) as early as possible to allow design changes to be incorporated into all the chambers. Additional chambers are not to be released for manufacture until the Buyer accepts the first article assembly. Each lot will be released for manufacture in writing by the Buyer.

3.0 GENERAL REQUIREMENTS

3.1 The design and materials of fabrication shall be as shown on the Buyer's vessel weldment drawings.

3.2 The vessels shall be fabricated and tested in accordance with drawings, standards, and specifications referred to or attached as part of this specification.

3.3 It shall be the responsibility of the Seller to call attention to any apparent conflicts between specifications, the Purchase Order, or Buyer's drawings and request an interpretation from the Buyer. The Seller is not to assume which instruction shall govern. In no case is the Seller to fabricate any component on the basis of Buyer's drawings or calculations if such drawings or calculations are in conflict with applicable code requirements.

3.4 If the Vendor uses PSI's design CAD files to program computer driven equipment, the vendor shall verify the drawings files are true full scale and have converted properly prior to the fabrication process.

3.5 The vessels covered by this specification are to be used in ultra-high vacuum service and require strict cleanliness and contamination prevention throughout the material handling, fabrication and shipping process. All storage and fabrication for this vessel shall be done in the area isolated (plastic room or equal) to prevent contamination from smoke, dust and oily vapors from other manufacturing areas. The area shall be purged with clean air to prevent contamination and adjacent areas.

3.6 Stainless steel fixtures (spiders, roundup rings, etc.) shall be used as required to maintain vessel and nozzle roundness during fabrication.

3.7 The vessel shall be fabricated per the attached PSI Quality Plan, and Fabrication Process Program in Attachments B & C.

3.8 A PSI Q.A. audit shall be performed prior to the start of all fabrication.

4.0 CODES AND STANDARDS

4.1 Priority Of Codes And Documents

1. This Specification
2. Fabrication drawings
3. Codes (highest priority - where applicable)

4.2 The following codes and standards shall be applicable to the fabrication of the equipment:

4.2.1 American Society of Mechanical Engineers (ASME)

a. ASME Boiler and Pressure Vessel Code, 1992 Edition Through 1994 Addenda.

Section II	Material Specifications
	Part A, Ferrous
	Part B, Nonferrous
	Part C, Welding Rods, Electrodes and Filler Metals
Section VIII	Pressure Vessels, Division I (Stamp Not Required)
Section IX	Welding and Brazing Qualification

4.3 Any apparent conflicts between the requirements given herein and the applicable ASME Specification shall be brought to the attention of PSI for clarification.

5.0 FABRICATION REQUIREMENTS

5.1 General

5.1.1 Mechanical design of the vessels shall be as shown on the Buyer's fabrication drawings. If additional drawing details are required, the vendor shall submit such details for approval prior to fabrication.

5.1.2 Vessels do not require ASME Code stamping or code inspection.

5.1.3 All vessels shall be furnished complete as shown on the Buyer's drawings, as required by the Purchase Order and as herein noted, and shall include all necessary hardware, such as bolts, washers, and nuts. Tolerances shall be adhered to as specified on the detail drawings.

5.2 Rolling Of Shells

5.2.1 Carbon steel rollers shall be covered with heavy (paper or carpet) or S/S during the rolling process to prevent carbon steel contamination of the stainless steel.

5.2.2 The seam edges of plates to be rolled are to be preworked to assure roundness of the final cylinder.

5.3 Cleanliness

No grinding with abrasive wheels, cloth or stones is allowed on the internal vacuum surface unless specified in this specification. This material is intended for use in a high vacuum application. Potential hydrocarbon contamination shall be prevented. Also, the material shall be wrapped and covered at all times the material is not being processed to minimize possible exposure to contaminants. The shells shall be cleaned (per 9.1) prior to shipment.

No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) are to come in contact with the vessel interior surfaces during material handling and assembly. Machining fluids shall be water soluble and free of oil and sulfur.

5.4 Welding

5.4.1 All welding shall be performed in accordance with the applicable codes (Para. 4.2.1) and PSI procedures for design and fabrication.

5.4.2 The Seller's fitup tack welding procedures and procedure qualifications shall be submitted to the Buyer for approval. Approval must be obtained prior to use.

5.4.3 All weld joint preparation shall be done by tungsten carbide tooling if possible.

5.4.4 Welding Process

1. Vacuum boundary and attachment welds shall be made with the Plasma Arc process per PSI weld procedure WPS151 PAW. Shielding gas shall be a 75% Argon/25% Helium mixture, backing gas shall be 100% Argon and Plasma gas shall be 100% Argon. Hydrogen gas is not permitted. GTAW welds are acceptable for minor welds per PSI procedure WPS153 GTAW.

2. All weld repairs shall be performed per PSI procedure V049-2-071.

3. External support structures may be welded using GMAW process. All attachments to the vessel shall be by plasma arc or GTAW.

4. All weld wire and weld joint preparation areas shall be cleaned with CO_2 scrubbing prior to welding per PSI procedure V049-2-070.

5.4.5 All penetrations in the chamber shall be continuously welded on the inside per drawing details. Internal weld surface to be smooth but NOT GROUND.

5.4.6 All welds at vacuum boundaries to be vacuum tight with a helium leak rate equivalent to a total of 1×10^{-9} torr liters/sec/chamber. PSI will leak test all vessel welds with a helium mass spectrometer. Vendor will repair all leak areas identified by PSI.

5.5 Backing strips or rings shall not be used.

5.6 Longitudinal seams shall be positioned as shown on detail drawings.

5.7 Sharp edges are to be removed from all carbon steel areas where external painting is to be applied.

5.8 Post Weld Heat Treatment

Post weld heat treatment shall be performed per Specification V049-2-046. Furnace shall be adjusted to provide a furnace atmosphere of at least 5% excess oxygen.

6.0 MATERIALS

6.1 All vacuum boundary shell material shall meet the requirement of SA240 for both grades 304 and 304L. Vessel head and flange material shall be type 304L. All materials listed on the PSI bill of material will be provided by the buyer, exceptions, shipping covers, paint, etc.

6.2 Any damaged material will be replaced by the Buyer. The cost of this material will be charged to the vendor.

6.3 The Seller shall issue PSI receiving reports for all material received direct from PSI suppliers.

7.0 IDENTIFICATION

7.1 Identification of the material shall be maintained through all manufacturing processes. All cutoff parts shall be marked with the heat number of the parent part as indicated below on the exterior surface only (not on the vacuum boundary).

7.2 If material identity is lost, the plate shall be requalified by making all tests that were required by the material specification or as indicated in this specification at the sellers expense. CMTRS have been provided to PSI for the above material, traceability of all materials must be maintained.

7.3 Marking the materials with marking fluids, die stamps, crayons, paints and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of .005" is acceptable for marking the outside only of the finished shell. All other marking methods must be approved by the purchaser prior to use. All parts shall be marked on outside surface only. Marking on interior boundary vacuum boundary surfaces is not allowed. The minimum marking is to be the heat/lot number.

8.0 REQUIRED DOCUMENTATION

Vendor shall furnish documentation in accordance with purchase order requirements. The following is a list of minimum documentation required.

8.1 General Requirements

8.1.1 All shop drawings (if used) shall be submitted to the Buyer for approval prior to fabrication.

8.1.2 Drawings (if used) which will supplement the general assembly or arrangement drawings shall contain the following information:

a. Full dimensions of all parts and subassemblies and, where applicable, the tolerances and finishing required.

b. Complete identification of materials used.

c. The Buyer's equipment number shall appear prominently in all drawing title blocks.

8.1.3 Two (2) copies shall be submitted to the Buyer for approval.

8.2 Shop Drawing Approval

Shop drawing approval must be obtained from the Buyer before starting fabrication. The Buyer's review of the fabricator's drawings is of a general nature. Approval of any drawings and/or calculations by the Buyer does not serve as approval of any errors or as approval of any deviation from these specifications, the Procurement Document, or instructions relating to the work. The fabricator shall call attention to any such deviations by a separate written notice when submitting the drawings for approval. Unless specific written approval is obtained from the Buyer, any such deviations are not acceptable. Conformance to the applicable codes and legal requirements is the responsibility of the Seller.

8.3 Changes

If changes are made to any drawings after drawing approval has been given, the fabricator shall furnish new copies to the Buyer showing all changes clearly identified on the drawing.

8.4 Test And Quality Assurance Documentation

Buyer requires two (2) copies of the following documentation for each vessel. This documentation shall be submitted by the Seller for the Buyer's review prior to shipment of the equipment.

1. Mill Test Reports (MTRS) for all vacuum boundary shell material purchased by the seller and certificates of compliance (C of Cs) for small stock pressure items purchased by the Seller.
2. Nondestructive test reports on all applicable NDE. Dye penetrant testing is not allowed.
3. Dimensional check report verifying vessel dimensions are within tolerance. This must be done on a CNC machine.

9.0 SHOP TESTING

9.1 Testing shall be per the Q.A. plan. All dimensional checks shall be done on a CNC machine.

9.2 PSI reserves the right to spot x-ray each vessel.

10.0 CLEANING AND PAINTING

10.1 Cleaning before shipment to PSI shall be per vendor's standard detergent steam cleaning procedure. (Buyer approved, include test data on water used for steam.)

10.2 Only carbon steel members are to be painted per specification V049-2-077.

11.0 STORING AND SHIPPING

11.1 Expansion bellows shall be protected from mechanical damage during all phases of manufacturing, storing and shipping.

11.2 Shipping covers shall be used on all flanged connections. Covers shall be provided by the buyer for protecting the connections from mechanical damage and preventing the entry of dirt into the equipment. The use of tape or plastic sheet alone as a shipping cover is not acceptable.

11.3 The vessels shall be wrapped in waterproof polyethylene and covered with a tarp immediately after cleaning operations have been completed to minimize contamination.

11.4 Finished flange surfaces must be covered and protected during all fabrication steps and during shipment to PSI.

11.5 The vessels shall be shrink wrapped and covered with waterproof tarps during shipment to PSI.

12.0 INSPECTION AND QUALITY REQUIREMENTS

12.1 The Seller shall have in effect in their shops at all times, an inspection, testing and documentation program that will ensure that the equipment furnished under the specification will meet in all respects the requirements of the specification. The responsibility for inspection rests with the Seller. However, the Buyer reserves the right to inspect equipment at any time during fabrication to assure that the materials and workmanship are in accordance with this specification. The Buyer's inspector will need to personally witness that certain critical dimensions are within the specified tolerances while the fabricated parts are set-up and indexed in the vendor's computer controlled equipment.

12.2 The Seller shall notify PSI on the day of arrival of materials, so that PSI can inspect the items in a timely manner materials shall be stored indoors in a clean dry storage space after delivery.

13.0 NON-ESCORT PRIVILEGES AND INSPECTION RIGHT

Non-escort privileges for Buyer, Owner, Government and Owner representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to all areas where material is being processed and stored.

The Seller shall cooperate with the Buyer's shop inspectors in establishing when the various inspections or tests will be performed during manufacture, testing, cleaning, and preparation for shipment. The Quality Plan designates which operations require to witness or verification The Seller will furnish an agreed upon amount of notification prior to the start of each. The shop inspector will warn the Seller at any time that he notices anything that may lead to rejection of the equipment or material when it is presented later for inspection and acceptance.

It is not intended that the Buyer's shop inspection shall relieve the Seller in any way whatsoever of his obligation to maintain an adequate test inspection and documentation program of his own, or of any other obligation under the specification. Furthermore, the fact that Buyer's shop inspector may inadvertently overlook a deviation from some requirement of this specification shall not constitute a waiver of that requirement or of the Seller's obligation to correct the condition when it is discovered, or any other obligation under the specification.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR: V59049	JOB NO.: V59049
EQUIPMENT: Vacuum Vessel Fabrication - HAM	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-044

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		
CLEANING PROCEDURE			X	2	X		
PREP FOR SHIPMENT PROCEDURE			X	2	X		
WELDING PROCEDURES			X	2	X		
SHOP DRAWINGS			X	2	X		
DESIGN REVIEW							
CERTIFIED MATERIAL TEST REPORTS			X	2	X		
IN-PROCESS INSPECTIONS		X		2	X		
OPERATION & MAINTENANCE MANUALS							
SHOP TEST PLAN			X	2	X		
SHOP TEST (WITH REPORT)		X	X	2	X	Per QA Plan No.	
SHOP DIMENSIONAL INSPECTION		X	X	2	X	Per QA Plan No.	

Pg 12 of 13

LEGEND

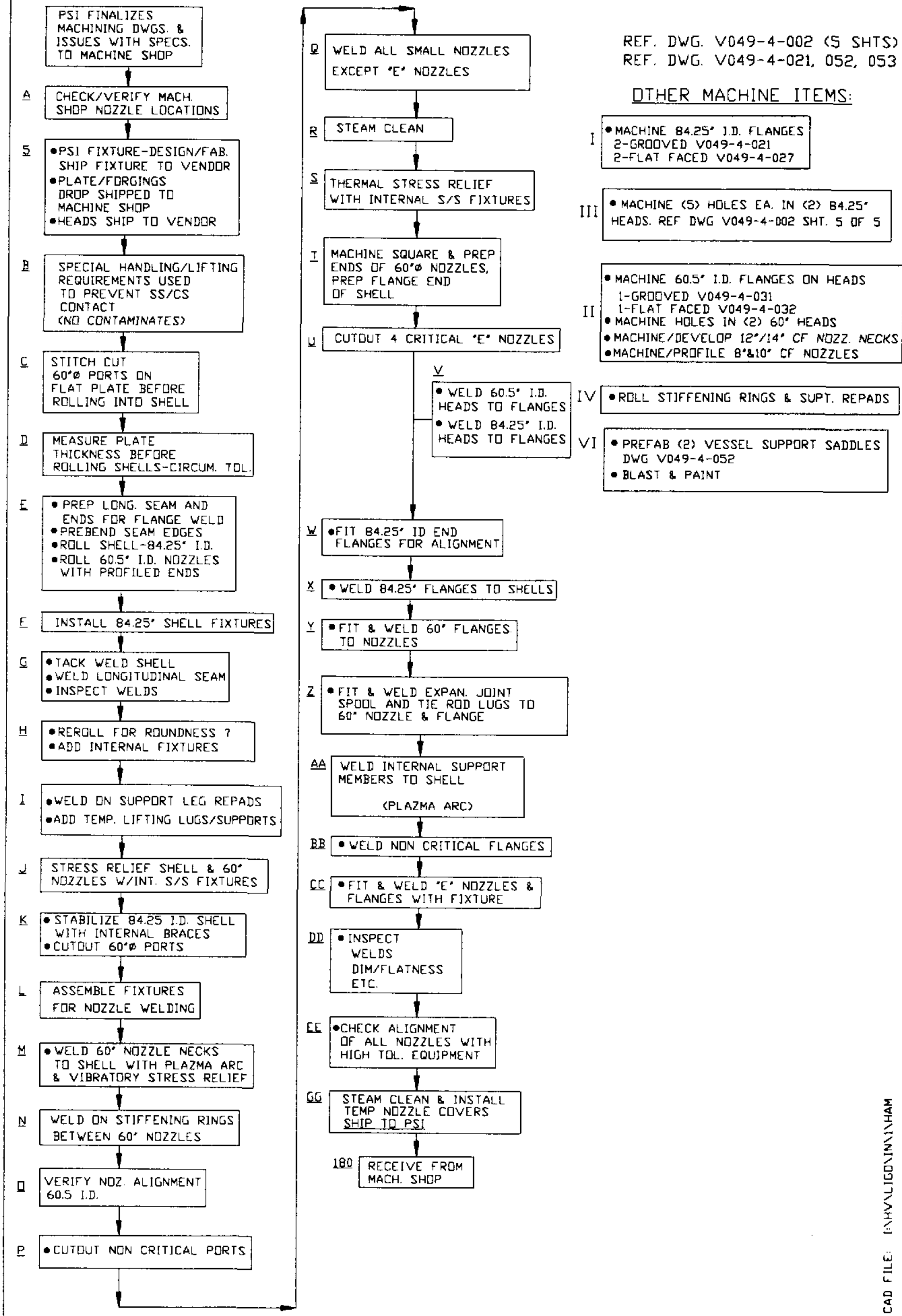
NUMBERS=PSI MANUFACTURING ACTIVITY
LETTERS=MACHINE SHOP ACTIVITY (VENDOR)

HAM FABRICATION PROCESS DIAGRAM

APR 2, 1996

REF. DWG. V049-4-002 (5 SHTS)
REF. DWG. V049-4-021, 052, 053

SPEC. V049-2-078 ATTACHMENT B.



CAD FILE: I:\HAM\CIGON\HAM

3.3 HAM Quality Plan V049-2-087

Title: QUALITY PLAN FOR HORIZONTAL ACCESS MODULE (HAM) PROTOTYPE

QUALITY PLAN

FOR

LIGO

HORIZONTAL ACCESS MODULE (HAM) PROTOTYPE

ϕ	ARS 4/8/96	RB	released per DEO 0114
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.		SPECIFICATION	
INITIAL APPROVALS	PREPARED ARBudbrook DATE 4/8/96	APPROVED R. Bayl DATE 4/17/96	Number V049-2-087	Rev. ϕ

APPLICABLE DRAWINGS

V049-4-002	Horizontal Access Module Chamber Assembly
V049-4-031	60-1/2" I.D. Flange Detail (Grooved)
V049-4-032	60-1/2" I.D. Flange Detail (Flat Face)
V049-4-021	84-1/4" I.D. Flange Detail (Grooved)
V049-4-027	60-1/2" I.D. Flange Detail (Flat Face)
V049-4-0A4	60" End Cover
V049-4-052	Ham Chamber Support Saddle
V049-4-053	60-1/2" I.D. Expansion Joint
V049-4-014	60" Type II Cover

APPLICABLE PROCEDURES

V049-2-072	Welding GTAW (PWHT) P8-P8
V049-2-071	Welding PAW (PWHT) P8-P8
V049-2-074	General Repair Procedure
V049-2-046	Thermal Stress Relief
V049-2-078	Ham Chamber Fabrication

SPECIFICATION V049-2-087 REV. ϕ

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581-5003
(508) 366-9111 Fax (508) 870-5930

PROJECT LIGO - PROTOTYPE - HAM JOB NO. V59049-
ITEM HORIZONTAL ACCESS MODULE DWG NO. V049-4-002
APPLICABLE CODE ASME VIII DIV. 1 (WHERE APPLICABLE) PG 3 OF 7

ASME CODE QUALITY PLAN

LEGEND: **D** = DIMENSIONAL, **V** = VISIUAL, **RT** = RATIOGRAPHY, **PT** = LIQUID PENETRANT, **MT** = MAGNETIC PARTICLE, **ET** = EDDY CURRENT, **LT** = LEAK TEST, **UT** = ULTRASONIC, **W** = WITNESS, **X** = HOLD POINT, √ = APPROVED, **R** = REVIEW

QUALITY PLAN REVIEWED QA AKB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI INSPECTION SIGN/DATE	VENDOR INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
PERFORM QA SURVEY	X			X			
VERIFY SHELL FIXTURES IN LOWER SHELL	V				X		
INSPECT WELDING LONG SEAM LOWER SHELL	V		V049-2-071		X		
VERIFY ROUNDNESS OF SHELL	V-D	V049-4-002			X		
INSPECT WELDING LONG SEAM 60" NOZZLES	V		V049-2-071		X		
VERIFY ROUNDNESS OF 60" NOZZLES	V-D	V049-4-002			X		

SPECIFICATION V049-2-087 REV. Ø

QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI INSPECTION SIGN/DATE	VENDOR INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
VERIFY WELDING AND LOCATION OF SADDLE SUPPORT PLATES AND LIFT LUGS	V-D	V049-4-002	V049-2-071		X		
THERMAL STRESS RELIEF SHELL AND 60" NOZZLES		V049-2-046		X	X		PSI TO VERIFY HEAT CHARTS AND OVEN CALIBRATION CERT.
VERIFY FIXTURES IN SHELL AND IN 60" NOZZLES	V				X		
INSPECT WELDING OF 60" NOZZLES	V		V049-2-071		X		
VERIFY NOZZLE ALIGNMENT AND DIMENSIONS.	V-D	V049-4-002			X		
VERIFY CUTOUT LOCATION OF ALL NON-CRITICAL NOZZ.	V-D	V049-4-002			X		
INSPECT WELDING OF ALL NON-CRITICAL NOZZLES	V	V049-4-002	V049-2-071		X		
VERIFY ALL NON-CRITICAL NOZZLE ALIGNMENT AND DIMENSIONS.	V-D	V049-4-002			X		

FILED:F:\TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-087 REV. Ø

QUALITY PLAN REVIEWED QA ALB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI INSPECTION SIGN/DATE	VENDOR INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
VERIFY STEAM CLEANING OF VESSEL	V			X	X		
THERMAL STRESS RELIEF VESSEL		V049-2-046		X	X		PSI TO VERIFY HEAT CHARTS AND OVEN CALIBRATION CERT.
VERIFY 60" NOZ. END DIMENSIONS AFTER MACHINING	V-D	V049-2-046		X	X		
VERIFY CUTOUT LOCATION OF THE 4-CRITICAL "E"- NOZZLES	V-D	V049-4-002			X		
INSPECT WELDING OF 60" HEADS TO FLANGES	V	V049-4-002 V049-4-A4	V049-2-071		X		
INSPECT WELDING OF 84" HEADS TO FLANGES	V	V049-4-002	V049-2-071		X		
INSPECT WELDING OF 84" FLANGES TO SHELL	V	V049-4-002	V049-2-071		X		
VERIFY FLANGE (84") STRAIGHTNESS AND FLATNESS	V-D	V049-4-002		X	X		

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-087 REV. Ø

QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI INSPECTION SIGN/DATE	VENDOR INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
INSPECT WELDING OF 60" FLANGES TO NOZZLE NECK	V	V049-4-002	V049-2-071		X		
VERIFY 60" FLANGE STRAIGHTNESS AND FLATNESS	V-D	V049-4-002		X	X		
INSPECT WELDING OF EXPAN. JOINT TO 60" NOZZLE	V	V049-4-002 V049-4-053	V049-2-071		X		
INSPECT WELDING OF INTERNAL SUPPORTS TO SHELL	V	V049-4-002	V049-2-071		X		
INSPECT WELDING OF ALL NON-CRITICAL FLANGES	V	V049-4-002	V049-2-071		X		
INSPECT WELDING OF CRITICAL "E" NOZZLES AND FLANGES (WITH FIXTURES).	V	V049-4-002	V049-2-071		X		
VERIFY THE ALIGNMENT STRAIGHTNESS AND FLATNESS OF "E" NOZZLES	V-D	V049-4-002		X	X		

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI INSPECTION SIGN/DATE	VENDOR INSPECTION SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
STEAM CLEAN COMPLETE VESSEL INSIDE AND OUT				X	X		
INSTALL/VERIFY NOZZLE COVERS FOR SHIPMENT TO PSI	V-D			X	X		
VERIFY FINAL CLEANING AT PSI	V			X			
VERIFY FINAL BAKEOUT AT PSI	V	V049-2-019		X			
VERIFY FINAL VACUUM AND HELIUM LEAK TEST AT PSI	V	V049-2-047 V049-2-014		X			
SHIPMENT TO LIGO				X			

FILED:F:\TEMPLATE\ENGFORMS\ASMEQPL

3.4 HAM Testing/Inspections

Each HAM will be inspected at the Mechanical Fabrication contractor prior to being released for shipment to PSI (See "Dimensional Fabrication Procedure" V049-2-121 for additional details).

After shipment, to PSI the HAM will be leak checked, cleaned, baked out and prepared for shipment. (See "Component Shop Conditioning/Test Procedure" V049-2-047 and "Component Packaging, Handling and Preparation for Shipment" V049-2-123 for additional details).

4.1 80K Pump Fabrication Plan V049-2-082

Title: **FABRICATION PLAN FOR CRYOPUMPS**

FABRICATION PLAN

FOR

80K CRYOPUMPS

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Phillip Talbot

QUALITY ASSURANCE: Alan R Bradbrook

MANUFACTURING ENGINEER: Phillip Talbot

TECHNICAL DIRECTOR: D. G. McWilliam

PROJECT MANAGER: [illegible signature]

0	PF 5/1/96	RGB 5/2/96	ISSUED PER DEO 0161 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED PRF	DATE 5/1/96	APPROVED RGB	DATE 5/2/96	Number A V049-2-082	Rev. 0

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibility

4.0 Fabrication Plan

ATTACHMENTS:

1. Cryopump Fabrication Documents
2. Fabrication Flow Chart
3. Fabrication Priority List

Number Rev.

1.0 PURPOSE

The purpose of this procedure is to define design guidelines, specifications, and procedures to enable PSI to specify, purchase, inspect, fabricate, test and ship the 80K Cryopumps per LIGO requirements.

2.0 GENERAL

All Cryopumps shall be fabricated per this fabrication plan. Each fabrication process shall be controlled via a written procedure. A "first article" approach will be used to validate all fabrication processes prior to release of the full vessel lot.

All vessels will be fabricated in accordance with the Quality Plan. Key points in the fabrication process shall be verified to ensure consistent results.

All vacuum equipment shall be fabricated in accordance with LIGO Project Contract PC175730 dated September 12, 1995, and subsequent change orders.

3.0 RESPONSIBILITY

The Manufacturing Department is responsible for the execution of this procedure, with input and monitoring by the Project Engineer, the Quality Assurance Department, and the Project Manager.

4.0 FABRICATION PLAN

4.1 A first article approach will be used to start the Cryopump manufacturing cycle to validate the manufacturing procedures and technique prior to the full production release.

4.2 The Cryopumps will be fabricated at PSI. PSI will perform vessel cleaning, leak checking, bakeout and preparation for shipment.

4.3 The Cryopumps will be fabricated and tested per documents listed in Attachment I "Fabrication Documents".

4.4 The Cryopumps will be fabricated and tested per Attachment 2 Cryopump Fabrication Flow Chart.

4.5 The Cryopumps will be fabricated according to the Fabrication Priority List Attachment 3.

Number Rev.

4.6 Procurement

PSI will procure all S.S. plate and flange material.

PSI will purchase vessel heads.

4.7 Quality Assurance

The Cryopump Fabrication Process shall be monitored and control via the Quality Plan V049-2-098.

PSI will inspect all incoming materials to the purchase documents.

4.8 Shop Conditioning/Testing

The Cryopumps will be shop conditioned (cleaned, bakeout, etc.) per PSI Procedure V049-2-047.

4.9 Preparation For Shipment

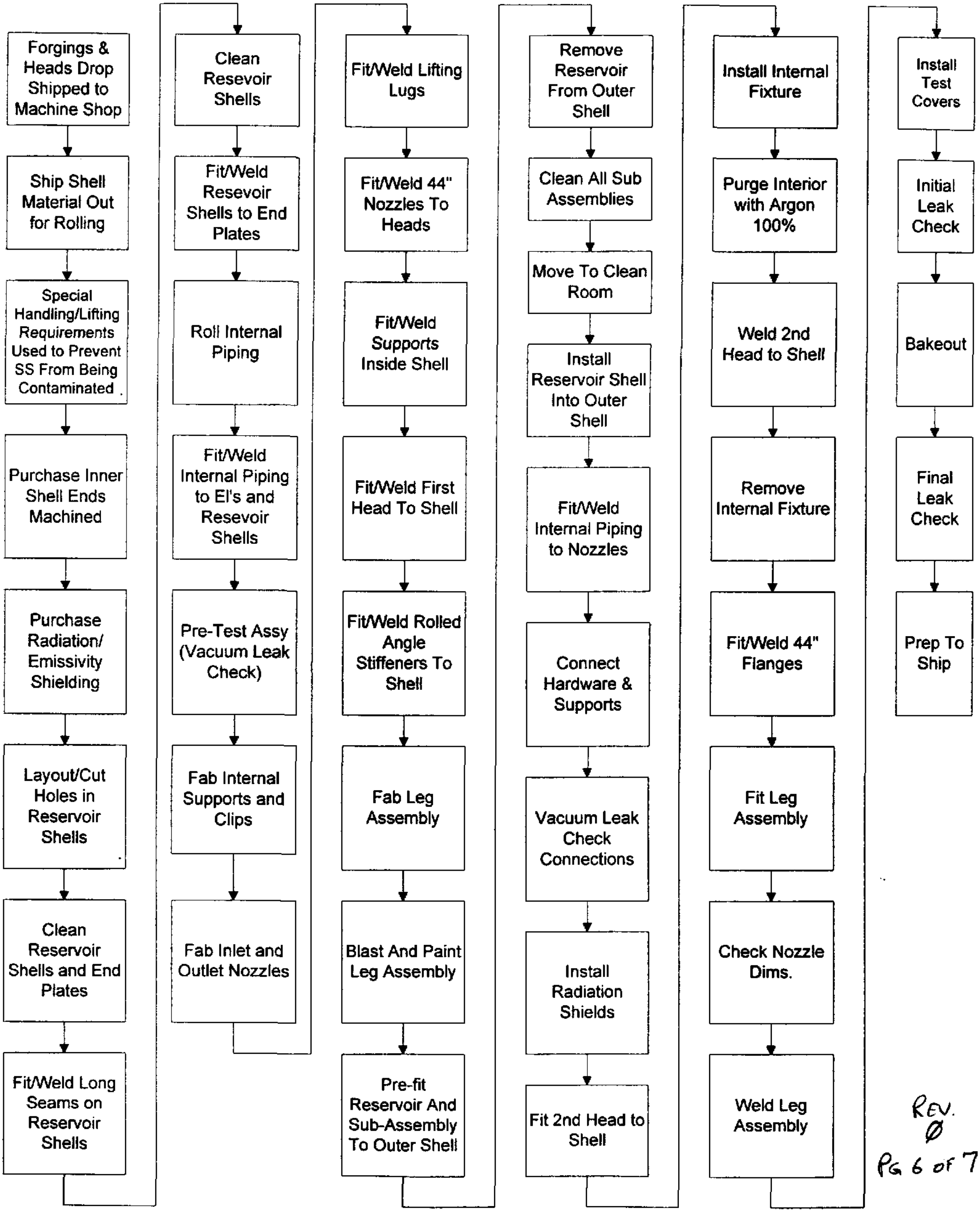
The Cryopumps will be prepared and shipped per PSI Procedure V049-2-123.

ATTACHMENT 1

CRYOPUMP DOCUMENTS

1.	Spec. For Cryopump Fabrication	V049-2-096
2.	Cryopump Quality Plan	V049-2-098
3.	Bill of Material	V049-4-004, V049-4-005
4.	Flanges	V049-2-040 & V049-2-042
5.	Heads	V049-2-039
6.	Raw Material Handling Procedure	V049-2-120
7.	Weld Data Sheet Spec.	V049-2-084
8.	Weld Procedures	V049-2-070, V049-2-071, V049-2-072, V049-2-073
9.	Weld Repair Procedure	V049-2-074
10.	Cleaning Procedures	V049-2-015
11.	Painting Procedures	V049-2-077
12.	Components Shop Conditioning/Test Plan	V049-2-047
13.	Bakeout Procedure	V049-2-019
14.	Leak Test Procedure	V049-2-014
15.	Dimensional Verification Procedure	V049-2-121
16.	Component Packaging, Handling, and Shipping Procedure	V049-2-123
17.	PSI Drawing	
	80K Cryopump - Long	V049-4-004
	80K Cryopump - Short	V049-4-005
	44 5/8" ID Flange Detail (Grooved)	V049-4-017

ATTACHMENT 2
80K CRYOPUMP FABRICATION PROCESS DIAGRAM



REV. Ø
Pg 6 of 7

ATTACHMENT 3

80K CRYOPUMP FABRICATION PRIORITY LIST

WCP1	(CS)
WCP2	(CS)
WCP3	(LMS)
WCP4	(LMS)
WCP7	(LES)
WCP5	(RMS)
WCP6	(RMS)
WCP8	(RES)
LCP1	(CS)
LCP2	(CS)
LCP3	(LES)
LCP4	(RES)

4.2 80K Pump Fabrication Specification V049-2-096

Title: SPECIFICATION FOR 80K CRYOPUMP FABRICATION

SPECIFICATION FOR
80K CRYOPUMP FABRICATION

PREPARED BY: R.E. Curtis 4/26/96

STRUCTURAL ENGINEER: R. D. Gatto

QUALITY ASSURANCE: A L Bradbrook

MANUFACTURING ENGR: Phillip Feland

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.

1	DM 5/6/96	REG 5/6/96	REVISED PER DEO 0174
0	REG 4/26/96	REG 5/2/96	RELEASED PER DEO0148 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE REG 4/26/96	APPROVED DATE REG 5/2/96	Number A V049-2-096	Rev. 1

TABLE OF CONTENTS

1.0 Scope
2.0 Schedule
3.0 General Requirements
4.0 Codes And Standards
5.0 Fabrication Requirements
6.0 Materials
7.0 Identification
8.0 Required Documentation
9.0 Shop Testing
10.0 Cleaning & Painting
11.0 Storing And Shipping
12.0 Inspection And Quality Requirements
13.0 Non-Escort Privileges And Inspection Right

ATTACHMENTS:

1. Cryopump Fabrication Documents
2. Fabrication Flow Chart
3. Fabrication Priority List

1.0 SCOPE

1.1 This specification covers the minimum requirements of the manufacturing engineering, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of vacuum vessels for the LIGO vacuum system.

1.2 All attachments are incorporated herein by reference and made a part of this specification.

1.3 The specified equipment is intended 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 Richmond, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system of the sensitive interferometer components and optical beams, and other support facilities.

1.4 Fabrication and material procurement will be by PSI.

2.0 SCHEDULE

2.1 Chamber delivery shall be as follows:

Quantity/Size	Delivery Site	Dates	Production Lots
1-Long	PSI, Westborough	1 Aug. 1996	1 (First Article)
1-Long	PSI, Westborough	1 Nov. 1996	2
2-Long	PSI, Westborough	1 Feb. 1997	3
3-Short	PSI, Westborough	15 April 1997	4
1-Long	PSI, Westborough	15 June 1997	5
2-Long	PSI, Westborough	1 Oct. 1997	6
2-Short	PSI, Westborough	1 Dec. 1997	7
12 Total			

3.0 GENERAL REQUIREMENTS

3.1 The design and materials of fabrication shall be as shown on the PSI vessel weldment drawings.

3.2 The vessels shall be fabricated and tested in accordance with drawings, standards, and specifications referred to or attached as part of this specification.

3.3 The vessels covered by this specification are to be used in ultra-high vacuum service and require strict cleanliness and contamination prevention throughout the material handling, fabrication and shipping process. All storage and fabrication for this vessel shall be done in the area isolated (plastic room or equal) to prevent contamination from smoke, dust and oily vapors from other manufacturing areas. The area shall be purged with clean air to prevent contamination and adjacent areas.

3.4 Stainless steel fixtures (spiders, roundup rings, etc.) shall be used as required to maintain vessel and nozzle roundness during fabrication.

3.5 The vessel shall be fabricated per the attached PSI Quality Plan, and Fabrication Flow Chart - Attachment 2.

4.0 CODES AND STANDARDS

4.1 Priority Of Codes And Documents

1. This Specification
2. Fabrication drawings

4.2 The following codes and standards shall be applicable to the fabrication of the equipment:

4.2.1 American Society of Mechanical Engineers (ASME)

a. ASME Boiler and Pressure Vessel Code, 1992 Edition Through 1994 Addenda.

Section II	Material Specifications
	Part A, Ferrous
	Part B, Nonferrous
	Part C, Welding Rods, Electrodes and Filler Metals
Section VIII	Pressure Vessels, Division I (Stamp Not Required)
Section IX	Welding and Brazing Qualification

5.0 FABRICATION REQUIREMENTS

5.1 General

5.1.1 Mechanical design of the vessels shall be as shown on the PSI's fabrication drawings.

5.1.2 Vessels do not require ASME Code stamping or code inspection.

5.1.3 All vessels shall be furnished complete as shown on the PSI's drawings, as required, bolts, washers, and nuts. Tolerances shall be adhered to as specified on the detail drawings.

5.2 Rolling Of Shells

5.2.1 Carbon steel rollers shall be covered with heavy (paper or carpet) or S/S during the rolling process to prevent carbon steel contamination of the stainless steel vacuum shell and the aluminum reservoir shells.

5.2.2 The seam edges of plates to be rolled are to be preworked to assure roundness of the final cylinder.

5.3 Cleanliness

No grinding with abrasive wheels, cloth or stones is allowed on the internal vacuum surface unless specified in this specification. This material is intended for use in a high vacuum application. Potential hydrocarbon contamination shall be prevented. Also, the material shall be wrapped and covered at all times the material is not being processed to minimize possible exposure to contaminants. The shells shall be cleaned (per 9.1) prior to shipment.

No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) are to come in contact with the vessel interior surfaces during material handling and assembly. Machining fluids shall be water soluble and free of oil, sulfur and chlorides.

5.4 Welding

5.4.1 All welding shall be performed in accordance with the applicable codes (Para. 4.2.1) and PSI procedures for design and fabrication.

5.4.2 The PSI fitup tack welding procedures and procedure qualifications shall be used.

5.4.3 All weld joint preparation shall be done by tungsten carbide tooling if possible.

5.4.4 Welding Process

1. Vacuum boundary and attachment welds shall be made with the Plasma Arc process per PSI weld procedure WPS151 PAW. Shielding gas shall be a 75% Argon/25% Helium mixture, backing gas shall be 100% Argon and Plasma gas shall be 100% Argon. Hydrogen gas is not permitted. GTAW welds are acceptable for minor welds per PSI procedure WPS153 GTAW.

2. All weld repairs shall be performed per PSI procedure V049-2-074.

3. External support structures may be welded using GMAW process. All attachments to the vessel shall be by plasma arc or GTAW.

4. All weld wire and weld joint preparation areas shall be cleaned with CO_2 scrubbing prior to welding per PSI procedure V049-2-070.

5.4.5 All penetrations in the chamber shall be continuously welded on the inside per drawing details. Internal weld surface to be smooth but <u>NOT GROUND</u>.

5.4.6 All welds at vacuum boundaries to be vacuum tight with a helium leak rate equivalent to a total of 1×10^{-9} torr liters/sec/chamber. PSI will leak test all vessel welds with a helium mass spectrometer.

5.5 Backing strips or rings shall not be used.

5.6 Longitudinal seams shall be positioned as shown on detail drawings.

5.7 Sharp edges are to be removed from all carbon steel areas where external painting is to be applied.

5.8 <u>Post Weld Heat Treatment - Not Required</u>

6.0 MATERIALS

6.1 All vacuum boundary shell material shall meet the requirement of SA240 for both grades 304 and 304L. Vessel head and flange material shall be type 304L. All materials listed on the PSI bill of material will be provided by PSI.

7.0 IDENTIFICATION

7.1 Identification of the material shall be maintained through all manufacturing processes. All cutoff parts shall be marked with the heat number of the parent part as indicated below on the exterior surface only (not on the vacuum boundary).

7.2 If material identity is lost, the plate shall be requalified by making all tests that were required by the material specification or as indicated in this specification at the sellers expense. CMTRS have been provided to PSI for the above material, traceability of all materials must be maintained.

7.3 Marking the materials with marking fluids, die stamps, crayons, paints and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of .005" is acceptable for marking the outside only of the finished shell. All other marking methods must be approved by the purchaser prior to use. All parts shall be marked on outside surface only. Marking on interior boundary vacuum boundary surfaces is not allowed. The minimum marking is to be the heat/lot number.

8.0 SHOP TESTING

8.1 Testing of the external shell of the cryopump shall be per the Q.A. plan (V049-2-098) and Shop Conditioning/Test (V049-2-047). Helium leak testing of the reservoir shells shall be as follows:

The specification requires all leaks greater than 1x10E-9 torr-l/sec of helium to be repaired in accordance with LIGO approved procedures. In the case of the 80K pump, the reservoir assembly must be leak checked prior to its installation into the pump vacuum chamber. The assembly consists of the annular reservoir and that attached piping which must be welded to the reservoir prior to its installation in the pump chamber. Welds on attached piping made subsequent to installation of the reservoir must be tested separately. All leak testing and calibration of test equipment shall conform to ASTM E498, Test Method A. The results of the leak testing shall be documented by PSI Quality Assurance personnel in a brief test report.

Since the volume of the reservoir is large, in order to pump it down in a reasonable time, it will be necessary to use an auxiliary roughing pump in conjunction with the mass spectometer leak detector. A cold trap shall used to ensure that no oil from the roughing pump enters the reservoir. The leak detector and auxiliary pump shall be connected to the gaseous nitrogen vent nozzle on the reservoir. Other nozzles on the reservoir must be temporarily welded closed. Following the method in ASTM E498, proceed as follows:

1) Rough down the reservoir to the lowest pressure that the roughing pump is capable of - preferably 50 microns or less.

2) Open the valve to the leak detector and close the valve to the roughing pump.

3) Probe with helium around all welds to check for leaks. All welds are to be leak tight to 1x10E-9 torr-l/sec or less.

4) In the event that any weld fails, the test shall be repeated to verify that it is an actual failure rather than a false indication.

5) In the event that a weld fails to pass, it shall be repaired, and subjected to another leak test.

6) After all leaks have been found and repaired, the entire reservoir assembly shall be enclosed in a plastic enclosure into which helium is admitted to determine the entire reservoir assembly integrity.The reservoir shall be held in the enclosure containing helium for 5 minutes prior to testing with the leak detector. The entire assembly must be leak tight to 1x10E-9 torr-l/sec. If the assembly fails, the test shall be repeated to verify that the failure is real, and not just a false indication.

9.0 CLEANING AND PAINTING

9.1 Cleaning before shipment to be per PSI Specification V049-2-015.

9.2 Only carbon steel members are to be painted per specification V049-2-077.

10.0 STORING AND SHIPPING

10.1 Shipping covers shall be used on all flanged connections. Covers shall be used for protecting the connections from mechanical damage and preventing the entry of dirt into the equipment. The use of tape or plastic sheet alone as a shipping cover is not acceptable.

10.2 The vessels shall be wrapped in waterproof polyethylene and covered with a tarp immediately after cleaning operations have been completed to minimize contamination.

10.3 Finished flange surfaces must be covered and protected during all fabrication steps.

10.4 The Cryopump shall be prepared and shipped per PSI Procedure V049-2-123.

11.0 INSPECTION AND QUALITY REQUIREMENTS

11.1 PSI shall have in effect at all times, an inspection, testing and documentation program that will ensure that the equipment furnished under the specification will meet in all respects the requirements of the specification. ~~The responsibility for~~ inspection rests with the Q.A. Department.

11.2 PSI is to inspect the materials in a timely manner and the materials shall be stored indoors in a clean dry storage space after delivery.

12.0 NON-ESCORT PRIVILEGES AND INSPECTION RIGHT

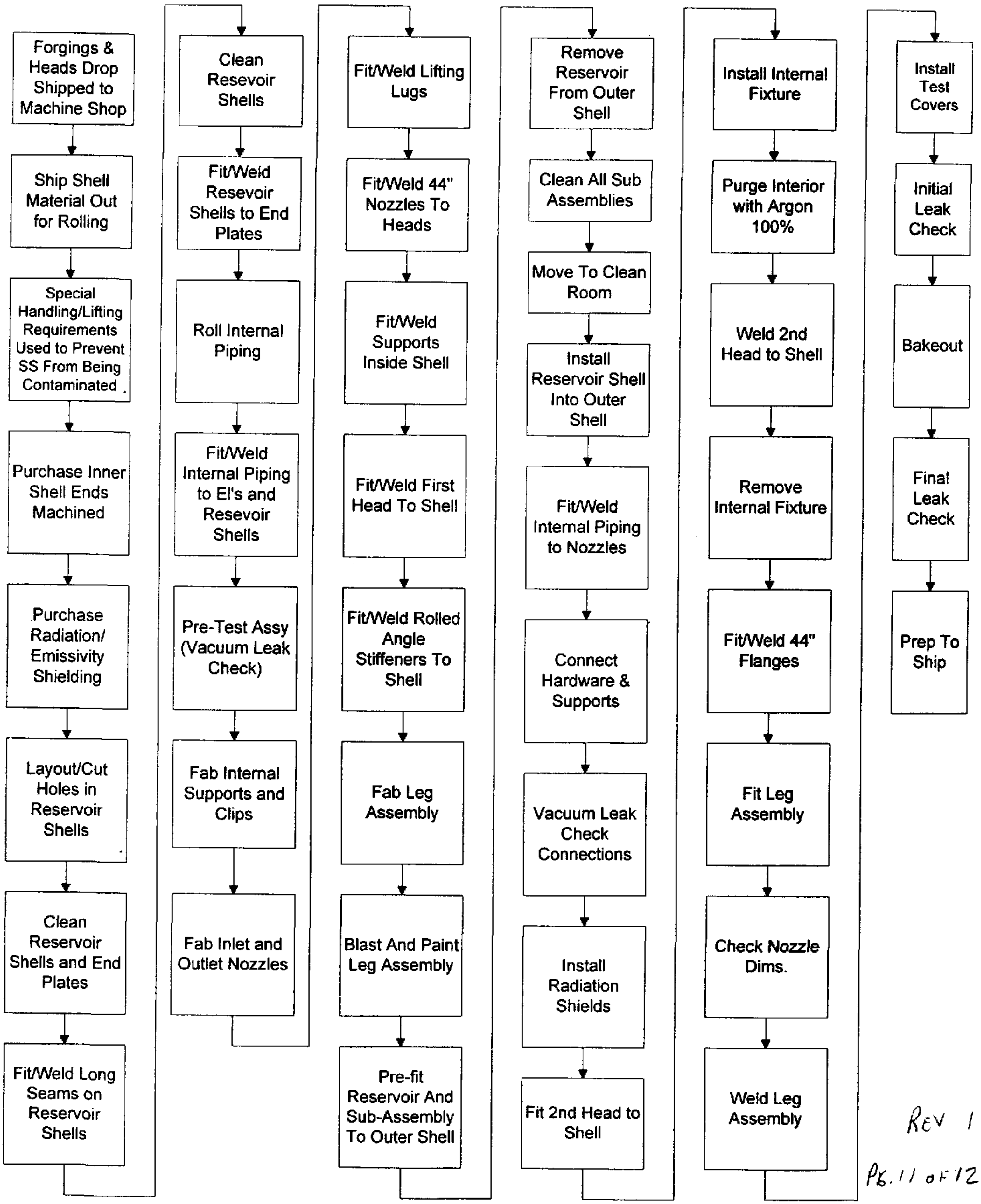
Non-escort privileges for LIGO or Government and LIGO representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to all areas where material is being processed and stored.

ATTACHMENT 1

CRYOPUMP DOCUMENTS

1.	Spec. For Cryopump Fabrication	V049-2-096
2.	Cryopump Quality Plan	V049-2-098
3.	Bill of Material	V049-4-004, V049-4-005
4.	Flanges	V049-2-040 & V049-2-042
5.	Heads	V049-2-039
6.	Raw Material Handling Procedure	V049-2-120
7.	Weld Data Sheet Spec.	V049-2-084
8.	Weld Procedures	V049-2-070, V049-2-071, V049-2-072, V049-2-073
9.	Weld Repair Procedure	V049-2-074
10.	Cleaning Procedures	V049-2-015
11.	Painting Procedures	V049-2-077
12.	Components Shop Conditioning/Test Plan	V049-2-047
13.	Bakeout Procedure	V049-2-019
14.	Leak Test Procedure	V049-2-014
15.	Dimensional Verification Procedure	V049-2-121
16.	Component Packaging, Handling, and Shipping Procedure	V049-2-123
17.	PSI Drawing	
	80K Cryopump - Long	V049-4-004
	80K Cryopump - Short	V049-4-005
	44 5/8" ID Flange Detail (Grooved)	V049-4-017

ATTACHMENT 2
80K CRYOPUMP FABRICATION PROCESS DIAGRAM



Rev 1

ATTACHMENT 3

80K CRYOPUMP FABRICATION PRIORITY LIST

WCP1	(CS)
WCP2	(CS)
WCP3	(LMS)
WCP4	(LMS)
WCP7	(LES)
WCP5	(RMS)
WCP6	(RMS)
WCP8	(RES)
LCP1	(CS)
LCP2	(CS)
LCP3	(LES)
LCP4	(RES)

4.3 80K Pump Quality Plan V049-2-098

Title: **QUALITY PLAN FOR LIGO - 80K CRYO PUMPS**

QUALITY PLAN

FOR

LIGO

80K CRYO PUMPS

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

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED A.L. Bradbrook DATE 4/30/96	APPROVED REB DATE 4/30/96	Number: A V-049-2-098	Rev Ø

Number

Rev

APPLICABLE DRAWINGS

V049-4-004	80 K CRYO PUMP, LONG
V049-4-005	80K CRYO PUMP, SHORT

APPLICABLE PROCEDURES

V049-2-070	WELDING PLASMA-ARC	P8-P8
V049-2-073	WELDING GTAW	P8-P8
V049-2-015	CLEANING	
V049-2-019	BAKEOUT	
V049-2-047	FINAL VACUUM TEST	
V049-2-014	HELIUM LEAK TEST	
V049-2-096	80K PUMP FABRICATION SPEC	

SPECIFICATION V049-2-098 **REV.** ∅

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581-5003
(508) 366- 9111 Fax (508) 870-5930

PROJECT LIGO
ITEM 80K CRYO PUMP
APPLICABLE CODE ASME VIII DIV. I (WHERE APPLICABLE)
JOB NO. V59049-
DWG NO.
PG 3 OF 5

ASME CODE QUALITY PLAN

LEGEND: **D** = DIMENSIONAL **V** = VISIUAL **RT** = RATIOGRAPHY **PT** = LIQUID PENETRANT **MT** = MAGNETIC PARTICLE **ET** = EDDY CURRENT **LT** = LEAK TEST **UT** = ULTRASONIC **W** = WITNESS **X** = HOLD POINT **√** = APPROVED **R** = REVIEW

QUALITY PLAN REVIEWED
QA ALB
AI N/A

QUALITY PLAN	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	**PSI** QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
VERIFY ACCEPTANCE OF MATERIALS				X			
VERIFY DIA. & CIR. OF HEADS & SHELLS				X			
VERIFY ROUNDNESS OF SHELL AFTER ROLLING.				X			
VERIFY ROUNDNESS OF HEADS				X			
INSPECT FIT-UP & WELDING OF FOLLOWING NOZZ			V049-2-070 V049-2-073	X			
- LONG SEAM SHELL				X			
- 1ST HEAD TO SHELL				X			

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

QUALITY PLAN REVIEWED QA aRB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
INSPECT FIT-UP &			V049-2-070				
WELDING OF NOZZLES:			V049-2-073				
GN2 VENT				X			
LN2 LEVEL CONTROL				X			
WARM GN2 INLET				X			
ELECTRICAL				X			
RELIEF VALVE				X			
VACUUM GAUGE				X			
ROUGHING PORT				X			
LN2 INLET				X			
CLEAN AIR VENT				X			
45° NOZ. TO HEAD				X			
45" NOZ. TO HEAD				X			
INSPECT FIT-UP &			V049-2-070				
WELDING OF:			V049-2-073				
INTERNAL LN2				X			
RESERVOIR				X			
LEG SUPPORTS							
TO SHELL				X			
VISUALLY INSPECT				X			
ALL INTERNAL							
WELDS.							

SPECIFICATION V049-2-098 REV. Ø

QUALITY PLAN REVIEWED QA aRB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
VISUALLY INSPECT				X			
INTERNAL SHIELDING.							
INSPECT FIT-UP &			V049-2-070	X			
WELDING OF 2ND			V049-2-073				
HEAD TO SHELL.							
VISUALLY INSPECT				X			
LEG SUPPORT							
STRUCTURE.							
FINAL DIMENSIONAL				X			
INSPECTION.							
VERIFY FINAL		V049-2-015		X			
CLEANING.							
VERIFY FINAL		V049-2-019		X			
BAKEOUT.							
VERIFY FINAL							
VACUUM TEST AND		V049-2-047		X			
HELIUM LEAK TEST.		V049-2-014		X			
SHIP TO LIGO				X			DOCUMENTATION PACKAGE

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

4.4 80K Pump Testing/Inspections

Each 80K pump will be inspected after mechanical assembly is complete prior to being released for conditioning/testing. (See "Dimensional Fabrication Procedure" V049-2-121 for additional details).

After release, the 80K pump will be leak checked, cleaned, baked out and prepared for shipment. (See "Component Shop Conditioning/Test Procedure" V049-2-047 and "Component Packaging, Handling and Preparation for Shipment" V049-2-123 for additional details).

5.1 Spool/Mode Cleaner/Beam Manifold Fabrication Plan V049-2-083

Title: FABRICATION PLAN FOR SPOOLS AND BEAM TUBES

FABRICATION PLAN

FOR

SPOOLS AND BEAM TUBES

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Phillip Fabal

QUALITY ASSURANCE: Alan L. Bradbrook

MANUFACTURING ENGINEER: Phillip Fabal

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: Buckel Begley

Ø	PF 5/2/96	RB 5/2/96	ISSUED PER DED 0161 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED PEF	DATE 5/2/96	APPROVED RB	DATE 5/2/96	Number A V049-2-083	Rev. Ø

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibility

4.0 Fabrication Plan

ATTACHMENTS:

1. Spool and Beam Tube Fabrication Documents
2. Fabrication Flow Chart
3. Fabrication Priority List

1.0 PURPOSE

The purpose of this procedure is to define design guidelines, specifications, and procedures to enable PSI to specify, purchase, inspect, fabricate, test and ship the spools and beam tubes per LIGO requirements.

2.0 GENERAL

All Spools and Beam Tubes shall be fabricated per this fabrication plan. Each fabrication process shall be controlled via a written procedure. A "first article" approach will be used to validate all fabrication processes prior to release of the full vessel lot.

All vessels will be fabricated in accordance with the Quality Plan. Key points in the fabrication process shall be verified to ensure consistent results.

All vacuum equipment shall be fabricated in accordance with LIGO Project Contract PC175730 dated September 12, 1995, and subsequent change orders.

3.0 RESPONSIBILITY

The Manufacturing Department is responsible for the execution of this procedure, with input and monitoring by the Project Engineer, the Quality Assurance Department, and the Project Manager.

4.0 FABRICATION PLAN

4.1 A first article approach will be used to start the manufacturing cycle to validate the manufacturing procedures and technique prior to the full production release.

4.2 All Spoosl and Beam Tubes will be fabricated at PSI. PSI will perform vessel cleaning, leak checking, bakeout and preparation for shipment.

4.3 All Spools and Beam Tubes will be fabricated and tested per documents listed in Attachment I "Fabrication Documents".

4.4 All Spools and Beam Tubes will be fabricated according to the Fabrication Priority List, Attachment 2.

4.5 Procurement

PSI will procure all S.S. plate and flange material.

PSI will purchase vessel heads.

4.6 Quality Assurance

Each Spool and Tube Fabrication Process shall be monitored and control via the Quality Plan.

PSI will inspect all incoming materials to purchase documents.

4.7 Shop Conditioning/Testing

The Spools and Beam Tubes will be shop conditioned (cleaning, bakeout, etc.) per PSI Procedure V049-2-047.

4.8 Preparation For Shipment

The Spools and Beam Tubes will be prepared and shipped per PSI Procedure V049-2-123.

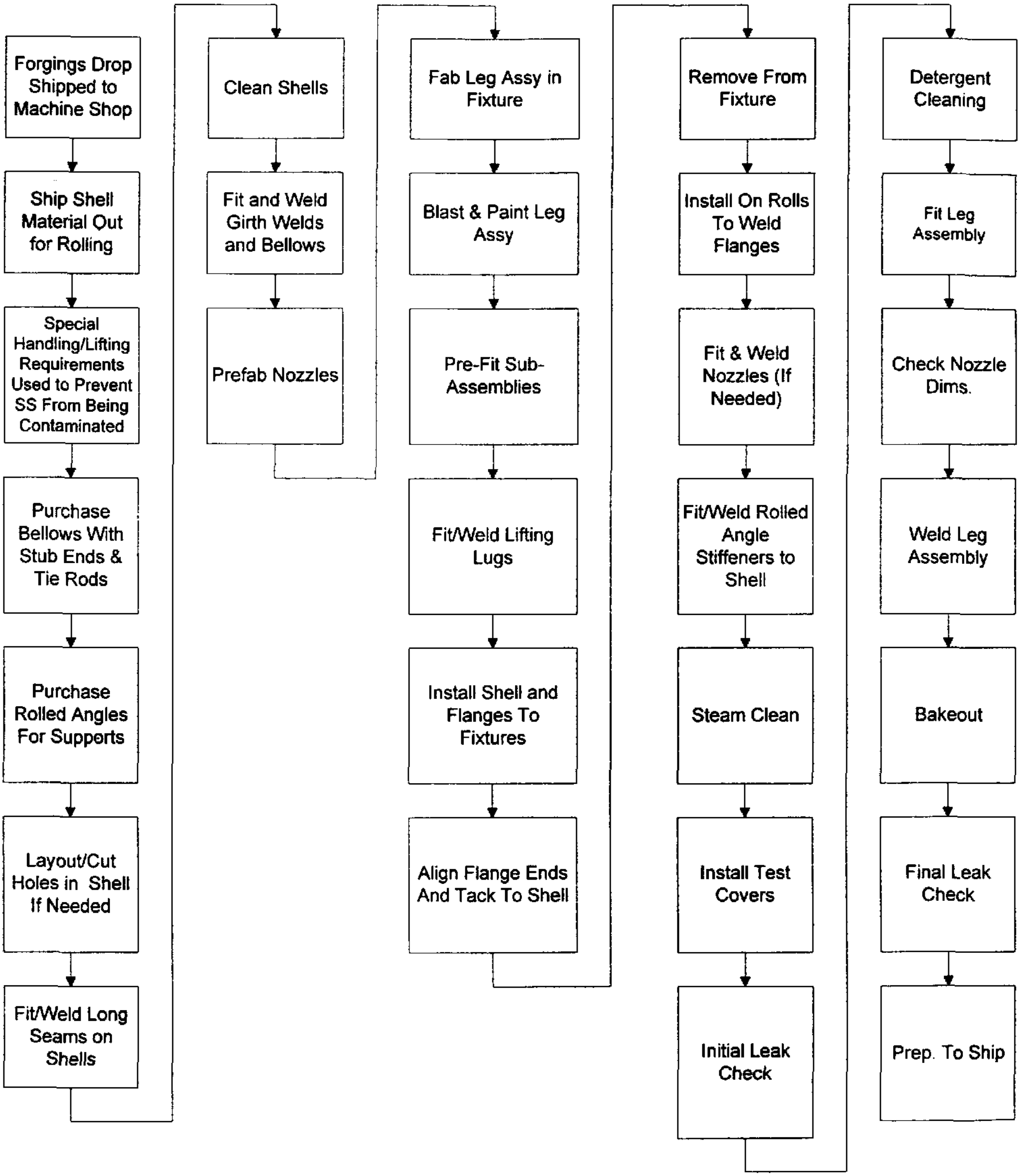
ATTACHMENT 1

SPOOLS AND BEAM TUBES DOCUMENTS

1.	Spec. For Spool and Beam Tube Fabrication	V049-2-097
2.	Spool and Beam Tube Quality Plan	V049-2-099
3.	Flanges	V049-2-040 & V049-2-042
4.	Raw Material Handling Procedure	V049-2-120
5.	Weld Data Sheet Spec.	V049-2-084
6.	Weld Procedures	V049-2-070, 071, 072, 073
7.	Weld Repair Procedure	V049-2-074
8.	Cleaning Procedures	V049-2-015
9.	Painting Procedures	V049-2-077
10.	Component Shop Conditioning/Test Plan	V049-2-014
11.	Bakeout Procedure	V049-2-019
12.	Leak Test Procedure	V049-2-047
13.	Dimensional Verification Procedure	V049-2-121
14.	Component, Handling, and Shipping Procedure	V049-2-123
15.	PSI Drawings	

Adapter A-1, 44.62" ID x 72.25 ID	V049-4-A1
Adapter A-2, 48.25" ID x 72.25 ID	V049-4-A2
Adapter A-3, 48.25" ID x 60.5 ID	V049-4-A3
60" HAM Cover, Grooved	V049-4-A4
Adapter A-6, 48.25" ID x 60.5 ID	V049-4-A6
Adapter A-7, 60.5" ID x 72.25 ID	V049-4-A7
Adapter A-12, 48.25" ID x 60.5 ID	V049-4-A12
BSC End Cover 60"	V049-4-All
Adapter A-13, 60.5" ID With 72.25 ID	V049-4-A13
Adapter A-14, 44.62" ID With 60.5 ID	V049-4-A14
Adapter A-15, 48.25" ID With 60.5 ID	V049-4-A15
Spool B-1, 72.25 ID	V049-4-B1
Spool B-2A, 30.5 ID x 60.5 ID	V049-4-B2A
Spool B-2B, 30.5 ID x 60.5 ID	V049-4-B2B
Spool B03A, 30.5 ID x 60.5 ID	V049-4-B3A
Spool B-4, 48.25" ID	V049-4-B4
Spool B-5A, 30.5 ID x 60.5 ID	V049-4-B5A
Spool B-6, 48.25" ID	V049-4-B6
Spool B-7, 48.25" ID	V049-4-B7
Spool B-8, 72.25" ID	V049-4-B8
Spool B-9, 72.25" ID	V049-4-B9
Spool BE-1, 72.25" ID	V049-4-BE1
Spool BE-2, 60.5" ID	V049-4-BE2
Off Set Spool BE-3, 60.5" ID x 60.5 ID	V049-4-BE3
Off Set Spool BE-3A, 60.5" ID x 60.5 ID	V049-4-BE3A
Spool, BE-4, 44.62" ID	V049-4-BE4
Spool, BE-5, 72.25" ID	V049-4-BE5
Spool, BE-6, 72.25" ID x 72.25 ID	V049-4-BE6

ATTACHMENT 2
SPOOLS AND BEAM TUBE FABRICATION PROCESS DIAGRAM



REV Ø

ATTACHMENT 3

SPOOL AND BEAM TUBE FABRICATION PRIORITY LIST

First Priority For Washington	**Second Priority For Washington**
2-A1	
2-A3	4-A1
1-A6	2-A7
1-A12	
2-A13	2-A14
2-A15	2-BE4
2-A15	
2-B1	
2-B2A	
1-B3A	
1-B4	
1-B5A	
1-B6	
1-B7	
2-B8	
2-BE2	
2-BE3	
2-BE3A	
2-BE4	
1-BE5	
1-BE6	
2-BE9	

ATTACHMENT 3

SPOOLS AND BEAM TUBE FABRICATION PRIORITY LIST

For Louisiana Site

4-A1

2-A2

2-A3

2-A4

2-A7

2-B1

1-B3A

1-B5A

2-B9

2-BE1

2-BE2

4-BE3

4-BE4

1-BE5

1-BE6

5.2 Spool/Mode Cleaner/Beam Manifold Fabrication Specification V049-2-097

Title: SPECIFICATION FOR SPOOLS/MODE CLEANERS/BEAM TUBE MANIFOLDS FABRICATION

SPECIFICATION FOR

SPOOLS/MODE CLEANERS/BEAM TUBE MANIFOLDS FABRICATION

PREPARED BY:	R.E. Curtis 4/29/96
STRUCTURAL ENGINEER:	R.P. Catt
QUALITY ASSURANCE:	A A Bradbook
MANUFACTURING ENGR:	Phillip F Eland
TECHNICAL DIRECTOR:	D.C. McWilliams
PROJECT MANAGER:	Randall Bagg

0	REC	REB 5/2/96	RELEASED PER DEO 3148 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

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

INITIAL APPROVALS	PREPARED DATE	APPROVED DATE	Number	Rev.
	R.E.C. 4/29/96	REB 5/2/96	A **V049-2-097**	0

TABLE OF CONTENTS

1.0 Scope

2.0 Schedule

3.0 General Requirements

4.0 Codes And Standards

5.0 Fabrication Requirements

6.0 Materials

7.0 Identification

8.0 Required Documentation

9.0 Shop Testing

10.0 Cleaning & Painting

11.0 Storing And Shipping

12.0 Inspection And Quality Requirements

13.0 Non-Escort Privileges And Inspection Right

ATTACHMENTS:

1. Fabrication/Test Documents
2. Fabrication Flow Chart
3. Fabrication Priority List

1.0 SCOPE

1.1 This specification covers the minimum requirements of the manufacturing engineering, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of vacuum vessels for the LIGO vacuum system.

1.2 All attachments are incorporated herein by reference and made a part of this specification.

1.3 The specified equipment is intended 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 Richmond, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system of the sensitive interferometer components and optical beams, and other support facilities.

1.4 Fabrication and material procurement will be by PSI.

2.0 SCHEDULE

2.1 Spool Assembly delivery shall be as follows: (To be determined by PSI Manufacturing)

3.0 GENERAL REQUIREMENTS

3.1 The design and materials of fabrication shall be as shown on the PSI vessel weldment drawings.

3.2 The vessels shall be fabricated and tested in accordance with drawings, standards, and specifications referred to or attached as part of this specification.

3.3 The vessels covered by this specification are to be used in ultra-high vacuum service and require strict cleanliness and contamination prevention throughout the material handling, fabrication and shipping process. All storage and fabrication for this vessel shall be done in the area isolated (plastic room or equal) to prevent contamination from smoke, dust and oily vapors from other manufacturing areas. The area shall be purged with clean air to prevent contamination and adjacent areas.

3.4 Stainless steel fixtures (spiders, roundup rings, etc.) shall be used as required to maintain vessel and nozzle roundness during fabrication.

3.5 The vessel shall be fabricated per the attached PSI Quality Plan, and Fabrication Flow Chart Attachment 2.

4.0 CODES AND STANDARDS

4.1 Priority Of Codes And Documents

1. This Specification
2. Fabrication drawings

4.2 The following codes and standards shall be applicable to the fabrication of the equipment:

4.2.1 American Society of Mechanical Engineers (ASME)

a. ASME Boiler and Pressure Vessel Code, 1992 Edition Through 1994 Addenda.

Section II	Material Specifications
	Part A, Ferrous
	Part B, Nonferrous
	Part C, Welding Rods, Electrodes and Filler Metals
Section VIII	Pressure Vessels, Division I (Stamp Not Required)
Section IX	Welding and Brazing Qualification

5.0 FABRICATION REQUIREMENTS

5.1 General

5.1.1 Mechanical design of the vessels shall be as shown on the PSI's fabrication drawings.

5.1.2 Vessels do not require ASME Code stamping or code inspection.

5.1.3 All vessels shall be furnished complete as shown on the PSI's drawings, as required, bolts, washers, and nuts. Tolerances shall be adhered to as specified on the detail drawings.

5.2 Rolling Of Shells

5.2.1 Carbon steel rollers shall be covered with heavy (paper or carpet) or S/S during the rolling process to prevent carbon steel contamination of the stainless steel.

5.2.2 The seam edges of plates to be rolled are to be preworked to assure roundness of the final cylinder.

5.3 Cleanliness

No grinding with abrasive wheels, cloth or stones is allowed on the internal vacuum surface unless specified in this specification. This material is intended for use in a high vacuum application. Potential hydrocarbon contamination shall be prevented. Also, the material shall be wrapped and covered at all times the material is not being processed to minimize possible exposure to contaminants. The shells shall be cleaned (per 9.1) prior to shipment.

No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) are to come in contact with the vessel interior surfaces during material handling and assembly. Machining fluids shall be water soluble and free of oil, sulfur, and chorides.

5.4 Welding

5.4.1 All welding shall be performed in accordance with the applicable codes (Para. 4.2.1) and PSI procedures for design and fabrication.

5.4.2 The PSI fitup tack welding procedures and procedure qualifications shall be used.

5.4.3 All weld joint preparation shall be done by tungsten carbide tooling if possible.

5.4.4 Welding Process

1. Vacuum boundary and attachment welds shall be made with the Plasma Arc process per PSI weld procedure WPS151 PAW. Shielding gas shall be a 75% Argon/25% Helium mixture, backing gas shall be 100% Argon and Plasma gas shall be 100% Argon. Hydrogen gas is not permitted. GTAW welds are acceptable for minor welds per PSI procedure WPS153 GTAW.

2. All weld repairs shall be performed per PSI procedure V049-2-074.

3. External support structures may be welded using GMAW process. All attachments to the vessel shall be by plasma arc or GTAW.

4. All weld wire and weld joint preparation areas shall be cleaned with CO_2 scrubbing prior to welding per PSI procedure V049-2-070.

5.4.5 All penetrations in the chamber shall be continuously welded on the inside per drawing details. Internal weld surface to be smooth but NOT GROUND.

5.4.6 All welds at vacuum boundaries to be vacuum tight with a helium leak rate equivalent to a total of 1×10^{-9} torr liters/sec/chamber. PSI will leak test all vessel welds with a helium mass spectrometer.

5.5 Backing strips or rings shall not be used.

5.6 Longitudinal seams shall be positioned as shown on detail drawings.

5.7 Sharp edges are to be removed from all carbon steel areas where external painting is to be applied.

5.8 Post Weld Heat Treatment - Not Required

6.0 MATERIALS

6.1 All vacuum boundary shell material shall meet the requirement of SA240 for both grades 304 and 304L. Vessel head and flange material shall be type 304L. All materials listed on the PSI bill of material will be provided by PSI.

7.0 IDENTIFICATION

7.1 Identification of the material shall be maintained through all manufacturing processes. All cutoff parts shall be marked with the heat number of the parent part as indicated below on the exterior surface only (not on the vacuum boundary).

Number

Rev.

7.2 If material identity is lost, the plate shall be requalified by making all tests that were required by the material specification or as indicated in this specification at the sellers expense. CMTRS have been provided to PSI for the above material, traceability of all materials must be maintained.

7.3 Marking the materials with marking fluids, die stamps, crayons, paints and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of .005" is acceptable for marking the <u>outside only</u> of the finished shell. All other marking methods must be approved by the purchaser prior to use. <u>All parts shall be marked on outside surface only</u>. Marking on interior boundary vacuum boundary surfaces is <u>not allowed</u>. The minimum marking is to be the <u>heat/lot number</u>.

8.0 SHOP TESTING

8.1 Testing shall be per the Q.A. plan (V049-2-099).

9.0 CLEANING AND PAINTING

9.1 Cleaning before shipment to be per PSI Specification V049-2-015.

9.2 Only carbon steel members are to be painted per specification V049-2-077.

10.0 STORING AND SHIPPING

10.1 Shipping covers shall be used on all flanged connections. Covers shall be provided by the buyer for protecting the connections from mechanical damage and preventing the entry of dirt into the equipment. The use of tape or plastic sheet alone as a shipping cover is not acceptable.

10.2 The vessels shall be wrapped in waterproof polyethylene and covered with a tarp immediately after cleaning operations have been completed to minimize contamination.

10.3 Finished flange surfaces must be covered and protected during all fabrication steps and during shipment to PSI.

10.4 The components of this specification shall be prepared and shipped per PSI Procedure V049-2-123.

11.0 INSPECTION AND QUALITY REQUIREMENTS

11.1 PSI shall have in effect at all times, an inspection, testing and documentation program that will ensure that the equipment furnished under the specification will meet in all respects the requirements of the specification. The responsibility for inspection rests with Q.A. Department.

11.2 PSI is to inspect the materials and store them indoors in a clean dry storage space after delivery.

12.0 NON-ESCORT PRIVILEGES AND INSPECTION RIGHT

Non-escort privileges for LIGO or Government and LIGO representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to all areas where material is being processed and stored.

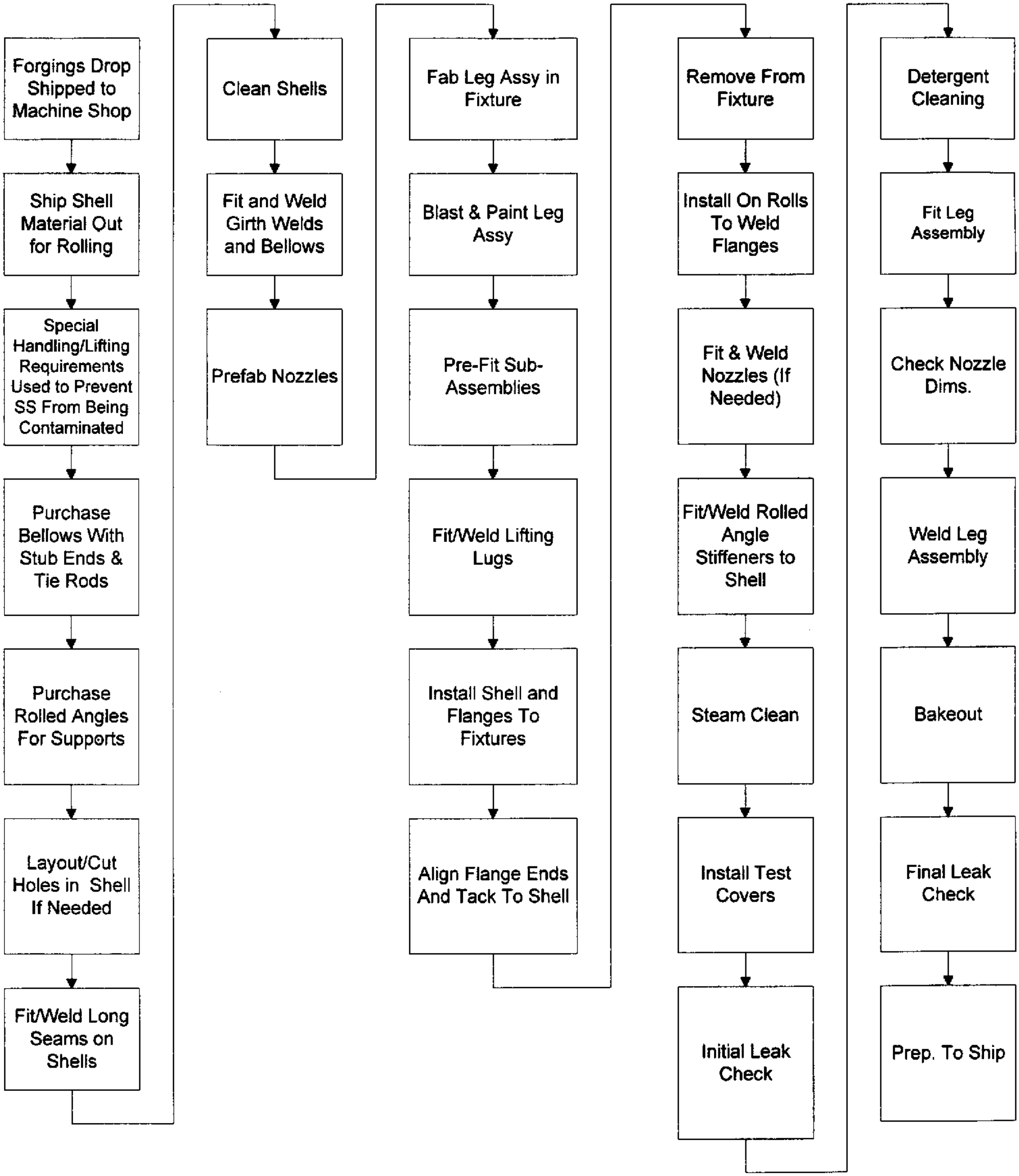
Title	SPECIFICATION FOR SPOOLS/MODE CLEANERS/BEAM TUBE MANIFOLDS FABRICATION

ATTACHMENT 1

SPOOLS AND BEAM TUBES DOCUMENTS

1.	Spec. For Spool and Beam Tube Fabrication	V049-2-097
2.	Spool and Beam Tube Quality Plan	V049-2-099
3.	Flanges	V049-2-040 & V049-2-042
4.	Raw Material Handling Procedure	V049-2-120
5.	Weld Data Sheet Spec.	V049-2-084
6.	Weld Procedures	V049-2-070, 071, 072, 073
7.	Weld Repair Procedure	V049-2-074
8.	Cleaning Procedures	V049-2-015
9.	Painting Procedures	V049-2-077
10.	Component Shop Conditioning/Test Plan	V049-2-047
11.	Bakeout Procedure	V049-2-019
12.	Leak Test Procedure	V049-2-014
13.	Dimensional Verification Procedure	V049-2-121
14.	Component, Handling, and Shipping Procedure	V049-2-123
15.	PSI Drawings	
	Adapter A-1, 44.62" ID x 72.25 ID	V049-4-A1
	Adapter A-2, 48.25" ID x 72.25 ID	V049-4-A2
	Adapter A-3, 48.25" ID x 60.5 ID	V049-4-A3
	60" HAM Cover, Grooved	V049-4-A4
	Adapter A-6, 48.25" ID x 60.5 ID	V049-4-A6
	Adapter A-7, 60.5" ID x 72.25 ID	V049-4-A7
	Adapter A-12, 48.25" ID x 60.5 ID	V049-4-A12
	BSC End Cover 60"	V049-4-All
	Adapter A-13, 60.5" ID With 72.25 ID	V049-4-A13
	Adapter A-14, 44.62" ID With 60.5 ID	V049-4-A14
	Adapter A-15, 48.25" ID With 60.5 ID	V049-4-A15
	Spool B-1, 72.25 ID	V049-4-B1
	Spool B-2A, 30.5 ID x 60.5 ID	V049-4-B2A
	Spool B-2B, 30.5 ID x 60.5 ID	V049-4-B2B
	Spool B03A, 30.5 ID x 60.5 ID	V049-4-B3A
	Spool B-4, 48.25" ID	V049-4-B4
	Spool B-5A, 30.5 ID x 60.5 ID	V049-4-B5A
	Spool B-6, 48.25" ID	V049-4-B6
	Spool B-7, 48.25" ID	V049-4-B7
	Spool B-8, 72.25" ID	V049-4-B8
	Spool B-9, 72.25" ID	V049-4-B9
	Spool BE-1, 72.25" ID	V049-4-BE1
	Spool BE-2, 60.5" ID	V049-4-BE2
	Off Set Spool BE-3, 60.5" ID x 60.5 ID	V049-4-BE3
	Off Set Spool BE-3A, 60.5" ID x 60.5 ID	V049-4-BE3A
	Spool, BE-4, 44.62" ID	V049-4-BE4
	Spool, BE-5, 72.25" ID	V049-4-BE5
	Spool, BE-6, 72.25" ID x 72.25 ID	V049-4-BE6

ATTACHMENT 2
SPOOLS AND BEAM TUBE FABRICATION PROCESS DIAGRAM



REV
Ø

ATTACHMENT 3

SPOOL AND BEAM TUBE FABRICATION PRIORITY LIST

First Priority For Washington

2-A1
2-A3
1-A6
1-A12
2-A13
2-A15
2-A15
2-B1
2-B2A
1-B3A
1-B4
1-B5A
1-B6
1-B7
2-B8
2-BE2
2-BE3
2-BE3A
2-BE4
1-BE5
1-BE6
2-BE9

Second Priority For Washington

4-A1
2-A7

2-A14
2-BE4

ATTACHMENT 3

SPOOLS AND BEAM TUBE FABRICATION PRIORITY LIST

For Louisiana Site

4-A1

2-A2

2-A3

2-A4

2-A7

2-B1

1-B3A

1-B5A

2-B9

2-BE1

2-BE2

4-BE3

4-BE4

1-BE5

1-BE6

5.3 Spools/Mode Cleaner/Beam Manifold Quality Plan V049-2-099

Title: **QUALITY PLAN FOR LIGO - SPOOLS AND BEAM TUBES**

QUALITY PLAN

FOR

LIGO

SPOOLS AND BEAM TUBES

Ø	ALB 5/3/96	RES 5/3/96	RELEASE PER DEO 0168
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED A L Bradbrook DATE 5/2/96	APPROVED RES DATE 5/3/96	Number A V049-2-099	Rev Ø

APPLICABLE DRAWINGS

REFER TO FABRICATION PLAN V049-2-083

APPLICABLE PROCEDURES

Spec. for Spool and Beam Tube Fabrication	V049-2-097
Flanges	V049-2-040 & V049-2-042
Raw Material Handling Procedure	V049-2-120
Weld Data Sheet Spec.	V049-2-084
Weld Procedures	V049-2-070, 071, 072, 073
Weld Repair Procedure	V049-2-074
Cleaning Procedures	V049-2-015
Painting Procedures	V049-2-077
Component Shop Conditioning/Test Plan	V049-2-014
Bakeout Procedure	V049-2-019
Leak Test Procedure	V049-2-047
Dimensional Verification Procedure	V049-2-121
Component, Handling and Shipping Procedure	V049-2-123

SPECIFICATION V049-2-099 **REV.** Ø

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581-5003
(508) 366- 9111 Fax (508) 870-5930

PROJECT LIGO JOB NO. V59049-
ITEM DWG NO.
APPLICABLE CODE ASME VIII DIV. 1 (WHERE APPLICABLE) PG 3 OF 5

ASME CODE QUALITY PLAN

LEGEND: D = DIMENSIONAL **V** = VISIUAL **RT** = RATIOGRAPHY **PT** = LIQUID PENETRANT **MT** = MAGNETIC PARTICLE **ET** = EDDY CURRENT **LT** = LEAK TEST **UT** = ULTRASONIC **W** = WITNESS **X** = HOLD POINT √ = APPROVED **R** = REVIEW

QUALITY PLAN REVIEWED QA QRB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
VERIFY ROUNDNESS OF ROLLED SHELLS.	V-D			X			
VERIFY LOCATION OF NOZZLE CUTOUTS IN SHELL.	V-D			X			
VERIFY FIT-UP AND WELDING OF LONG SEAM(S).	V-D	V049-2-128	V049-2-070 V049-2-073	X			
CLEAN SHELL MATERIAL (STEAM)	V			X			
VERIFY FIT-UP AND WELDING OF GIRTH SEAMS.	V-D	V049-2-128	V049-2-070 V049-2-073	X			

SPECIFICATION V049-2-099 REV. Ø

QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
INSPECT FOLLOWING							
PRE FAB NOZZLES:	V-D	V049-2-128	V049-2-070	X			
LEG ASSEMBLY:	V-D		V049-2-073	X			
LIFTING LUGS:	V-D			X			
VERIFY FIT-UP AND	V-D	V049-2-128	V049-2-070	X			
WELDING OF			V049-2-073				
FLANGES TO SHELL.							
INSPECT FOLLOWING							
FIT-UP AND WELDING:							
NOZZLES:	V-D	V049-2-128	V049-2-070	X			
ANGLE STIFFENERS:	V-D		V049-2-073	X			
STEAM CLEAN	V			X			
ASSEMBLY.							
PERFORM GROSS	R			X			
LEAK CHECK.							
PERFORM FINAL	V	V049-2-015		X			
DETERGENT CLEAN							
PERFORM FINAL	V-D	V049-2-128		X			
DIMENSIONAL							
INSPECTION							

FILED F:\TEMPLATE\ENGFORMS\ASMEQPL

SPECIFICATION V049-2-099 **REV.** Ø

QUALITY PLAN REVIEWED QA ARB AI N/A	TYPE INSP.	PROCEDURE OR DRAWING	WELDING PROCEDURE	PSI QUALITY ASSURANCE SIGN/DATE	AUTHORIZED INSPECTOR SIGN/DATE	CUSTOMER QA SIGN/DATE	REMARKS
BAKEOUT	R	V049-2-019		X			
PERFORM FINAL LEAK CHECK	R	V049-2-047		X			
SHIP TO LIGO				X			DOCUMENTATION PACKAGE

FILED F:TEMPLATE\ENGFORMS\ASMEQPL

5.4 Spools/Mode Cleaner/Beam Manifold Testing/Inspections

Each Spool/Mode Cleaner and Beam Manifold will be inspected after Mechanical Assembly is complete prior to being released for conditioning/testing (See "Dimensional Fabrication Procedure" V049-2-121 for additional details).

After release, the components will be leak checked, cleaned, baked out and prepared for shipment. (See "Component Shop Conditioning/Test Procedure" V049-2-047 and "Component Packaging, Handling and Preparation for Shipment" V049-2-123 for additional details).

6.0 MISCELLANEOUS COMPONENTS

6.1 General

Miscellaneous components will be evaluated during the fabrication program on a make/buy basis. These components include clean air piping, Class 100 clean rooms, vacuum header piping and miscellaneous pipe/valve supports.

Once a decision has been made to make an item rather than to buy it, the appropriate fabrication documentation will be prepared and submitted to LIGO.

6.2 Manufacturing Documentation/Q.A.

Once PSI determines a component will be made in-house, detailed fabrication drawings will be made. The same project procedures included as attachments to this volume will be applied to these miscellaneous components as well.

6.3 Testing

Miscellaneous components will be tested at the site as part of the system acceptance tests.

7.0 SPECIAL EQUIPMENT REQUIREMENTS

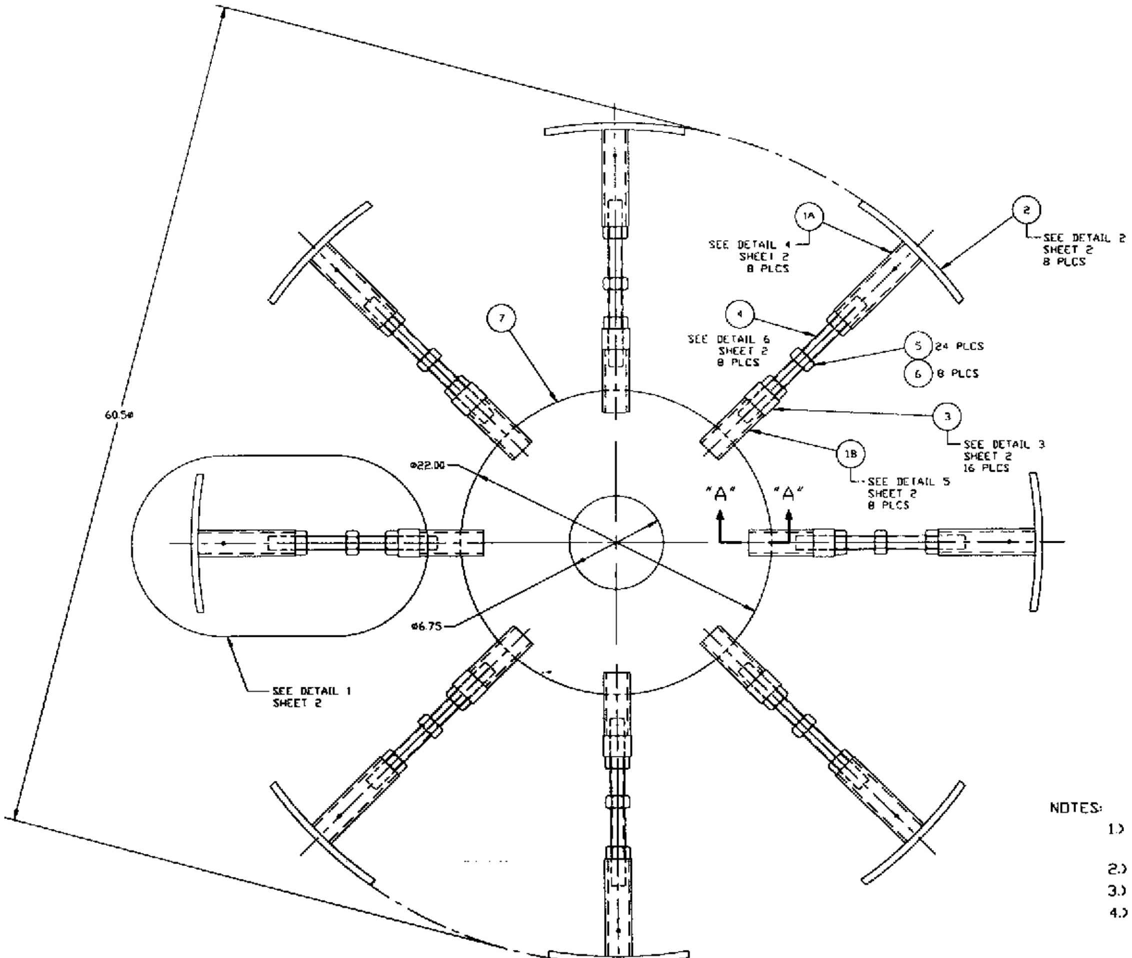
7.1 General

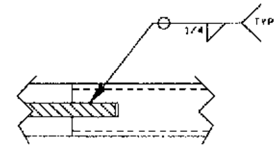
Various special devices/facilities will be used to fabricate the LIGO Vacuum Equipment. These devices/facilities are required to attain and maintain the required level of component dimensional accuracy and cleanliness.

7.2 Vessel Fixtures

Special rounding fixtures (internal spiders and external clam shell clamps) will be used to maintain vessel shell and nozzle roundness. These devices will remain in the vessel during machining, heat treating and welding operations. (See attached drawing.)

ITEM	PART NUMBER	SUFFIX	QTY	UM	DESCRIPTION
1	C011003-10		10	FT	PIPE, SCH 80 304 #312 1-1/2"
2	C387908-06		10	FT	BAR, 1/2" x 6" 304 A479
3	C457932		1	FT	ROUND BAR 2" O.D. 304 A479
4	V049M076		8	FT	ROD, THREADED 1"-8 UNC A193 GRB8 NICKLE PLATED
5	C106300		8	EA	NUT, HEAVY HEX 1"-8 UNC A193 GRB8
6	C429600		8	EA	WASHER, FLAT 1" SST
7	BY VENDOR		1	EA	PLATE, 304 SST 22" DIA X .75 THK





SECTION "A"-"A"
SCALE: HALF

NOTES:

1.) CLEANING: ASSEMBLY TO BE SCRUBBED WITH NYLON BRUSH AND DETERGENT, THEN RINSED WITH STEM AND DRYED.
2.) ITEM 2 TO BE CLEANED AND INSPECTED BEFORE EACH INSTALLATION IN A SHELL
3.) NO LUBRICANTS ARE ALLOWED ON ANY PARTS. KEEP CLEAN OF ALL HYDROCARBONS.
4.) SPECIAL CARE IS REQUIRED TO PREVENT CONTAMINATION OF FIXTURE BY COVERING WITH TARPS AND STORING INSIDE WHEN NOT IN USE.

4-REQ'D

DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION

REFERENCE DRAWINGS

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

DO NOT SCALE THIS DRAWING
USED ON
NEXT ASS'Y

REV	DESCRIPTION	CHKD	DRWN	DATE	DEO#
P2	RELEASED FOR FABRICATION		NA	03/26/96	0097
P1	PRELIMINARY DESIGN UPDATE		NAA	3/09/96	

ISSUE DESCRIPTION

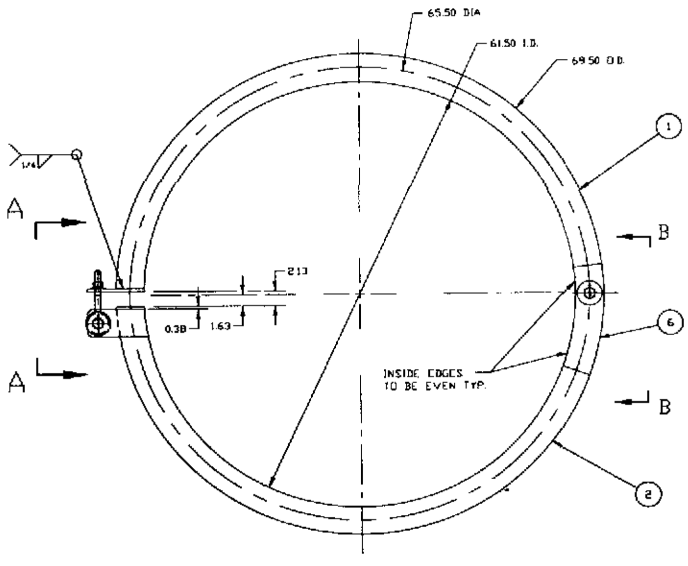
PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

FIXTURE
60.5 O.D. INTERNAL
LIGO VACUUM EQUIPMENT

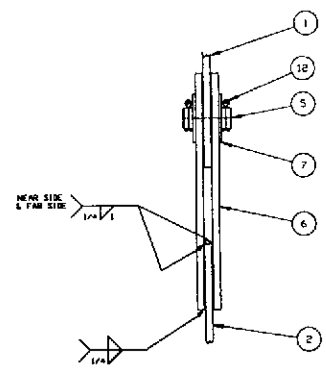
CAD FILE	SIZE	DWG. NO.	REV.
404951	D	V049-4-049	P2

SCALE: 3" = 1' SHEET 1 OF 2

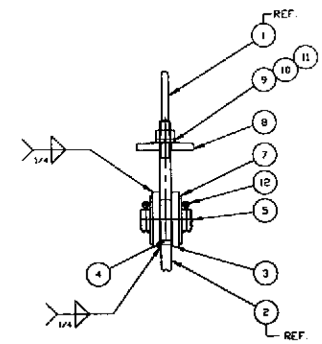
ITEM	PART NUMBER	SUFFIX	QTY	UM	DESCRIPTION
1	V049H075		2	EA	FLAT BAR 1/2X 4X 20FT. 304 A479 ROLLED HARD WAY TO 61 1/2" ID
2					MADE FROM OF ITEM (1)
3					MADE FROM DROP OF ITEM (1)
4			1	EA	EYE BOLT X 3" LG. MCMASTER CARR 6251K26
5	C467924		1	FT	ROUND BAR 1 1/2" X 3" LG. 304 A479
6					MADE FROM DROP OF ITEM (1)
7			4	EA	1 1/4" WASHER MCMASTER CARR 90108A041
8					MADE FROM DROP OF ITEM (2)
9	429806		1	EA	FLAT WASHER 3/4 A436
10	439806		1	EA	LOCK WASHER 3/4 A436
11	109706		1	EA	HEX NUT 3/4 A563
12			2	EA	COTTER PIN 1/4 X 3" C.S.



PLAN VIEW
SCALE: 1 1/2"=1'-0"



VIEW "B-B"
SCALE: 3"=1'-0"



VIEW "A-A"
SCALE: 3"=1'-0"

2-REQ'D

PROPRIETARY AND CONFIDENTIAL

DWG. NO.	DESCRIPTION	DWG. NO.	DESCRIPTION
		V049-4-001	BEAM SPLITTER CHAMBER ASSY

REFERENCE DRAWINGS

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES

DO NOT SCALE THIS DRAWING

USED ON

NEXT ASSY

REV	DESCRIPTION	CHKD	DRWN	DATE	DECO
P2	RELEASED FOR FABRICATION		NA	03/26/96	0097
P1	RELEASED FOR PROTOTYPE FABRICATION		PV	03/18/96	

ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL, INC.

EXTERNAL FIXTURE 61.5 I.D.

LIGO VACUUM EQUIPMENT

CAD FILE 405051 | SIZE B | DWG. NO. V049-4-050 | REV. P2

SCALE AS NOTED | SHEET 1 OF 2

7.3 Washing System

7.3.1 Hardware Description

All chambers, spools, tubes, adapters and covers will be given a final washing before final assembly or packaging for shipment to the sites. This will be done in a washing system in the PSI shop. The washing system consists of a component support dolly and sled, a washing booth and the systems to control the delivery of washing and rinsing fluids.

7.3.1.1 Support Dolly and Sled

Components will be moved around the shop for washing and final assembly on wheeled dollies. The actual component will be supported on a wheeled sled which sits on top of the dolly. The purpose of the sled is to provide an easily movable support having minimum elevation to move the component into and out of the washing booth. The sled has wheels with bearings which are appropriate for the conditions inside of the washing booth (the dolly's casters need to provide a greater degree of movement and are not suitable to be washed). The dolly also serves to keep the sled at the proper elevation for entry into the washing booth.

The sled has another important feature. It supports each chamber with an appropriate slope to assure free draining, and provides the means to turn the chamber inside the washing booth, thereby exposing all of the surfaces to the spray nozzles. This requires the mounting of an additional support ring to certain vessels to allow free rotation. Inside the washing booth, power is applied to the sled's drive wheels to turn the vessel.

7.3.1.2 Washing Booth

The washing booth is an enclosed cabinet approximately 16' x 16' x 14' H. It is enclosed by stainless steel sheet to contain the fluids, and has a sloped floor to direct the drains to a sump. The sump is equipped with a pump for recirculation of the fluids. The booth has a door on one side for entry from the shop of the component to be washed, and a door on the other side for removal of the component directly into a cleanroom.

The booth is equipped with two fixed spray headers having multiple nozzles. One header is for the washing detergent and primary rinse water, and the other is dedicated to the final DI water rinse. The second header not only provides greater separation of the fluids, thereby protecting the quality of the DI water, but it also allows optimizing the spray nozzles for the lower flowrate of DI water that is used (wash and primary rinse are at approximately 50 gpm at 80 psig, while the DI water rinse is at 20 gpm at 20 psig). The spray headers are constructed of threaded plastic pipe and are capable of being configured to provide the best spray coverage of the component being washed, and of being located as closely as possible to the component. This will be done manually prior to the start of a wash cycle.

A vent is also provided in the washing booth to discharge steam laden vapor to the outside. Clean air is also blown into the booth during the drying part of the cycle. Drying is accomplished by the evaporation of water from the heated metal surfaces into the clean air purge stream.

7.3.1.3 Fluid System

The washing detergent solution and rinse waters are managed with a system of tanks, pumps, filters, piping and valves. The washing cycle is automatically controlled by a PLC to assure repeatability. Refer to P&ID V049-0-031, Washing System.

The detergent solution and primary rinse water are continuously recirculated at a rate of 50 gpm between their storage tanks and the washing booth. Each tank (as well as the DI water tank) has a capacity of 100 gallons and is equipped with an electric heater to maintain the temperature at approximately 150 F. There are also the appropriate level indicators, interlocks, controls, relief valves and drain and fill valves.
Through the action of automatic valves controlled by the system PLC, either the detergent solution or the primary rinse water valves are opened, allowing flow to a recirculation pump. A filter at the pump discharge keeps any particulate from the spray nozzles. Indicators are provided for temperature, pressure and flowrate. Periodically, water can be pumped to a waste water hold-up tank for analysis and treatment, if required, before discharge.

After being sprayed onto the component being washed, water is directed into a sump at the bottom of the washing booth, where a pump pressurizes it to be recirculated to its tank. An in-line heater is provided to bring the temperature back to 150 F, since the tank heater will not have the capability to respond fast enough for the recirculating flow.

The final DI water rinse is accomplished similarly, but the water is not recirculated. A larger supply tank (200 gallons) is used, and the water is used on a once-through basis, being pumped by a dedicated pump through the separate DI water spray header.. It is returned to a separate 200 gallon storage tank. After the wash cycle is completed, and before the next cycle, this water is pumped at a reduced rate (approximately 5 gpm) through a deionizing system (city water can be used instead, if desired) to replenish the DI storage tank.

7.3.2 Washing System Qualification

The key issues in the washing process are the adequacy of:

The Detergent
The Washing and Primary Rinsing Conditions
- Flowrate, Temperature, Duration

The Sprays
- Pressure and Type of Spray Nozzle
- Coverage

The Final Rinse
- DI Water Quality
- Conditions
    - Flowrate, Temperature, Duration

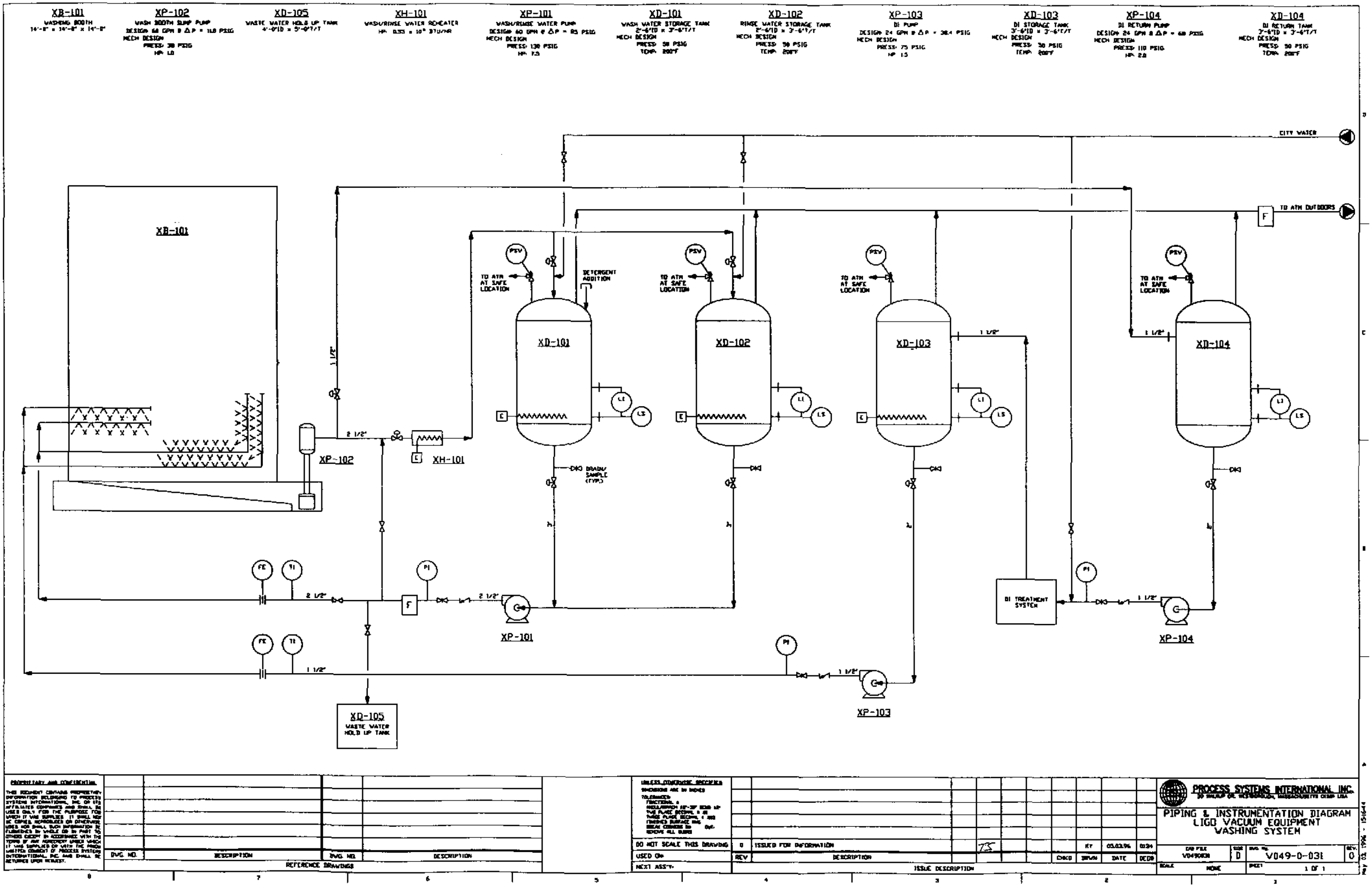
The ultimate proofs of the adequacy of the values or definitions chosen for the above listed variables are the final vacuum and RGA tests on the components being washed. In order to minimize risks, PSI has undertaken a 10" diameter bench scale prototype program and first article test programs for the chambers.

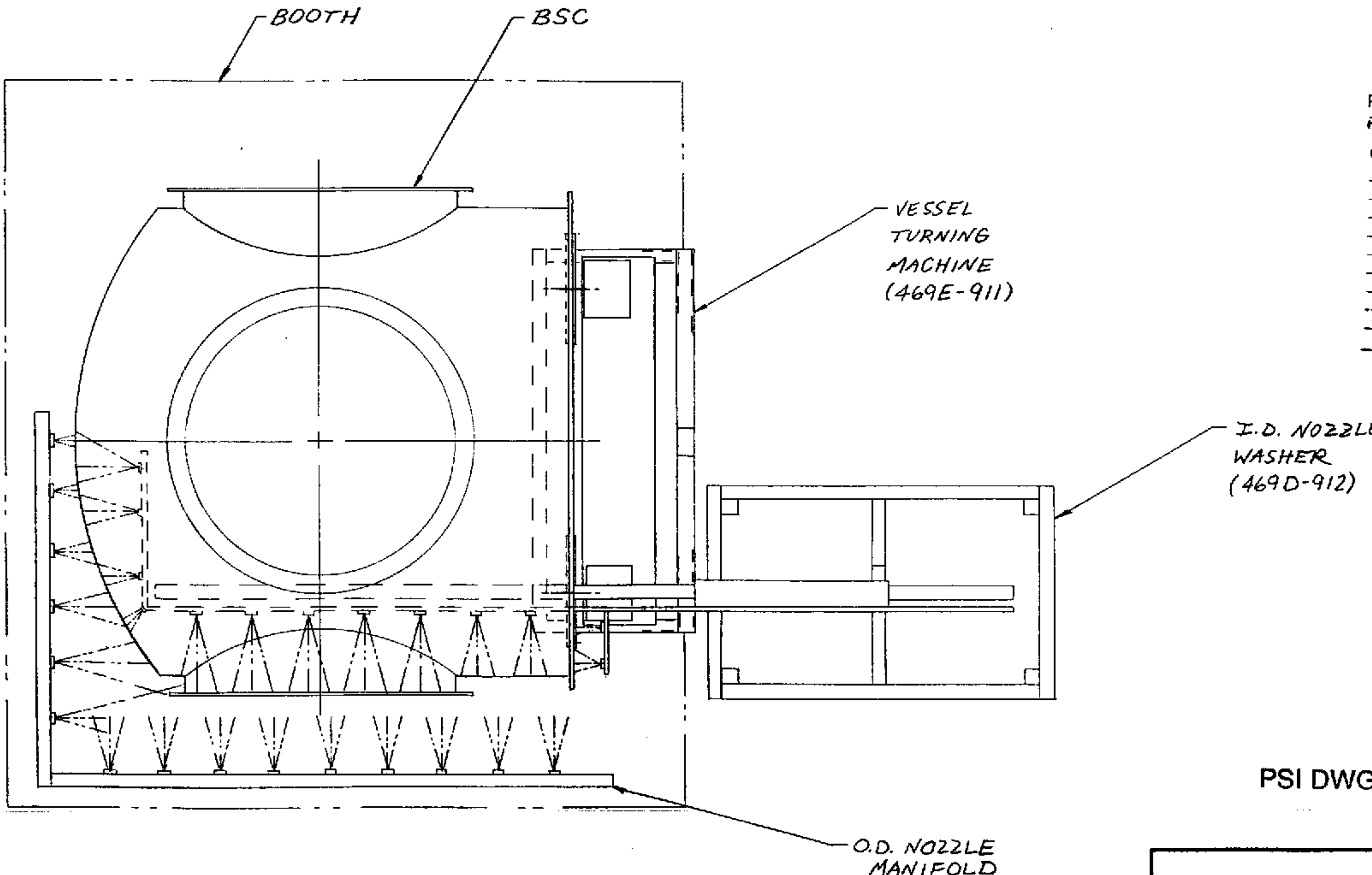
A manual washing station was constructed to allow the washing of relatively small pieces (including the 10" prototype chamber). Test coupons were washed using a manual pressure washer and DI water rinse using six different detergent candidates. The coupons were analyzed by XPS to allow ranking. The first 10" chamber test, however, was washed using the detergent that was the least corrosive and which was familiar to the Town of Westboro. Use of this detergent would facilitate obtaining the necessary waste discharge permit. Initial vacuum and RGA tests after bakeout indicate that this detergent and the washing cycle used would meet the cleanliness requirements. Testing of the first full scale chamber (manual washing) will confirm the detergent and cycle choices, or indicate the necessary changes.

For the automatic washing system, a design basis was chosen that would result in reasonably sized equipment (pumps, piping, tanks, etc.). Of primary importance was the spray header and nozzle design. The required number of nozzles and reasonable flows and pressures set the basis for the other equipment. The temperature of 150 F was chosen as being reasonably achievable. The final variable, duration, is truly variable and can be adjusted at any time. It will be set initially to assure multiple coverages of all surfaces of the component being washed by the sprays.

The spray coverage will be initially configured for each component. Immediately following washing and drying, a visual inspection will be made to determine if coverage was indeed complete. If necessary, the spray header configuration will be changed and the washing cycle repeated. Likewise, the conditions for the final DI water rinse will be initially checked by inspection. The adequacy of the DI water quality, as well as the adequacy of the entire washing process, will ultimately be proven only by vacuum and RGA testing.

The first component to be washed will be a 10" prototype vessel. This will allow a relatively quick washing, baking and testing compared to a full sized chamber. The results of the 10" test will indicate any immediate changes in the washing cycle that may be required.


XB-101
WASHING BOOTH
14'-8" x 14'-8" x 14'-8"
XP-102
WASH BOOTH SUMP PUMP
DESIGN 60 GPM @ ΔP = 118 PSIG
MECH DESIGN
PRESS: 30 PSIG
HP: 1.0
XD-105
WASTE WATER HOLD UP TANK
XH-101
WASH/RINSE WATER REHEATER
XP-101
WASH/RINSE WATER PUMP
DESIGN 60 GPM @ ΔP = 85 PSIG
MECH DESIGN
PRESS: 130 PSIG
HP: 7.5
XD-101
WASH WATER STORAGE TANK
2'-6"ID x 3'-6"T/T
MECH DESIGN
PRESS: 50 PSIG
TEMP: 200°F
XD-102
RINSE WATER STORAGE TANK
2'-6"ID x 3'-6"T/T
MECH DESIGN
PRESS: 50 PSIG
TEMP: 200°F
XP-103
DI PUMP
DESIGN 24 GPM @ ΔP = 38.4 PSIG
MECH DESIGN
PRESS: 75 PSIG
HP: 1.5
XD-103
DI STORAGE TANK
3'-6"ID x 3'-6"T/T
MECH DESIGN
PRESS: 50 PSIG
TEMP: 200°F
XP-104
DI RETURN PUMP
DESIGN 24 GPM @ ΔP = 60 PSIG
MECH DESIGN
PRESS: 110 PSIG
HP: 2.0
XD-104
DI RETURN TANK
3'-6"ID x 3'-6"T/T
MECH DESIGN
PRESS: 50 PSIG
TEMP: 200°F
CITY WATER
TO ATM OUTDOORS
F
PSV
TO ATM AT SAFE LOCATION
DETERGENT ADDITION
1 1/2"
2 1/2"
E
LI
LS
DRAIN/SAMPLE (TYP.)
FE
TI
PI
DI TREATMENT SYSTEM
XD-105
WASTE WATER HOLD UP TANK
PROPRIETARY AND CONFIDENTIAL
DWG. NO.
DESCRIPTION
REFERENCE DRAWINGS
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
DO NOT SCALE THIS DRAWING
USED ON
NEXT ASS'Y
0
ISSUED FOR INFORMATION
KY
05.03.96
REV
DESCRIPTION
CHKD
DRWN
DATE
ISSUE DESCRIPTION
PROCESS SYSTEMS INTERNATIONAL, INC.
PIPING & INSTRUMENTATION DIAGRAM
LIGO VACUUM EQUIPMENT
WASHING SYSTEM
CAD FILE
SIZE
D
DWG No.
V049-0-031
REV.
0
SCALE
NONE
SHEET
1 OF 1



PLAN VIEW

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

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

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

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

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

BY ______ DATE ______

PSI DWG # V049-2-264

APR 30 1996

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

DANGEL ROBOTS & MACHINERY INC.

SCALE: 1/25	APPROVED BY	DRAWN BY R. ANNIS
DATE: 4-29-96		
LIGO PROJECT		
WASHING MACHINE CONCEPT		DRAWING NUMBER 469B-914

CHARRETTE PRO-FORM 920PF PRINTED ON 920H CHARPRINT VELLUM

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

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

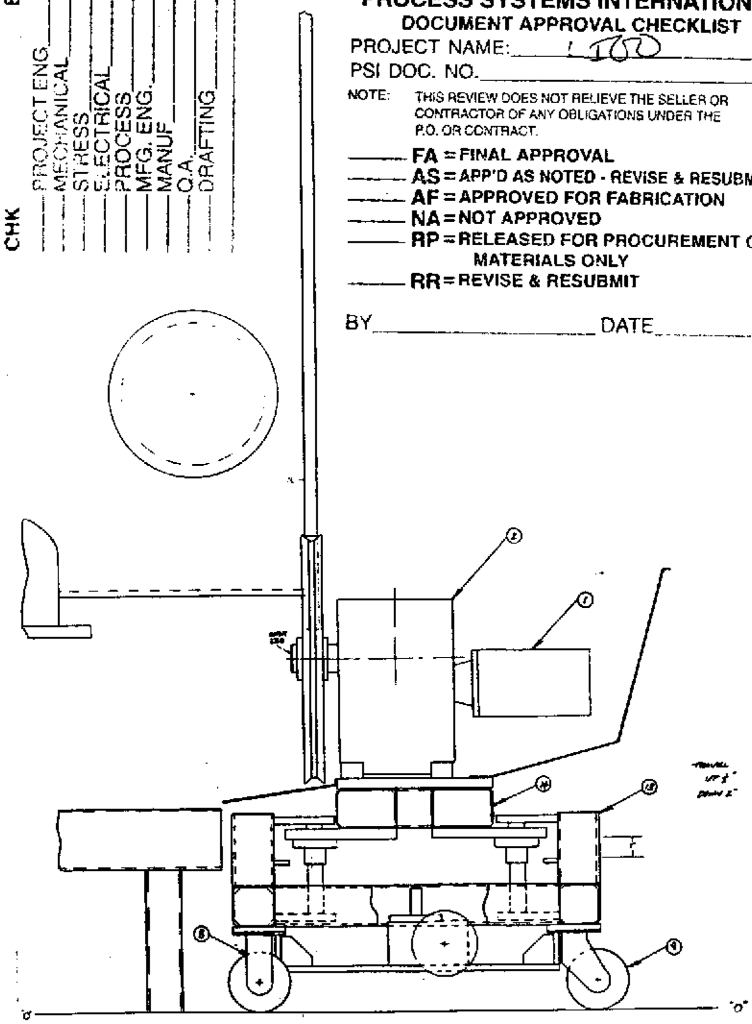
PROCESS SYSTEMS INTERNATIONAL
DOCUMENT APPROVAL CHECKLIST

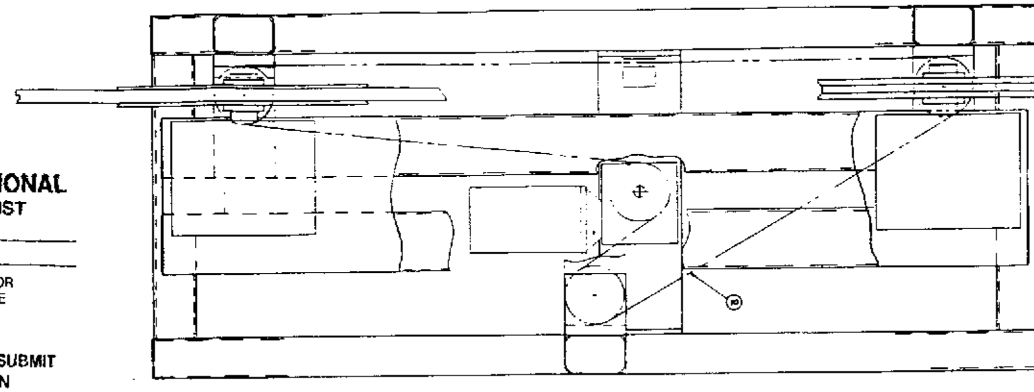
PROJECT NAME: ITD
PSI DOC. NO. ________

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

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

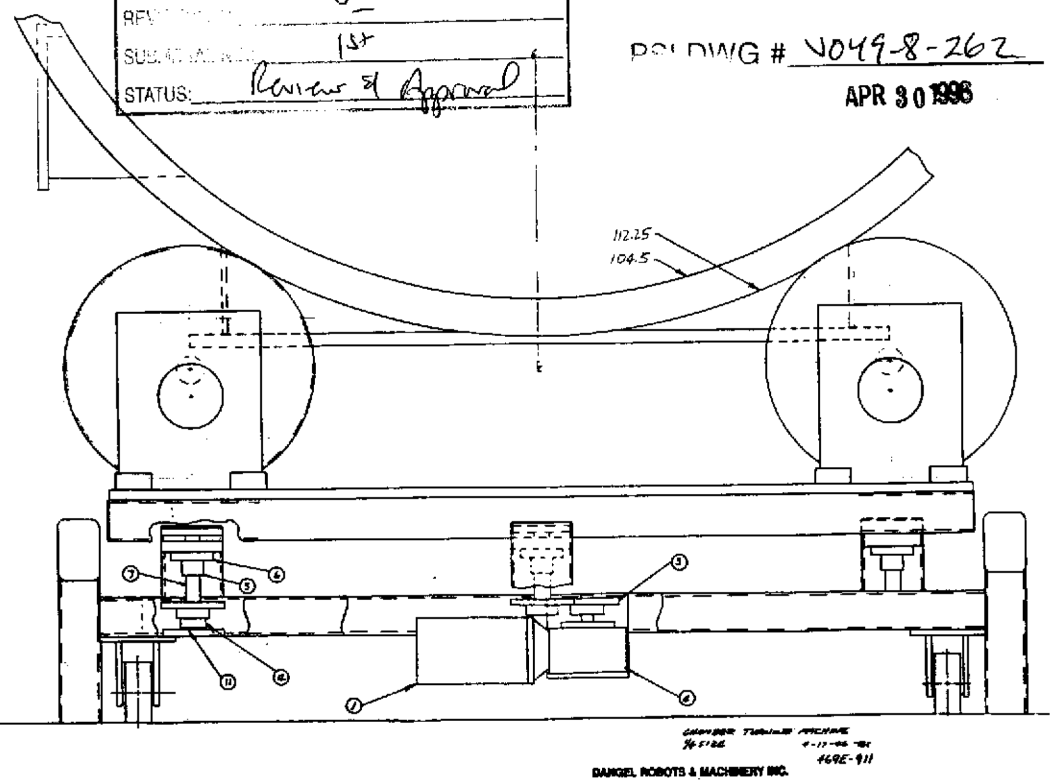
BY________ DATE________





VENDOR NAME: Dangel Robots
REV: –
SUBMITTAL NO.: 1st
STATUS: Review & Approval

PSI DWG # V049-8-262
APR 30 1996



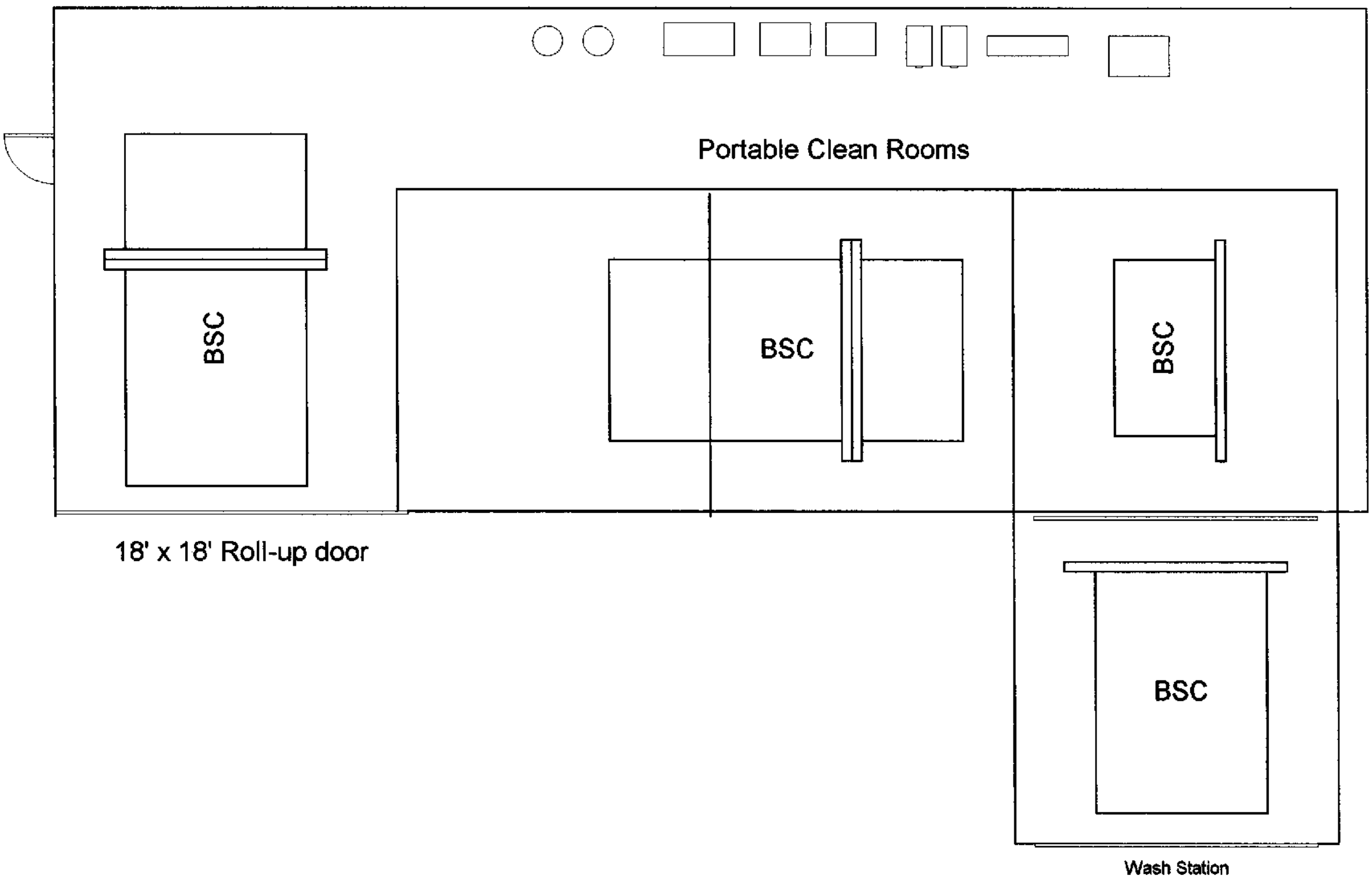
7.4 Clean Manufacturing Space

PSI is modifying part of its manufacturing space to create a clean manufacturing area. Filtered outside air will be used to pressurize this space and prevent contamination from the remainder of the fabrication shop. This area will also be dehumidified to eliminate contamination from condensation.

Welding stations in this area will be equipped with vent fans to discharge welding smoke outside of the clean space.

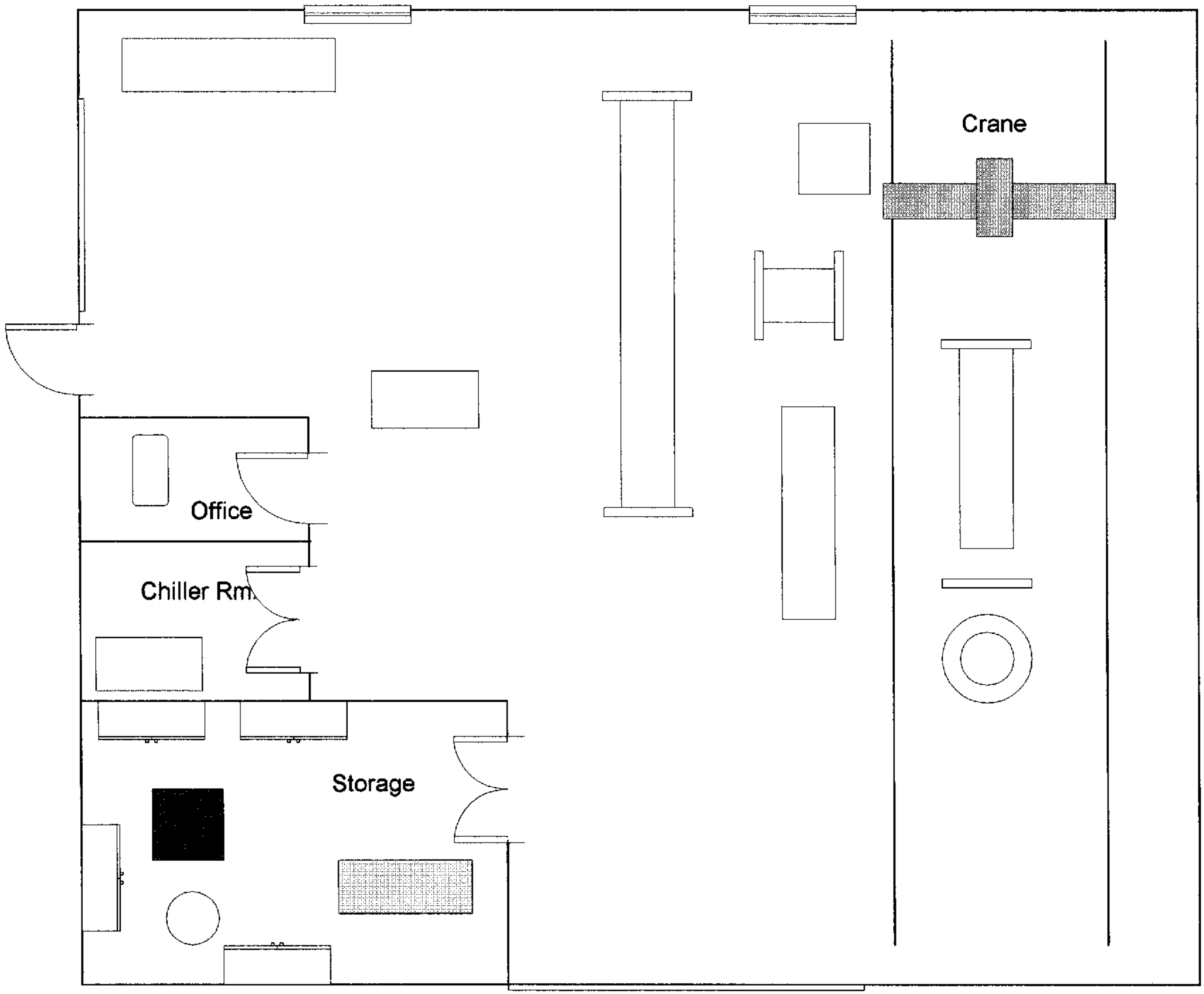
Class 100 clean rooms will be set up in this area to protect components after they have been cleaned. (See attached drawings). The Class 100 clean rooms are used whenever cleaned components are opened to the atmosphere.

LIGO
Custom Shop - Mezzanine
Clean Area
65 ft x 25 ft x 18 ft H



LIGO Spooling and Assembly Area

75 ft x 75 ft x 18 ft H



FDR VOLUME III
ATTACHMENTS

1.	Raw Material Handling Procedure	V049-2-120
2.	Control Of Non-Conformance	V049-2-124
3.	Weld Data Specifications	V049-2-084
4.	Weld Procedures	V049-2-070 V049-2-071 V049-2-072 V049-2-073
5.	Cleaning Procedures	V049-2-015
6.	Stress Relief Procedure (304 S.S.)	V049-2-046
7.	Component Bakeout Procedure	V049-2-019
8.	Leak Testing Procedure	V049-2-014
9.	Cleanliness Testing Procedure	V049-2-118
10.	Dimensional Verification Procedure	V049-2-121
11.	Component Packaging, Handling and Shipping Procedure	V049-2-123
12.	Project Q.A. Plan	V049-2-029
13.	Project Safety Plan	V049-2-023
14.	Viton O-Ring Bakeout Procedure	V049-2-122
15.	Component Shop Conditioning/Test Plan	V049-2-047
16.	Contamination Control Plan	V049-2-119
17.	Material Control Procedure	V048-2-125

FDR VOLUME III
ATTACHMENTS

18.	Component RGA Test Procedure	V049-2-127
19.	Visual Inspection Procedure	V049-2-128
20.	Black Light Inspection Procedure	V049-2-130

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/REB

MANUFACTURING ENGR: [signature]

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

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

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

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	T.M.S.	5-4-96	REB	5/4/96	A V049-2-120	Ø

Title RAW MATERIAL HANDLING PROCEDURE

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

Number

Rev.

SPECIFICATION

Number A V049-2-120 Rev. Ø

1.0 PURPOSE

The purpose of this procedure is to define the requirements for handling and storing LIGO raw material.

2.0 GENERAL

This procedure is applicable to all LIGO vacuum boundary and vacuum internal component raw materials.

Contamination of LIGO vacuum surface materials must be prevented during receiving, storage and fabrication in order for the vacuum system to achieve its design goals. Contamination is defined as any foreign material (carbon steel, oil, grease, etc.) which could come in contact with the 304/304L S.S. and aluminum.

3.0 RESPONSIBILITIES

The receiving department is responsible for preventing contamination during receiving and storage of the raw material.

The manufacturing department is responsible for preventing contamination during the fabrication process.

4.0 PROCEDURE

4.1 Receiving

4.1.1 All LIGO Vacuum Boundary Material (304/304L S.S.) shall be handled (i.e. lifted, rolled, etc.) without coming in contact with carbon steel or other contaminants.

4.2 Storage

4.2.1 Vacuum Boundary material shall be stored indoors and shall be protected from carbon steel, hydrocarbon and other types of contamination.

4.3 Fabrication

4.3.1 Raw materials shall be protected from contamination throughout the fabrication process. All welding and fitting shall be done in clean manufacturing space (Class 100,000 - 200,000) with outside air purge to minimize contamination. Welding gases shall be collected in exhaust systems and vented outside.

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

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

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

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

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

Title: SPECIFICATION FOR CONTROL OF NON-CONFORMANCES

SPECIFICATION FOR

CONTROL OF NON-CONFORMANCES

PREPARED BY: ALAN BRADBROOK

PROJECT ENGINEER: N/A

QUALITY ASSURANCE: Alan D Bradbrook

MANUFACTURING ENGR: Phillip P. Fisher

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Robert Bagley

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

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED A Bradbrook	DATE 5/1/96	APPROVED REB	DATE 5/1/96	Number A V049-2-124	Rev. Ø

TABLE OF CONTENTS

1.0 Scope

2.0 General Procedure

Exhibit 1 Tags

Exhibit 2 Discrepancy Report Form

1.0 SCOPE

This specification covers the minimum requirements for control, identification and the disposition of nonconforming items. This procedure applies to receiving inspection, in-process inspection, final inspection, testing documentation and procedural matters.

2.0 GENERAL PROCEDURE

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

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

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

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

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

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

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

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

EXHIBIT 1

REJECT

[redacted] PO. NO.	PART NO. OR DWG. NO.	QTY.	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

Process Systems International, Inc.

DISCREPANCY REPORT

ROUTE TO

D.R. NUMBER: 6589

JOB NUMBER	P.O. NO.	VENDOR	SHEET
T10001-	468500	ABC NUT & BOLT	1 OF 1

PROJECT	ORIGINATOR	DATE	REFER TO D.R. NUMBER
KOREA	J. JONES	6-1-95	—

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

EXHIBIT 2

DISPOSITION ---

① SA-490 WILL MEET THE REQUIREMENTS OF THE JOB
HOWEVER THE 3" LENGTH IS - NO GOOD.
B. SMITH DESIGN ENG.

② RETURN TO SUPPLIER FOR REPLACEMENT.
IF SA-490 IS USED ADVISE ME PRIOR TO ORDER PLACEMENT
SO AN RFC CAN BE WRITTEN AND APPROVED TO CHANGE DRAWING
AND BILL OF MATERIAL.

SIGNATURE B. SMITH DATE 6-2-95

DISPOSITION CONCURRENCE

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

REINSPECTION RETURNED TO SUPPLIER 6-2-95
REC'D. 1/2-13 x 4" LG. SA-193 B7 ON 6-3-95

SIGNATURE J. JONES DATE 6-3-95

CORRECTIVE ACTION --- VENDOR DID NOT SUPPLY CORRECT MATERIAL.
NOTIFY VENDOR OF THIS PROBLEM AND HAVE THEM PERFORM
TRAINING.

SIGNATURE J. JONES DATE 6-3-95

AI/ANI AI DATE 6-4-95 —CLOSED—

WELD DATA SHEET SPECIFICATIONS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Philip J Weber

QUALITY ASSURANCE: Allan L Bradbrook

MANUFACTURING ENGINEER: Phillip Talbot

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

Ø	PEF 5/2/96	RWB 5/3/96	RELEASE FOR FDR PER DEO 0169
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED PEF	DATE 5/2/96	APPROVED RWB	DATE 5/3/96	Number A V049-2-084	Rev. Ø

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

ATTACHMENTS:

1. List of Weld Procedures
2. Weld Data Sheets

1.0 PURPOSE

The purpose of this specification is to provide definitive guidelines for the welding of all components to assure a consistent and repeatable result per LIGO requirements.

2.0 GENERAL

The Weld Data Sheets shall be used to identify which welding procedures are to be used for specific weld joint configurations. Additionally, pertinent welding machine settings shall be provided. Notes concerning tack weld size and spacing and sequence of welding shall also be provided.

3.0 RESPONSIBILITIES

The Manufacturing Department is responsible for the execution of this procedure, with input and monitoring by the Project Engineer, the Quality Assurance Department, and the Project Manager.

4.0 PROCEDURE

Weld Data Sheets shall be numbered by type and shall be logically tied to the appropriate weld by a corresponding number in the weld symbol on the drawing.

Title

WELD DATA SHEET SPECIFICATIONS

ATTACHMENT 1

WELD PROCEDURES

Weld Procedure	V049-2-070
Weld Procedure	V049-2-071
Weld Procedure	V049-2-072
Weld Procedure	V049-2-073
Weld Repair Procedure	V049-2-074

Number

Rev.

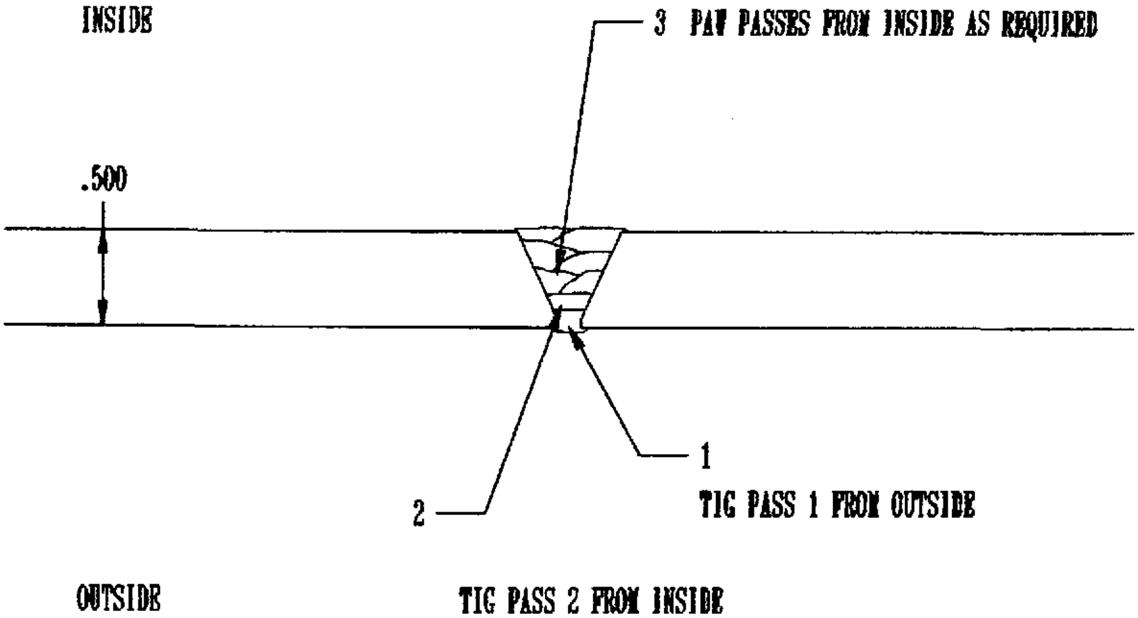
WELD # 1

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 151	Remarks	WPS# 153	Remarks
Plate Thks. or Pipe Size	1/2		1/2	
Bevel in Total Degress	50		50	
Land	.045		.045	
Root Opening			1/8	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8 - 4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4 - 5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	1/8 308L		1/8 308L	Also 3/32
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 1



WDS 1

FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

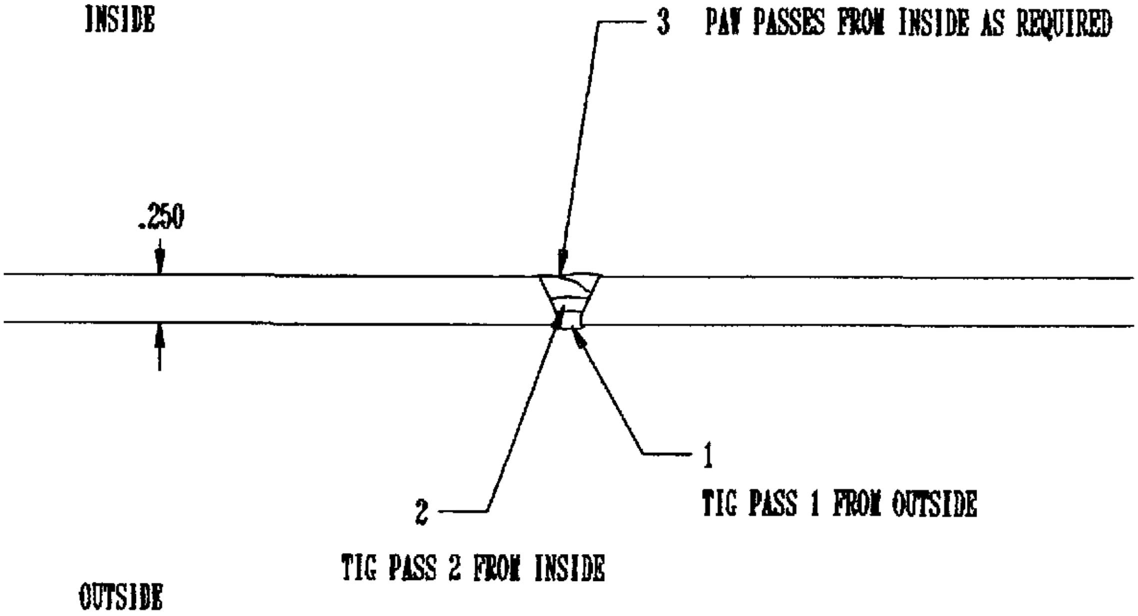
WELD # 2

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size	1/4		1/4	
Bevel in Total Degress	50		50	
Land	.045		.045	
Root Opening			1/8	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8 - 4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4 - 5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	1/8 308L		1/8 308L	Also 3/32
Cleaning Technique	CO_2	Wire & Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 2



WDS 2

FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

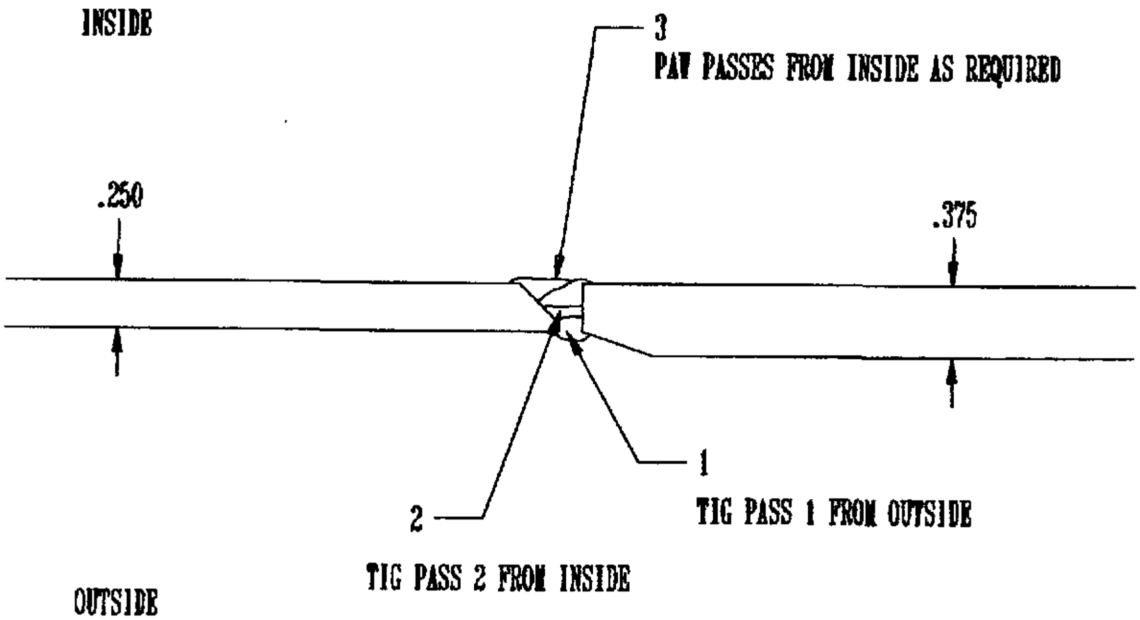
WELD # 3

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size	1/4 - 3/8		1/4 - 3/8	
Bevel in Total Degress	45		45	
Land	.045		.045	
Root Opening			1/8	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8 - 4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4 - 5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	1/8 308L		1/8 308L	Also 3/32
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 3



WDS 3

FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

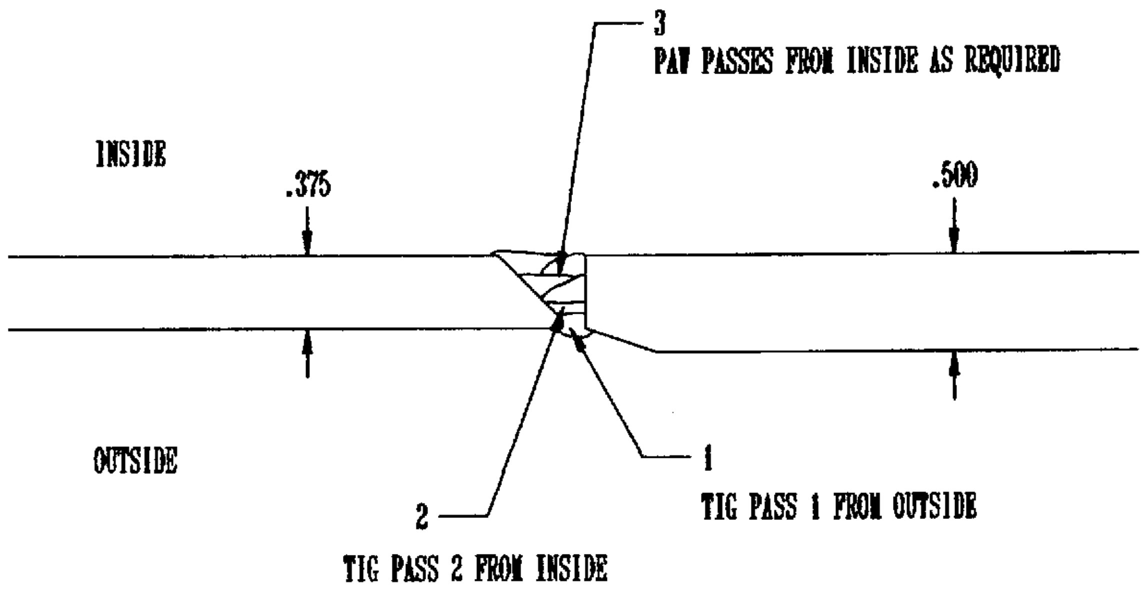
WELD # 4

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 151	**Remarks**	**WPS# 153**	**Remarks**
Plate Thks. or Pipe Size	3/8 - 1/2		3/8 - 1/2	
Bevel in Total Degress	45		45	
Land	.045		.045	
Root Opening				
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8 - 4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4-5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	1/8 308L		1/8 308L	Also 3/32
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 4



WDS 4

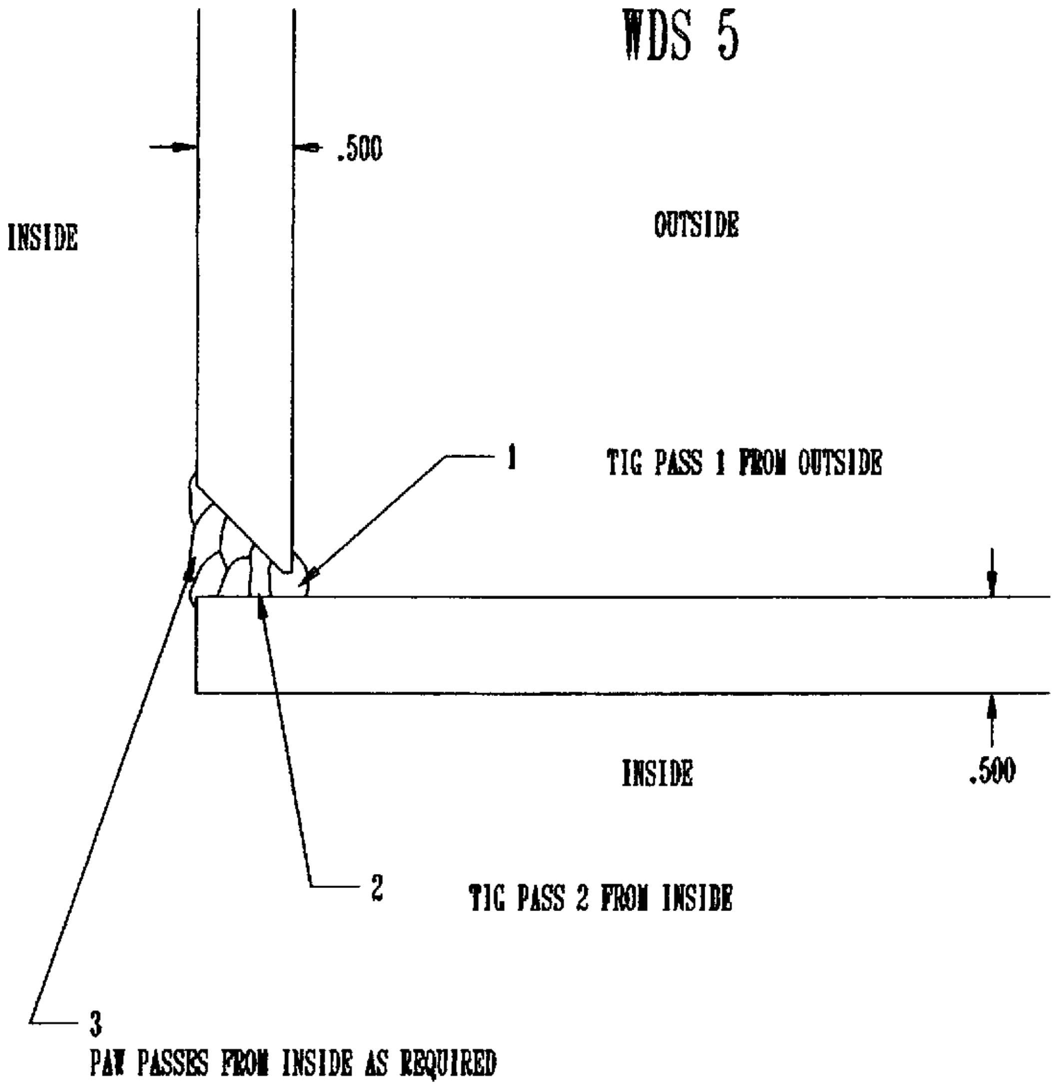
FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

WELD # 5

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 151	Remarks	WPS# 153	Remarks
Plate Thks. or Pipe Size	1/2		1/2	
Bevel in Total Degress	45		45	
Land	.045		.045	
Root Opening			1/8 - 3/16	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8-4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4-5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	V8 308L		1/8 308L	
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				



WDS 5

FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
DIVIDE NOZZLE INTO FOUR QUADRANTS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK
  FROM OUTSIDE (TIG); WORK FROM QUADRANT
  TO QUADRANT IN BOLT TORQUING PATTERN
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

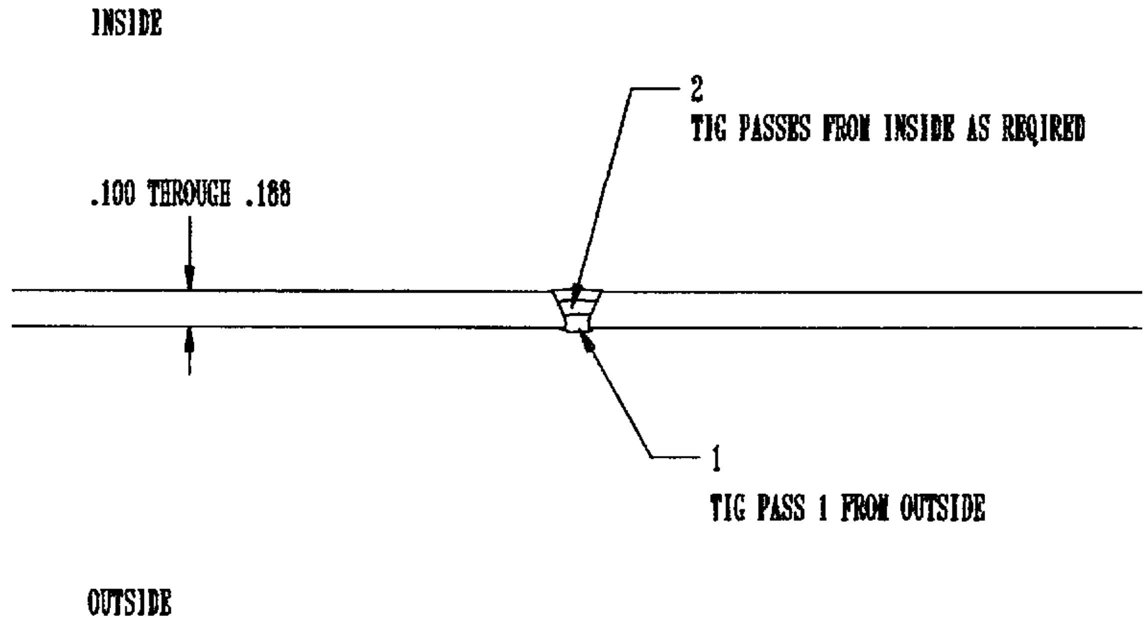
WELD # 6

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 153	Remarks
Plate Thks. or Pipe Size			11ga	
Bevel in Total Degress			50	
Land			.045	
Root Opening			1/16 - 3/32	
Root Pass TIG			Yes	
Root Pass Plasma				
Torch Size			350	
Tungsten Size			1/8	
Tungsten Set Back			N/A	
Cup Size			8	
Tip Size/Number			N/A	
Pass or Pass Number				Below
Amps Setting			190	
Volts			22	
Argon Gas			Shield	
Argon/He 75%/25%			N/A	
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			30	
Wire Size/Type			3/32 - 1/8	308L
Cleaning Technique			CO_2	Weld Zone and Wire
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

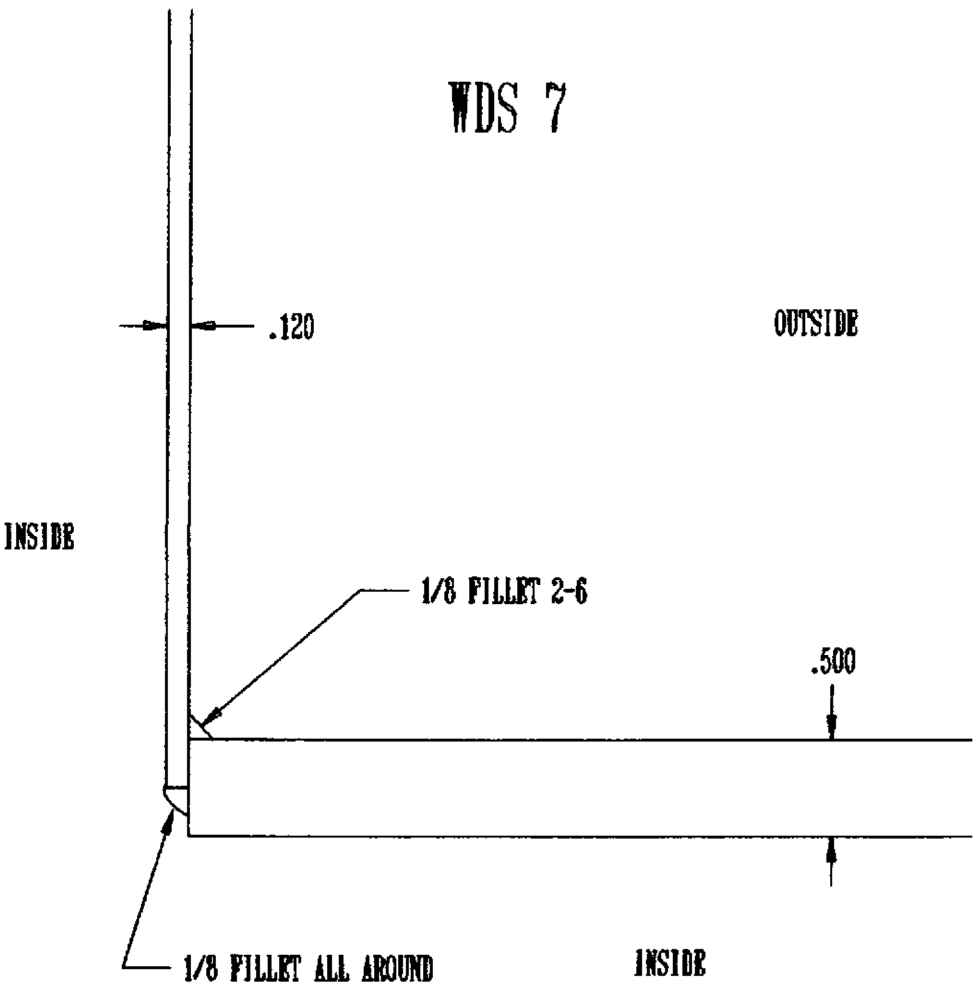
PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd					2nd	190	22	1/8	
3rd					3rd				
4th					4th				
5th					5th				

WDS 6



WDS 6

FIT UP WITH 1/8 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (TIG)



WDS 7

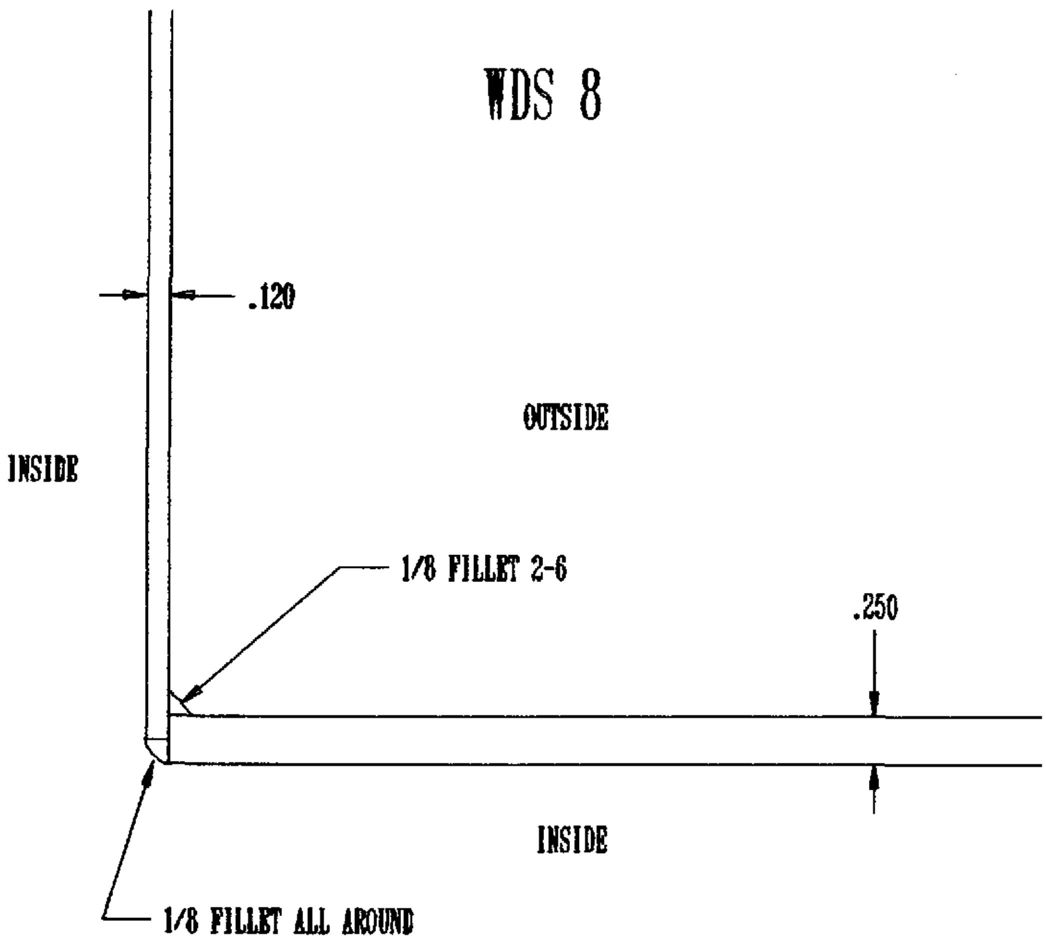
TACK NOZZLE TO SHELL FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

WELD # 8

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			1/8 - 1/4	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG				
Root Pass Plasma				
Torch Size			250	
Tungsten Size			3/32	
Tungsten Set Back			N/A	
Cup Size			7	
Tip Size/Number			N/A	
Pass or Pass Number				Below
Amps Setting			150	
Volts			17	
Argon Gas			Shield	
Argon/He 75%/25%				
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire/Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	150	17		
2nd					2nd	150	17		
3rd					3rd				
4th					4th				
5th					5th				



WDS 8

TACK NOZZLE TO SHELL FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

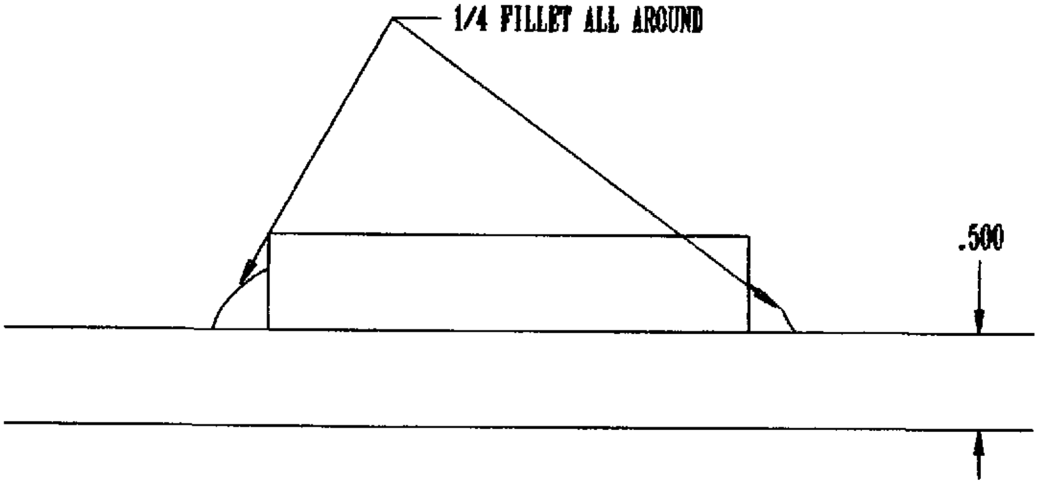
WELD # 9

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 151	**Remarks**	**WPS#**	**Remarks**
Plate Thks. or Pipe Size	3/8 - 1/2			
Bevel in Total Degress				
Land				
Root Opening				
Root Pass TIG				
Root Pass Plasma				
Torch Size	4A			
Tungsten Size	3/16			
Tungsten Set Back	Flush			
Cup Size	8-4088			
Tip Size/Number	.125/9-1892			
Pass or Pass Number		Below		
Amps Setting	180			
Volts	20			
Argon Gas	Plasma			
Argon/He 75%/25%	Shielding			
Gas Flow CFH	20			
Gas Plasma Flow CFH	4-5			
Purge Argon CFH	30			
Wire Size/Type	1/8 308L			
Cleaning Technique	CO_2	Wire & Weld Zone		
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

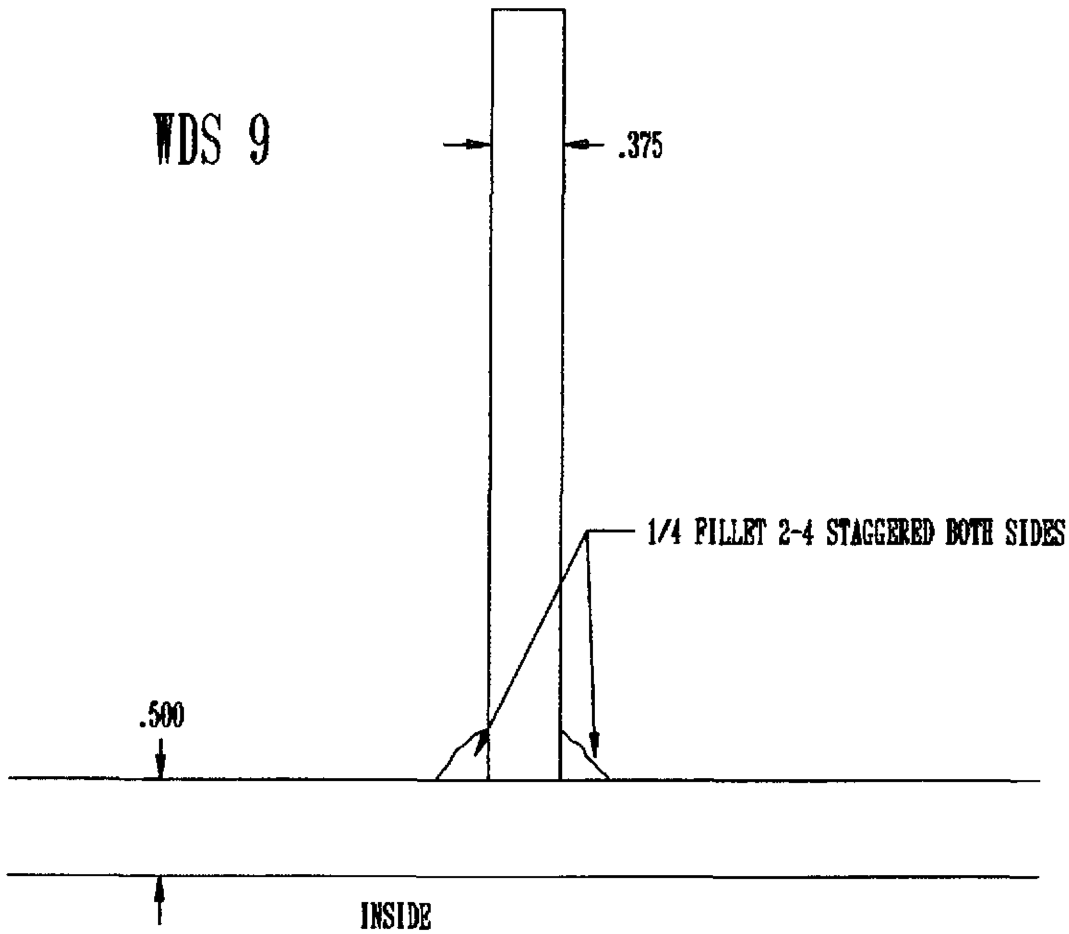
PAW	**AMPS**	**VOLTS**	**FILLER**	**W#**	**GTAW**	**AMPS**	**VOLTS**	**FILLER**	**W#**
Root					Root				
1st	180	20	1/8		1st				
2nd	180	20	1/8		2nd				
3rd					3rd				
4th					4th				
5th					5th				

WDS 21



WDS 21

TACK BOTH SIDES (PAW)
WELD BOTH SIDES (PAW)



WDS 9

TACK BOTH SIDES (PAW)
WELD BOTH SIDES ALTERNATING; END WELDS ON TACKS (PAW)

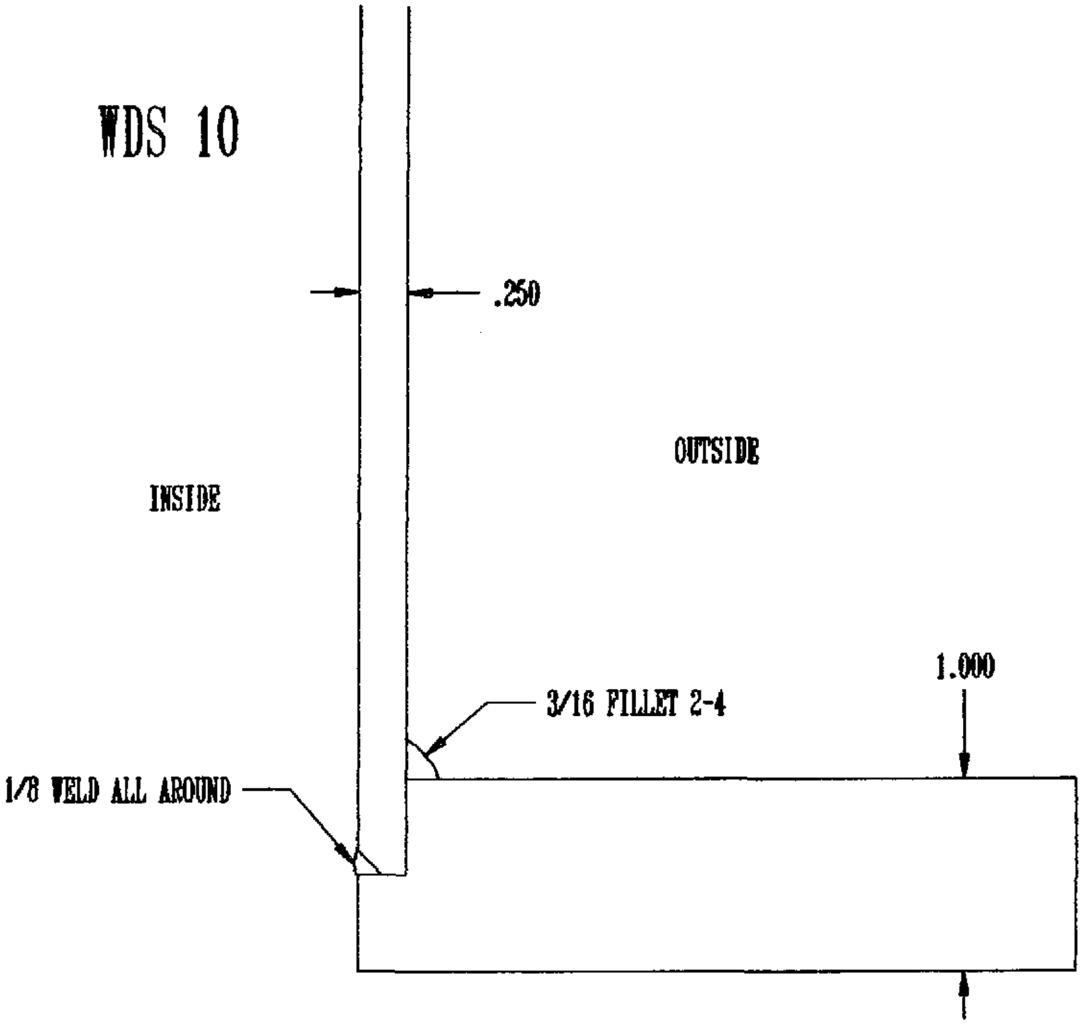
WELD # 10

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	Remarks	WPS#	Remarks
Plate Thks. or Pipe Size	1/4 - 1			
Bevel in Total Degress	45			
Land	N/A			
Root Opening	N/A			
Root Pass TIG	N/A			
Root Pass Plasma	N/A			
Torch Size	4A			
Tungsten Size	3/16			
Tungsten Set Back	Flush			
Cup Size	8-4088			
Tip Size/Number	.125/9-1892			
Pass or Pass Number		Below		
Amps Setting	180			
Volts	20			
Argon Gas	Plasma			
Argon/He 75%/25%	Shielding			
Gas Flow CFH	20			
Gas Plasma Flow CFH	4-5			
Purge Argon CFH	30			
Wire Size/Type	1/8 308L			
Cleaning Technique	CO_2	Wire & Weld Zone		
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st	180	20	1/8		1st				
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 10



WDS 10

TACK NOZZLE FROM OUTSIDE (PAW)
WELD NOZZLE FROM INSIDE (PAW)
WELD FILLETS TO TACKS ON OUTSIDE (PAW)

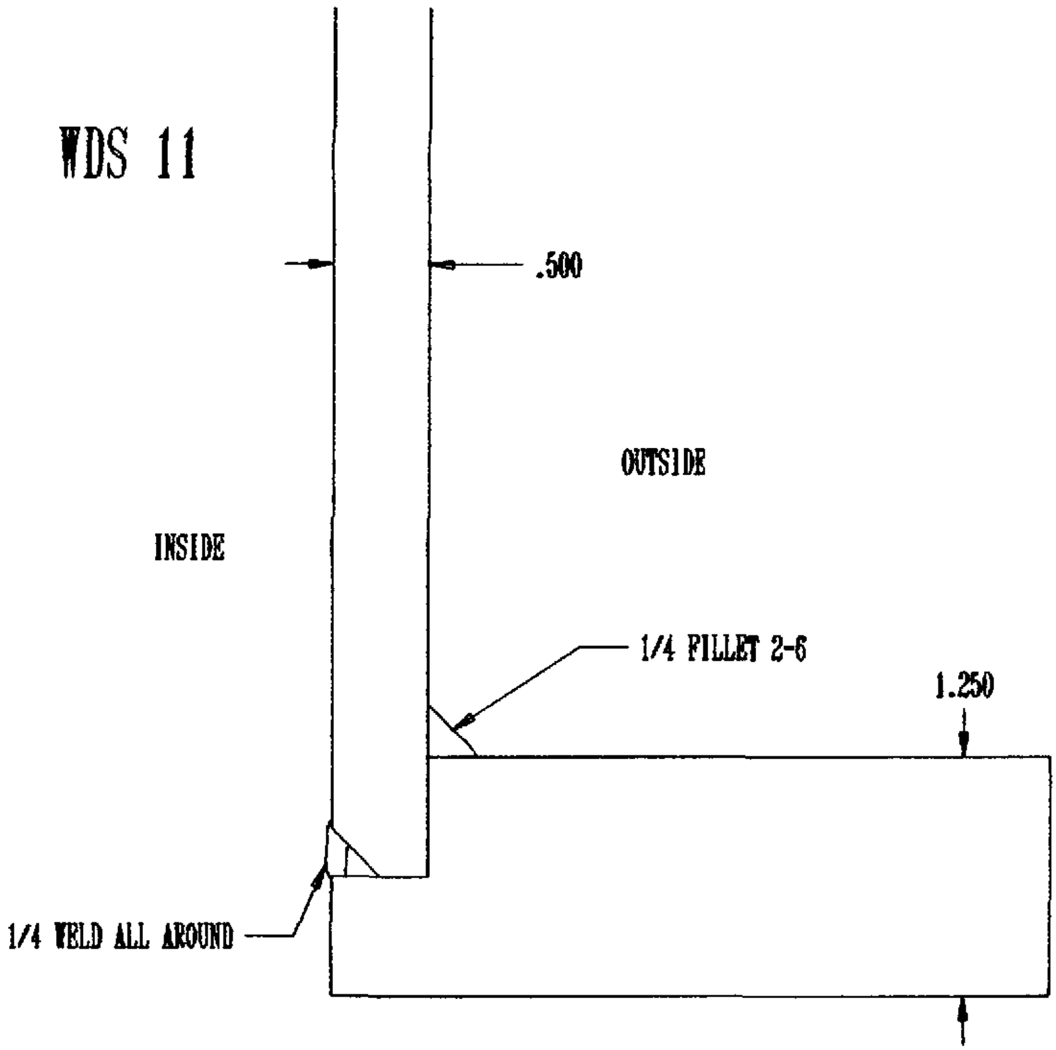
WELD # 11

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	**Remarks**	**WPS#**	**Remarks**
Plate Thks. or Pipe Size	1/2 - 1.250			
Bevel in Total Degress	45			
Land	N/A			
Root Opening	N/A			
Root Pass TIG	N/A			
Root Pass Plasma	N/A			
Torch Size	4A			
Tungsten Size	3/16			
Tungsten Set Back	Flush			
Cup Size	8-4088			
Tip Size/Number	.125/9-1892			
Pass or Pass Number		Below		
Amps Setting	180			
Volts	20			
Argon Gas	Plasma			
Argon/He 75%/25%	Shielding			
Gas Flow CFH	20			
Gas Plasma Flow CFH	4-5			
Purge Argon CFH	30			
Wire Size/Type	1/8 308L			
Cleaning Technique	CO_2	Wire & Weld Zone		
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st	180	20	1/8		1st				
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 11



WDS 11

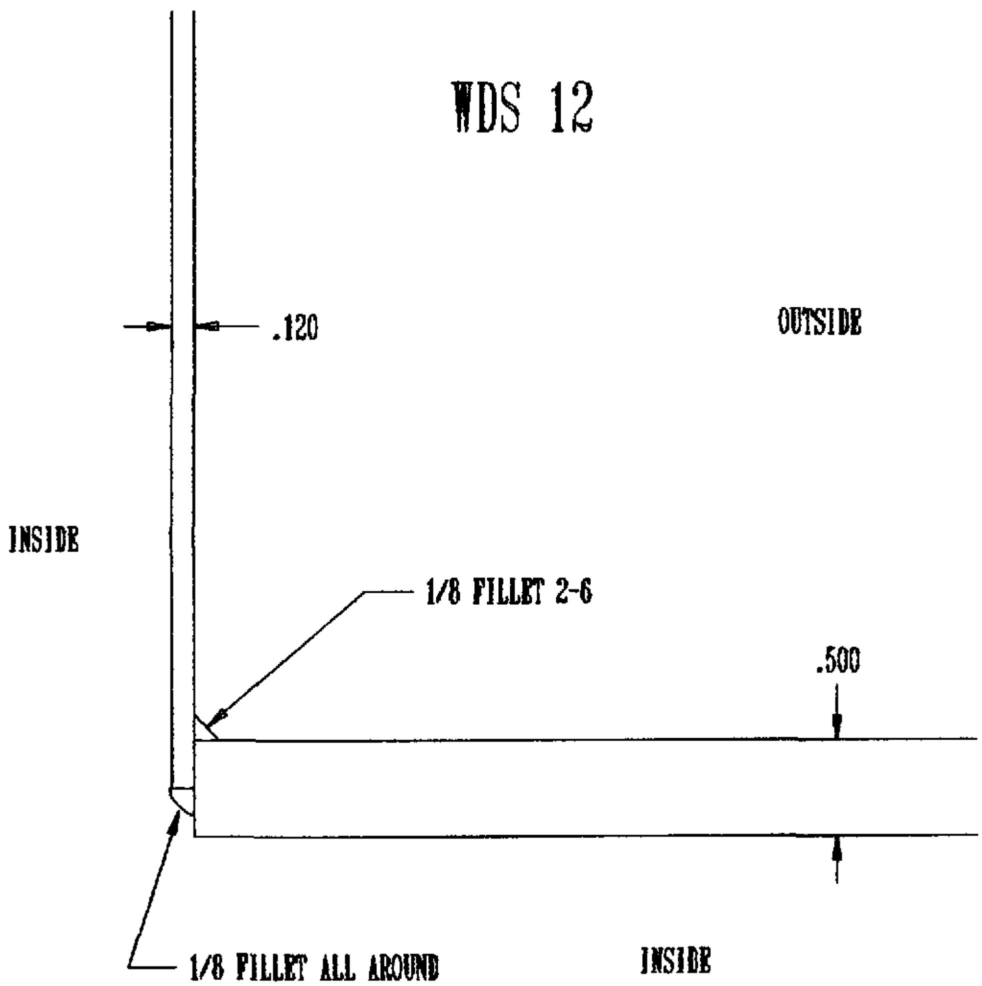
TACK NOZZLE FROM OUTSIDE (PAW)
WELD NOZZLE FROM INSIDE (PAW)
WELD FILLETS TO TACKS ON OUTSIDE (PAW)

WELD # 12

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			1/8 to 1/2	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG			N/A	
Root Pass Plasma				
Torch Size			350	
Tungsten Size			1/8	
Tungsten Set Back			N/A	
Cup Size			8	
Tip Size/Number			N/A	
Pass or Pass Number				
Amps Setting			190	
Volts			22	
Argon Gas			Shield	
Argon/He 75%/25%			N/A	
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	190	22	3/32	
2nd					2nd	190	22	3/32	
3rd					3rd				
4th					4th				
5th					5th				



WDS 12

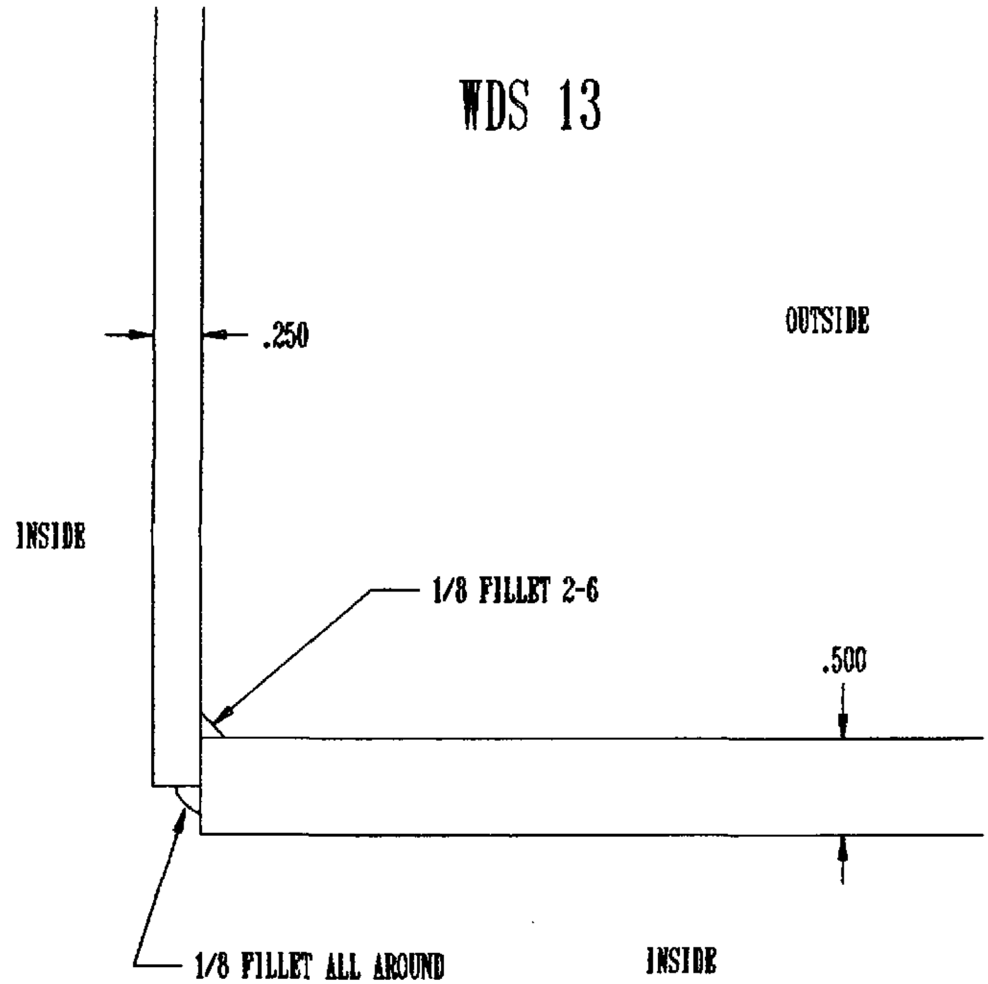
TACK NOZZLE TO SHELL FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

WELD # 13

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 153	Remarks
Plate Thks. or Pipe Size			1/4 to 1/2	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG			N/A	
Root Pass Plasma				
Torch Size			350	
Tungsten Size			1/8	
Tungsten Set Back			N/A	
Cup Size			8	
Tip Size/Number			N/A	
Pass or Pass Number				
Amps Setting			190	
Volts			22	
Argon Gas			Shield	
Argon/He 75%/25%			N/A	
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	190	22	3/32	
2nd					2nd	190	22	3/32	
3rd					3rd				
4th					4th				
5th					5th				



WDS 13

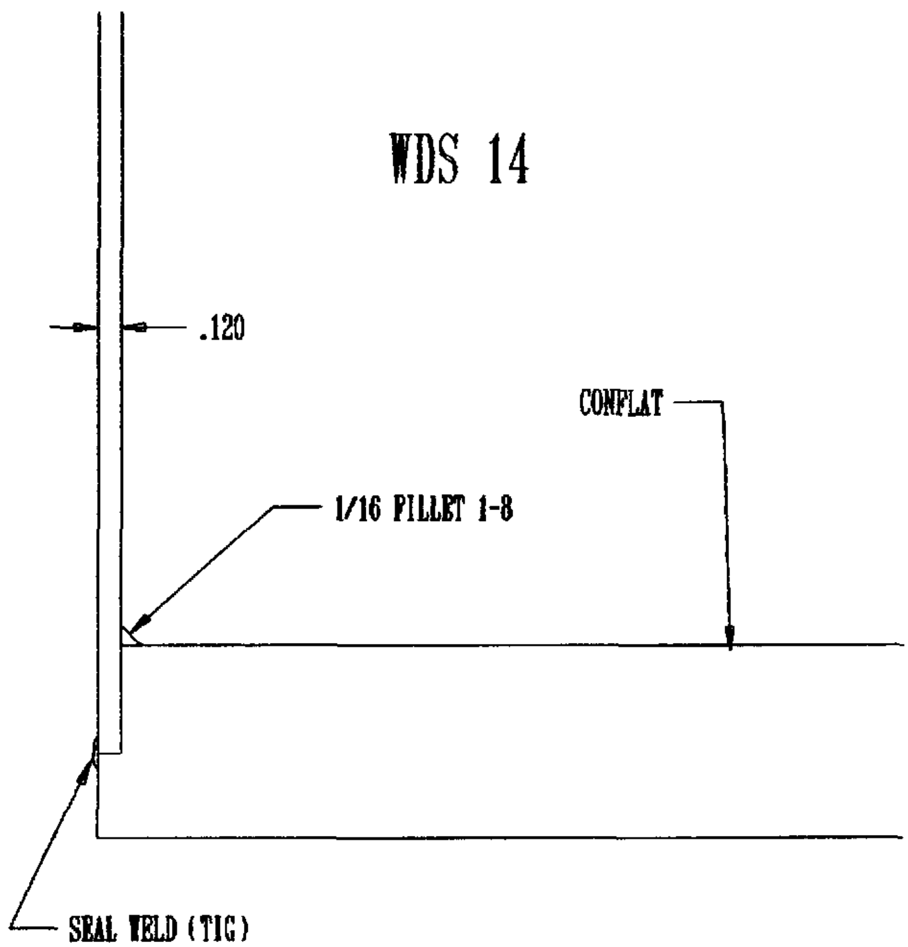
TACK NOZZLE TO SHELL FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

WELD # 14

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			1/8 - 1	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG				
Root Pass Plasma				
Torch Size			250	
Tungsten Size			3/32	
Tungsten Set Back			N/A	
Cup Size			7	
Tip Size/Number			N/A	
Pass or Pass Number				Below
Amps Setting			150	
Volts			17	
Argon Gas			Shield	
Argon/He 75%/25%				
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire/Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	150	17		
2nd					2nd	150	17		
3rd					3rd				
4th					4th				
5th					5th				



WDS 14

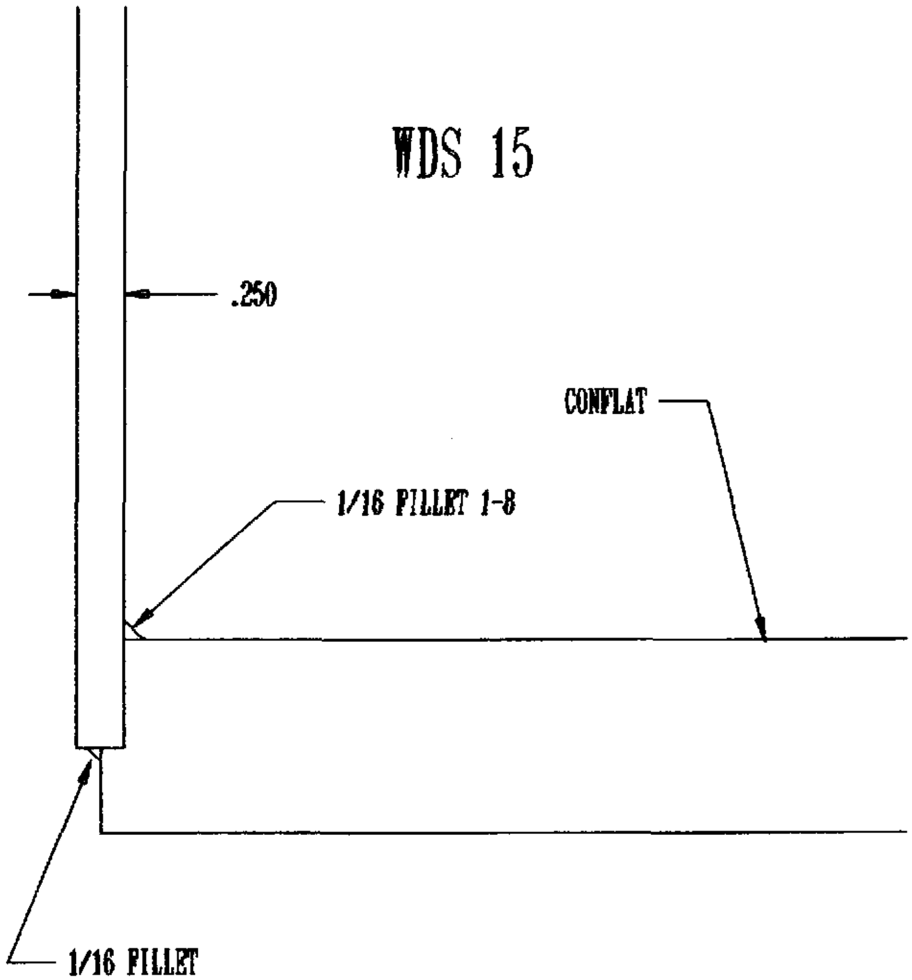
TACK CONFLAT TO NOZZLE FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

WELD # 15

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			1/4 - 1	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG				
Root Pass Plasma				
Torch Size			250	
Tungsten Size			3/32	
Tungsten Set Back			N/A	
Cup Size			7	
Tip Size/Number			N/A	
Pass or Pass Number				Below
Amps Setting			150	
Volts			17	
Argon Gas			Shield	
Argon/He 75%/25%				
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire/Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	150	17		
2nd					2nd	150	17		
3rd					3rd				
4th					4th				
5th					5th				



WDS 15

TACK CONFLAT TO NOZZLE FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

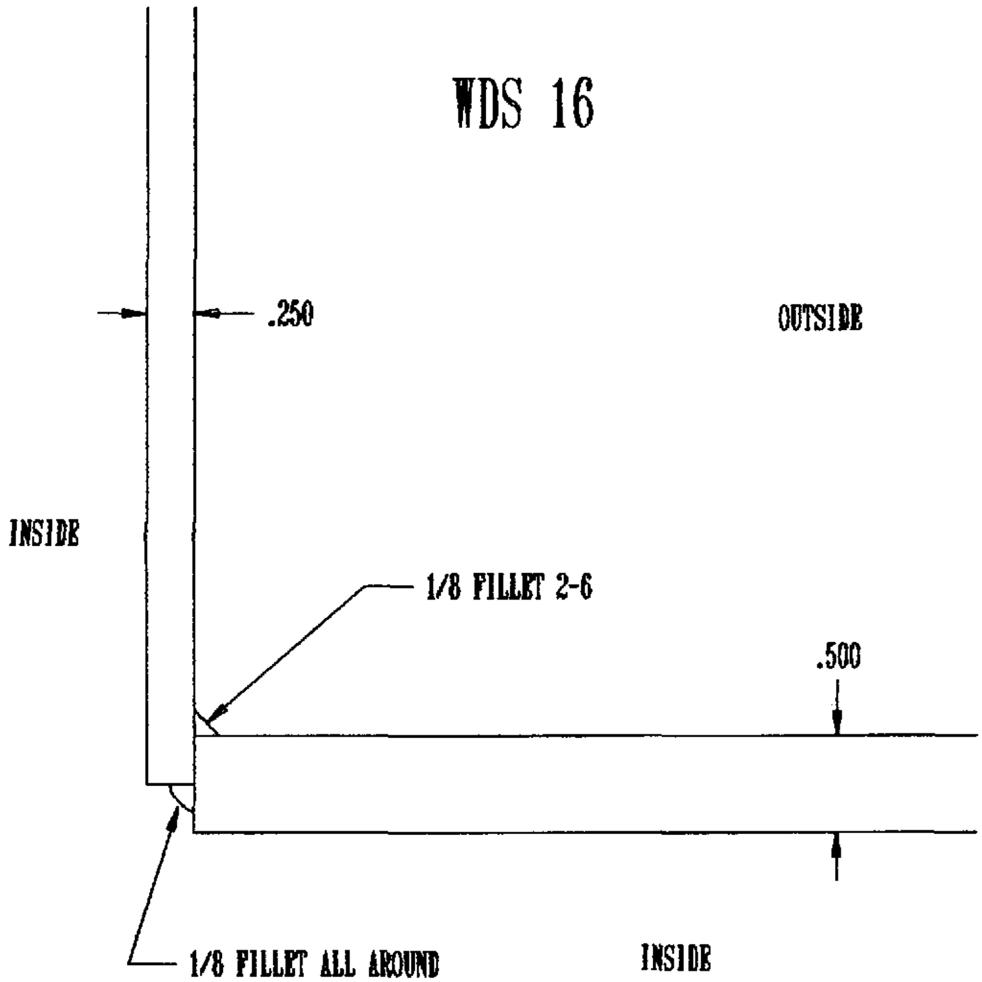
WELD # 16

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			1/4 to 1/2	
Bevel in Total Degress			N/A	
Land			N/A	
Root Opening			N/A	
Root Pass TIG			N/A	
Root Pass Plasma				
Torch Size			350	
Tungsten Size			1/8	
Tungsten Set Back			N/A	
Cup Size			8	
Tip Size/Number			N/A	
Pass or Pass Number				
Amps Setting			190	
Volts			22	
Argon Gas			Shield	
Argon/He 75%/25%			N/A	
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			N/A	
Wire Size/Type			3/32 308L	
Cleaning Technique			CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st					1st	190	22	3/32	
2nd					2nd	190	22	3/32	
3rd					3rd				
4th					4th				
5th					5th				

WDS 16



WDS 16

TACK NOZZLE TO SHELL FROM OUTSIDE (TIG)
WELD FROM INSIDE (TIG)
WELD TO TACKS FROM OUTSIDE (TIG)

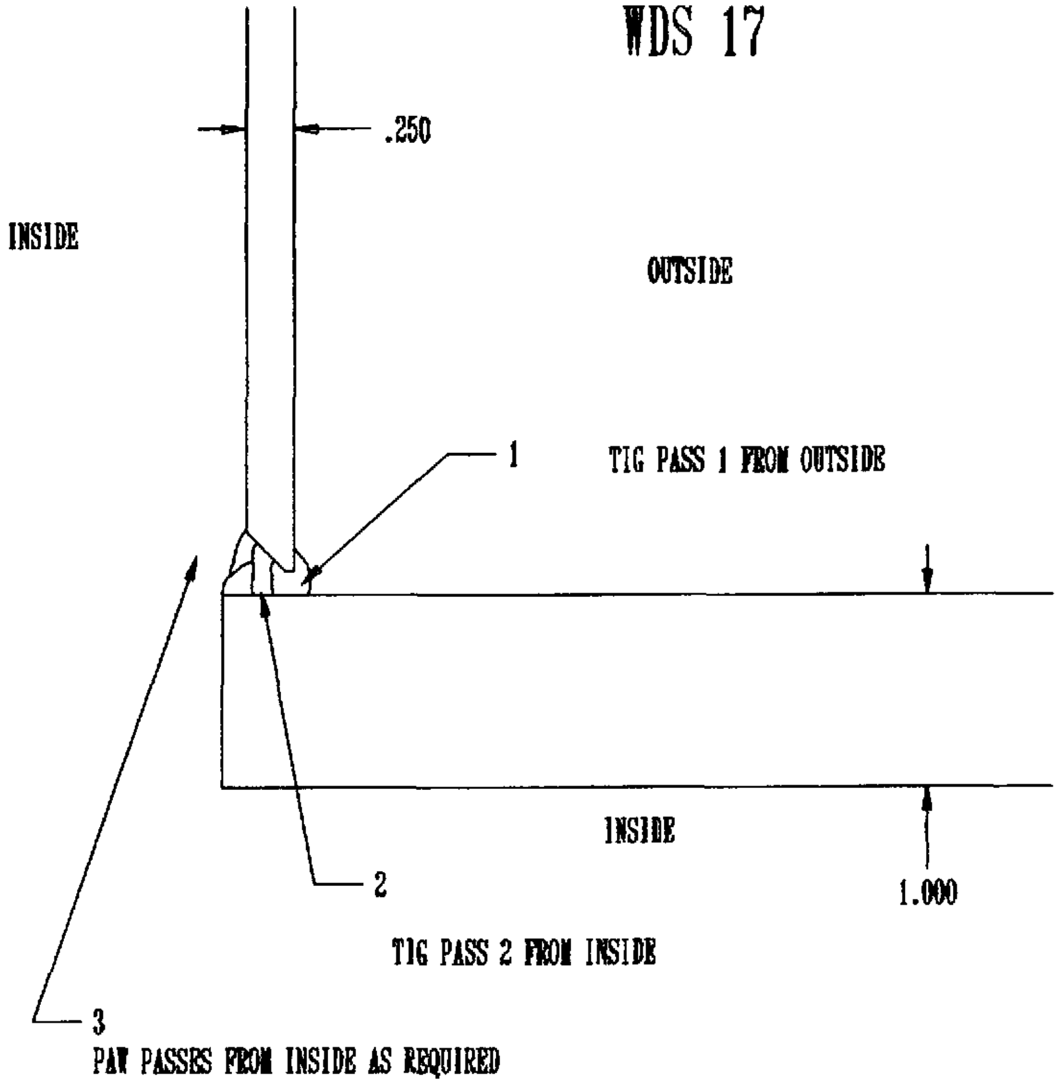
WELD # 17

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	**Remarks**	**WPS# 073-3**	**Remarks**
Plate Thks. or Pipe Size	1/4 to 1		1/4 to 1	
Bevel in Total Degress	50		50	
Land	.045		.045	
Root Opening			1/8	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8 - 4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4 - 5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	1/8 308L		1/8 308L	Also 3/32
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 17



WDS 17

FIT UP WITH 1/8-3/16 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
DIVIDE NOZZLE INTO FOUR QUADRANTS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK
  FROM OUTSIDE (TIG); WORK FROM QUADRANT
  TO QUADRANT IN BOLT TORQUING PATTERN
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (PAW)

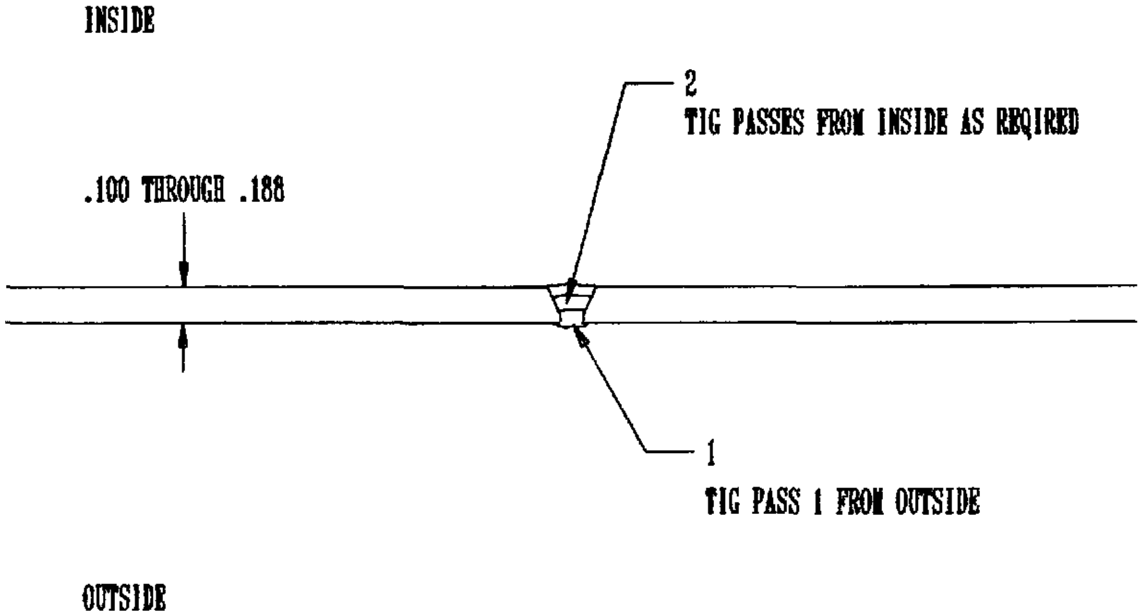
WELD # 18

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS#	Remarks	WPS# 073-3	Remarks
Plate Thks. or Pipe Size			11ga	
Bevel in Total Degress			50	
Land			.045	
Root Opening			1/16 - 3/32	
Root Pass TIG			Yes	
Root Pass Plasma				
Torch Size			350	
Tungsten Size			1/8	
Tungsten Set Back			N/A	
Cup Size			8	
Tip Size/Number			N/A	
Pass or Pass Number				Below
Amps Setting			190	
Volts			22	
Argon Gas			Shield	
Argon/He 75%/25%			N/A	
Gas Flow CFH			30	
Gas Plasma Flow CFH			N/A	
Purge Argon CFH			30	
Wire Size/Type			3/32 - 1/8	308L
Cleaning Technique			CO_2	Weld Zone and Wire
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd					2nd	190	22	1/8	
3rd					3rd				
4th					4th				
5th					5th				

WDS 18



WDS 18

FIT UP WITH 1/8 GAP
TACK FROM OUTSIDE WITH PURGE INSIDE (TIG)
ONE INCH TACKS ON TEN INCH CENTERS
BACKSTEP WELD ROOT PASS FROM TACK TO TACK FROM OUTSIDE (TIG)
TIG PASS FROM INSIDE (TIG)
FILL FROM INSIDE AS REQUIRED (TIG)

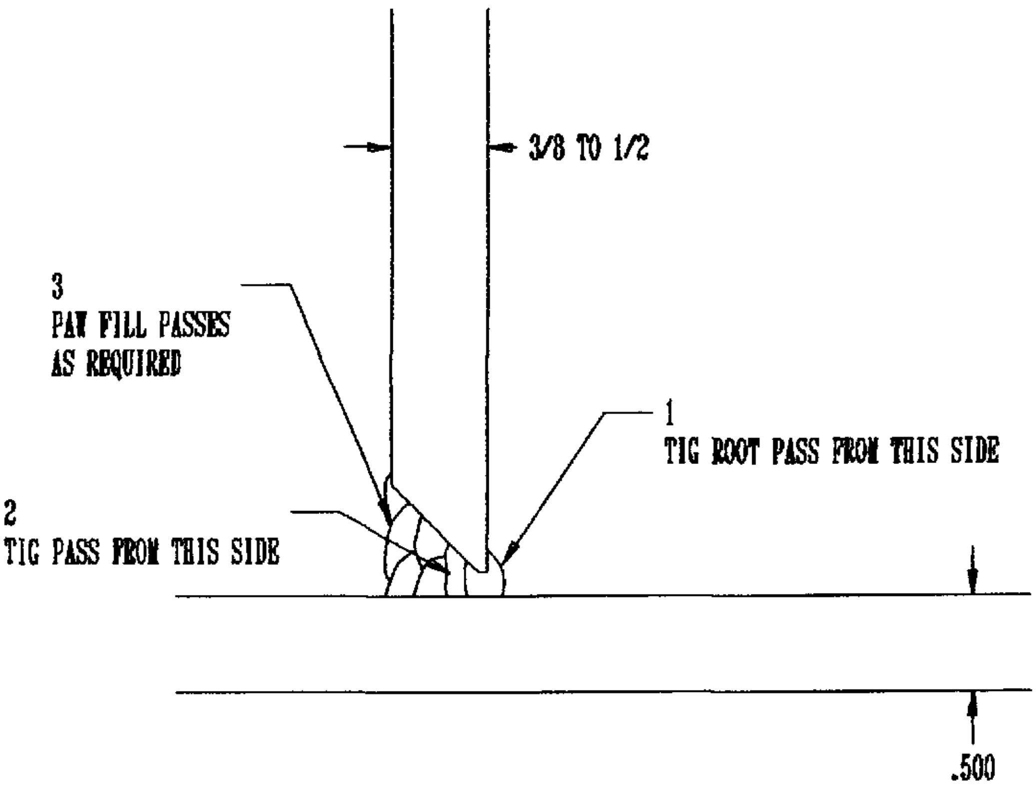
WELD # 19

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 151	**Remarks**	**WPS# 153**	**Remarks**
Plate Thks. or Pipe Size	1/2 - 3/8		1/2 - 3/8	
Bevel in Total Degress	45		45	
Land	.045		.045	
Root Opening			1/8 - 3/16	
Root Pass TIG			Yes	
Root Pass Plasma	No			
Torch Size	4A		350	
Tungsten Size	3/16		1/8	
Tungsten Set Back	Flush		N/A	
Cup Size	8-4088		8	
Tip Size/Number	.125/9-1892		N/A	
Pass or Pass Number		Below		Below
Amps Setting	180		190	
Volts	20		22	
Argon Gas	Plasma		Shield	
Argon/He 75%/25%	Shield		N/A	
Gas Flow CFH	20		30	
Gas Plasma Flow CFH	4-5		N/A	
Purge Argon CFH	30		30	
Wire Size/Type	V8 308L		1/8 308L	
Cleaning Technique	CO_2	Wire and Weld Zone	CO_2	Wire and Weld Zone
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root	190	22	1/8	
1st					1st	190	22	3/32	
2nd	180	20	1/8		2nd				
3rd	180	20	1/8		3rd				
4th					4th				
5th					5th				

WDS 19



WDS 19

TIG TACK FROM RIGHT SIDE (VIEW)
PURGE FROM LEFT [VIEW] (TIG)
TIG PASS FROM LEFT [VIEW] (TIG)
PAW FILL FROM LEFT [VIEW] (PAW)

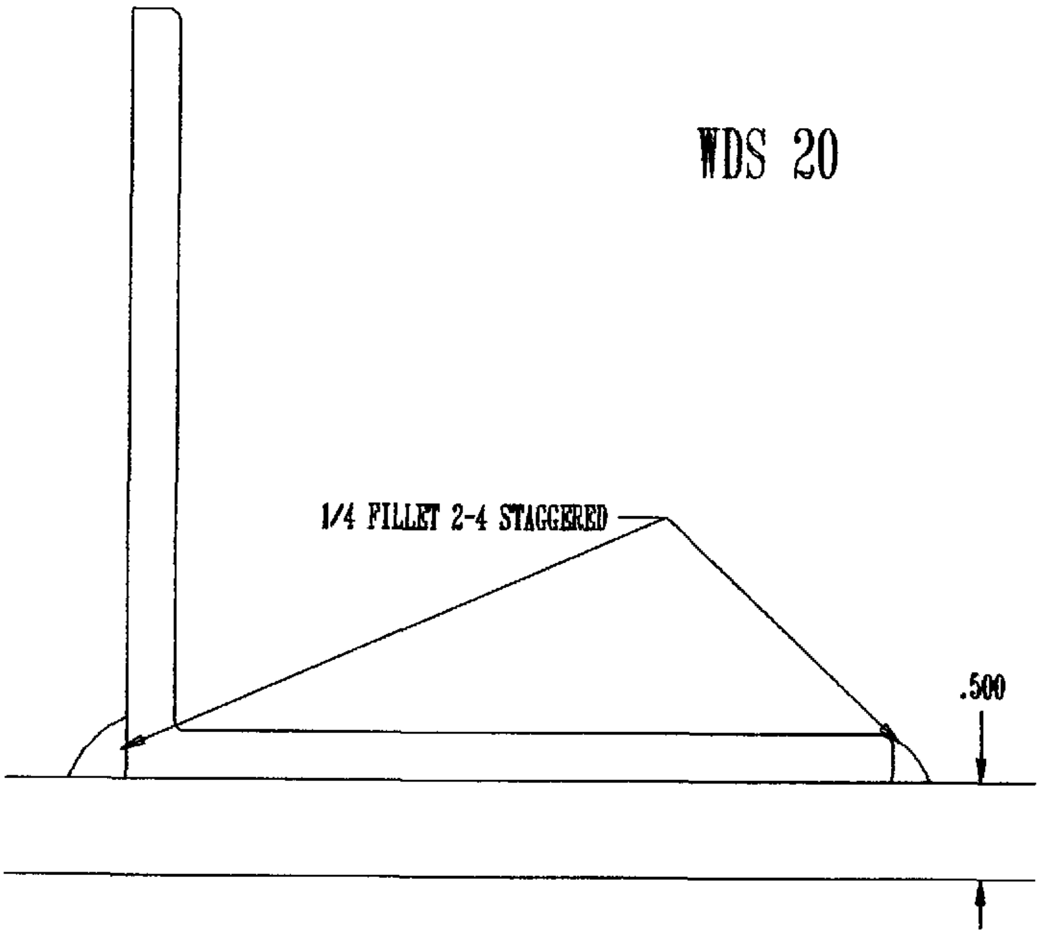
WELD # 20

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	Remarks	WPS#	Remarks
Plate Thks. or Pipe Size	1/4			
Bevel in Total Degress				
Land				
Root Opening				
Root Pass TIG				
Root Pass Plasma				
Torch Size	4A			
Tungsten Size	3/16			
Tungsten Set Back	Flush			
Cup Size	8-4088			
Tip Size/Number	.125/9-1892			
Pass or Pass Number		Below		
Amps Setting	180			
Volts	20			
Argon Gas	Plasma			
Argon/He 75%/25%	Shielding			
Gas Flow CFH	20			
Gas Plasma Flow CFH	4-5			
Purge Argon CFH	30			
Wire Size/Type	1/8 308L			
Cleaning Technique	CO_2	Wire & Weld Zone		
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st	180	20	1/8		1st				
2nd					2nd				
3rd					3rd				
4th					4th				
5th					5th				

WDS 20



WDS 20

TACK BOTH SIDES (PAW)
WELD BOTH SIDES ALTERNATING; END WELDS ON TACKS (PAW)

WELD # 21

WELD DATA SHEET

	PLASMA ARC WELDING P.A.W.		GAS TUNGSTEN ARC WELDING G.T.A.W.	
	WPS# 150	**Remarks**	**WPS#**	**Remarks**
Plate Thks. or Pipe Size	1/4 - 1/2			
Bevel in Total Degress	45			
Land	N/A			
Root Opening	N/A			
Root Pass TIG	N/A			
Root Pass Plasma	N/A			
Torch Size	4A			
Tungsten Size	3/16			
Tungsten Set Back	Flush			
Cup Size	8-4088			
Tip Size/Number	.125/9-1892			
Pass or Pass Number		Below		
Amps Setting	180			
Volts	20			
Argon Gas	Plasma			
Argon/He 75%/25%	Shielding			
Gas Flow CFH	20			
Gas Plasma Flow CFH	4-5			
Purge Argon CFH	30			
Wire Size/Type	1/8 308L			
Cleaning Technique	CO_2	Wire & Weld Zone		
Cold Wire Feeder				
Wire Speed				
Continuous				
Retract				
Delay				
Pulse				

PAW	AMPS	VOLTS	FILLER	W#	GTAW	AMPS	VOLTS	FILLER	W#
Root					Root				
1st	180	20	1/8		1st				
2nd					2nd				
3rd					3rd				
4th					4th				
5th					5th				

LIGO- V049-2-070

REV. A

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

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

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

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

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

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

(n1)No Pass > 1/2" t

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

(n3)

(n4) WELD WIRE SHALL BE CLEANED SPECIAL AND HANDLED WITH POLY GLOVES.

(n5) GRINDING WITH ABRASIVE WHEELS IS "NOT ALLOWED.

(n6) WIRE BRUSHING IS "NOT ALLOWED".

(n7) DEFECT REMOVAL MUST BE ACCOMPLISHED WITH A CARBIDE BURR CUTTER.

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 Rollaa (04/23/96) Weld Specialist

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

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

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

JOINT DESIGN (QW-402)	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 : 0-125" 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 ... : None Degrees F.
note:	PWHT Holding time(hr): None
	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. A

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

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

BASE METAL (QW-403, QW-405)	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 625-675 DEG. F.
Interpass Temp. Max. 350 Degrees F.	Time range 4
Preheat Maintenance. None	notes

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

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

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

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

JOINT (QW-402)

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

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

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

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

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

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

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

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

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

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

(a) NON-FUSABLE RETAINERS MAY BE USED.

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

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

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

(e)

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

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

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

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

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

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

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

note:

BASE METAL (QW-403)

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

HEAT TREATMENT (QW-406, QW-407)
Preheat Temperature: 60 Degrees F.
Preheat Maintenance: None
Interpass Temperature: 350 Degrees F.
PWHT temperature ... : 650 Degrees F.
PWHT Holding time(hr): 4.00
note: PWHT TEMP.= +/-25 DEG. F.

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

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

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

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

Procedure Qualification Record (PQR)

PQR No.: 151-H48

TENSILE TEST (QW-150)

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

GUIDED BEND TEST (QW-160)

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

TOUGHNESS TEST (QW-170)

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

HARDNESS TEST - No hardness test

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

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

Notes:

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

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

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

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

LIGO- V049-2-072
REV. A

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

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

BASE METAL (QW-403, QW-405)	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 650
Interpass Temp. Max. 350 Degrees F.	Time range 4 - n6, n7
Preheat Maintenance. None	notes STRESS RELIEF +/-25 DEG.F.

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

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

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

JOINT (QW-402)

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

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

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

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

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

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

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

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

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

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

(a) NON-FUSABLE RETAINERS MAY BE USED.

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

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

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

(e)

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

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

Accepted By: Alan Brookbrook (02/23/96) QA Manager:

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

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

JOINT DESIGN (QW-402)
WELD JOINT CONFIGURATION
Single-V groove
Gas backing was used
Groove Angle : 75 Degrees
Root Opening : 0-125 Inches
Root Face : 030-062 Inches

note:

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

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

HEAT TREATMENT (QW-406, QW-407)
Preheat Temperature: 60 Degrees F.
Preheat Maintenance: None
Interpass Temperature: 350 Degrees F.
PWHT temperature ... : 650 Degrees F.
PWHT Holding time(hr): 4
note: STRESS RELIEF 650 +/-25 DEG.F.

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

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

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

Procedure Qualification Record (PQR)

PQR No.: 153-H48

TENSILE TEST (QW-150)

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

GUIDED BEND TEST (QW-160)

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

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp.		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: 14087
PQR was done & welding of coupon was witnessed by : Process Systems

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

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

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

LIGO - V049-2-073

REV. A

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

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

BASE METAL (QW-403, QW-405)	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)			None		
Process / type	GTAW / manual					
Process thickness limit.	0.0625" to 0.7500"			None		
GAS (QW-408)						
Shielding Gas / CFH.....	100% Argon / 15-25			None / -		
Trailing Gas / CFH......	None / -			None / -		
Backing Gas / CFH.......	100% Argon / 9-30			None / -		
FILLER METAL (QW-404)						
AWS classification......	ER308L			None		
SFA Spec. No. & F No....	SFA#: 5.9 F#: 6			SFA#: None F#: -		
A No. or Chem. Comp.....	8			None		
Filler metal trade name.	SOLID FILLER METAL			None		
SAW flux trade name/type	N/A / -			None / -		
Elec./Wire size (in) ...	1/16	3/32	1/8	-	-	-
ELECTRICAL (QW-409)						
Welding amperage range..	70-150	80-180	130-275	-	-	-
Welding voltage range...	n/r	n/r	n/r	-	-	-
Travel speed (ipm)......	Var.	Var.	Var.	-	-	-
Max. Heat Input (J/in)..	None			None		
Tungsten Type/Size......	EWTh-2 / 1/16" - 3/16"			N/A / -		
Current & Polarity......	DCEN (straight)			N/A		
TECHNIQUE (QW-410)						
String / weave bead.....	String & Weave Bead			N/A		
Orifice / gas cup.......	# 5 to # 10			None		
Contact tube to work....	N/A			None		
Oscillation.............	N/A			None		
Mult./Single electrode..	Single Electrode			N/A		
Other Technique Notes...				None		

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

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

WELDING PROCEDURE SPECIFICATION (WPS)

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

JOINT (QW-402)

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

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

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

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

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

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

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

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

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

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

(a) NON-FUSABLE RETAINERS MAY BE USED.

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

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

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

(e)

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

Prepared By: R 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 Rev A

JOINT DESIGN (QW-402)
WELD JOINT CONFIGURATION
Single-V groove
Gas backing was used
Groove Angle : 75 Degrees
Root Opening : 062-125 Inches
Root Face : 030-062 Inches

note:

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

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

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

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

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

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

Procedure Qualification Record (PQR)

PQR No.: 073-H9

TENSILE TEST (QW-150)

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

GUIDED BEND TEST (QW-160)

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

TOUGHNESS TEST (QW-170)

Spec. No.	Notch Location	Notch Type	Test Temp. (F)	Impact Values (ft-lbs)	Lateral exp.		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 L Bradbook (05/29/74) QA Manager:

Title: SPECIFICATION FOR CLEANING PROCEDURE

SPECIFICATION FOR

CLEANING PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

QUALITY ASSURANCE: ______________________

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [illegible]

0	TMS 4-30-96		GENERAL REVISION PER DEO # 0151
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED: T. Starr	DATE: 4-30-96	APPROVED: RGB	DATE: 5/1/96	Number A V049-2-015	Rev. 0

TABLE OF CONTENTS

1.0	Purpose
2.0	General
3.0	Responsibility
4.0	Equipment and Systems
5.0	Procedure
6.0	Required Documentation
Attachment	Component Cleaning Data Sheet

1.0 PURPOSE

The purpose of this procedure is to define the necessary steps for the cleaning of the LIGO vacuum equipment components such that all vacuum exposed surfaces are compatible with ultra high vacuum service.

2.0 GENERAL

This procedure is applicable to any fabricated stainless or aluminum component that is exposed to UHV service. It applies to the cleaning of these components subsequent to completion of all machining and welding operations.

3.0 RESPONSIBILITY

3.1 PSI Engineering is responsible for identifying all components and portions of components that are subject to this procedure. All cleaning will be as specified on the drawings.

3.2 PSI manufacturing is responsible for the execution of this procedure in the PSI shop.

3.3 The installation contractor is responsible for maintaining this procedure at the sites.

3.4 Quality Assurance is responsible for monitoring compliance with this procedure in the PSI shop. Engineering will be responsible for compliance at the sites.

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

4.0 EQUIPMENT AND SYSTEMS

4.1 The cleaning equipment consists of the following:

4.1.1 Washing Cabinet
- Enclosure
- Spray header system
- Drain collection system and pump
- Vent system
- Controls

4.1.2 Cleaning Solution and Rinse System

Cleaning solution tank and heater
Initial rinse water tank and heater
DI Water tank and heater
Used DI water tank
Deionized (DI) water clean-up system
Pumps, filters, piping, valves

4.2 Clean Manufacturing Area

An isolated section of the PSI shop will be provided with an outside air purge to form a clean manufacturing space. Class 100 cleanrooms will be operated in this area. Because the air is recirculated through the cleanroom filters, it will also be cleaner than the shop atmosphere. It is expected that it may reach a level as low as Class 50,000 to 100,000. The components cleaned in the washing cabinet will be moved into the Class 100 cleanrooms for packaging (or closure of the vessel ports) without going back into the shop atmosphere.

4.3 Class 100 Cleanroom

4.3.1 Two Class 100 soft-wall portable cleanrooms are joined together to make a large working area. The cleanrooms circulate air through HEPA filters at the tops of the rooms downward. The air exits under the soft-walls (plastic curtains) at the bottom and recirculates through the room to the blower inlets at the top.

4.3.2 Cleanroom activities shall be performed in accordance with Cleanroom Procedure V049-2-118. Specific cleanroom training is required for anyone entering the cleanroom. This training, given by Manufacturing Engineering, covers principles, gowning and necessary behavior.

5.0 PROCEDURE

5.1 <u>Starting Condition</u>

a.. All welding completed to the degree possible.

b. Remove gross contamination from all interior and exterior surfaces (including flange faces) by steam cleaning with a portable steam system.

5.2 Equipment Set-Up

a. Establish the proper level of DI water in the supply tank. This may require pumping the DI water from the used DI water tank through the resin bed system and into the supply tank.

b. If any water remains in the used DI water tank, pump it to the initial rinse water tank.

c. Establish the proper water level in the initial rinse water tank, adding filtered city water as required.

d. Establish the proper level in the detergent tank, adding detergent and filtered city water as required. (The entire contents of this tank should be drained every 2 months or longer if the system is not used continuously.)

e. Turn on the tank heaters to maintain approximately 150 F in each tank.

f. Confirm proper piping connections and valve lineup for the system.

g. Confirm proper operation of the vent fan.

h. Confirm proper operation of the cleanroom.

5.3 Cleaning Precautions

5.3.1 There shall be a minimum of two operators present (in the area) for all cleaning operations.

5.3.2 The operator doing the washing shall wear a lab coat, shoe covers and clean room gloves. (This applies to anyone handling the cleaned pieces.)

5.3.3 The operators should be familiar with the washing system and its components before operating the equipment.

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

5.3.5 Handle each piece or component with appropriate care and clean gloves.

5.4 Cleaning

5.4.1 *General*

a. The heater controls should be set to provide approximately 150 F water.

b. When using DI water, periodically monitor the quality light at the DI system.

5.4.2 *Component Loading*

a. Mount the component to be cleaned on a sled and dolly, and position in the washing cabinet.

b. Assemble and position the spray headers as appropriate for the piece being washed.

c. Close and secure the cabinet door.

5.4.3 *Wash*

a. Start the cleaning cycle (the vent fan will automatically start). Note: Do not start the cleaning cycle unless there is sufficient time to complete it and package (or close up) the component during the work shift. The cycle should not be interrupted between steps.

b. As the controller steps through the washing and rinsing steps of the cycle, periodically monitor the status of the pumps, valves, filters and tanks.

5.4.4 *Drying*

a. Drying will be accomplished by blowing clean air over the component before allowing it to cool.

b. Inspect and bag the component (or close up the vessel) immediately after drying.

5.5 Inspection

a. Inspection shall be done (before removing the piece from the washing cabinet) using a black light on all interior surfaces or flange faces. No visible contaminant of any form shall be detected when viewed with the naked eye under both natural and ultraviolet light.

b. The presence of any hydrocarbon or fingerprints on any interior surface or flange face shall be cause for rejection. This will require CO_2 cleaning to rectify.

c. A visual inspection shall be made of exterior surfaces. Visible particulates or actual contamination shall be removed.

5.6 Bagging/Wrapping

a. Immediately after drying and inspection, double bag the component using clean, oil-free polyethylene bags or wrap and seal using the same material.

b. Remove the component to the clean area.

6.0 REQUIRED DOCUMENTATION

A component cleaning data sheet containing the following data shall be filled out on completion of cleaning. The data sheet will become part of the component QA package.

- Cleaning log describing parts cleaned and procedure used
- Comments and observations
- Record of flow rates, temperatures and durations used
- Record of inspection results

Attachment

LIGO COMPONENT CLEANING DATA SHEET

Project V59049

Component	Serial Number
______________________________	____________________
______________________________	____________________
______________________________	____________________
______________________________	____________________

Wash Cycle: ____

Flowrate: ______________ Max. Temp.: __________ Duration: __________

Operator: ________________________ Date: ____________

Comments: ____

____

____

Component(s) Inspected By: __________________ Date: ____________

Quality Assurance: __________________ Date: ____________

Comments: ____

____

____

Number

Rev.

Title: SPECIFICATION FOR THERMAL STRESS RELIEVING

SPECIFICATION FOR

THERMAL STRESS RELIEVING

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: D. McWilliams

STRUCTUAL ENGINEER: R. D. Gatto

QUALITY ASSURANCE: Alan H. Bullock

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
0	D. McW	RGB	ISSUED PER DEO 0143 FOR FDR

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED D. McW	DATE 4-26-96	APPROVED RGB	DATE 4/26/96	Number A V049-2-046	Rev. 0

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibility

4.0 Procedure

1.0 PURPOSE

The purpose of this procedure is to minimize distortion and provide dimensional stability on LIGO stainless steel vacuum vessels with critical tolerances.

2.0 GENERAL

This procedure is applicable to BSC lower vessel and the HAM main assembly only. Stress relieving operations shall be performed at the points in fabrication cycle as described in the vessel fabrication procedure.

3.0 RESPONSIBILITY

This procedure is applicable to the fabricator and its personnel.

4.0 PROCEDURE

4.1 Steam clean vessel to remove any hydrocarbons. Use straight steam without any detergent.

4.2 The temperature of the vessel shall be measured and recorded throughout the stress relieving process .using a type K thermocouple mounted to the external surface of the vessel.

4.3 Furnace shal be natural fired and is to be adjusted so the that atmosphere shall run lean with an excess O_2 content in the flue gas of at least 5%. Documentation of the furnace atmosphere shall be provided.

4.4 The vessel shall be protected from direct impingement of the furnace flames.

4.5 Heat the vessel at the rate of 100 F/ hour above 350F up to 1000F+/- 50F. Hold for four hours. Cool at a rate of 100F/hour to 300F before removing from furnace.

Title: SPECIFICATION FOR BAKE OUT PROCEDURE VACUUM ENVELOPE COMPONENT

SPECIFICATION FOR COMPONENT BAKE OUT PROCEDURE

FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Roberto Than

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Rich Bagley

0		REB 5/3/96	INITIAL RELEASE PER DEO 166 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE	Approved DATE REB 5/3/96	Number: V049-2-019 A	Rev. 0

1.0 PURPOSE

The purpose of this is to define the necessary steps to perform a factory bakeout of a vacuum vessel component at 150 °C. This includes the steps necessary to prepare for the bake out sequence.

2.0 GENERAL

The procedure will general apply to any vessel component and vacuum monitoring equipment that goes with the component.

Required References

A. Blanket System mechanical layout configuration and electric configuration drawings for vacuum envelope.
B. Bakeout System Control Cart Operating Manual & Procedure.
C. RGA Operating Manual
E. STPH2000C Turbomolecular Pump Operating Manuals
F. QDP80 Dry Backing Pump Operating Manuals
G. Vacuum Gauges: Cold Cathode & Pirani Gauges Operating Manuals
H. 500 L/s Ion Pumps Operating Manual

3.0 RESPONSIBILITY

The procedure is applicable to PSI Personnel.

4.0 PROCEDURE

Summary of bakeout sequence

-Install blankets
-Equipment checkout
-Pumpdown vessel
-RGA reading
-Rampup temperature (warmup)
-Soak for 48 hours
-Rampdown temperature (cooldown)
- RGA reading

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

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

4.1.3 Electrical and thermocouples connection and checkout

Connect each blanket power cable and thermocouple cable to the controlled cart according to procedures and drawing for connecting blankets electricals and instrumentation to control carts
Refer to: Blanket System mechanical layout configuration and electric configuration.

4.2 Vacuum System

4.2.1 Vacuum Pump(s)

The Main turbo system will be used to pumpdown the component.

A cryotrap upstream of the turbo inlet will be used to trap hydrocarbons and water and to keep the turbo pump clean during initial bake of the vessel.
Do functional check of turbomolecular pump system.
Refer to: STPH2000C Turbomolecular Pump Operating Manuals
QDP80 Dry Backing Pump Operating Manuals

4.3 Vacuum Instrumentation

4.3.1 RGA

The RGA will be used before and after bakeout. The RGA itself needs to be baked. The RGA assembly will be mounted off a 2½ all metal UHV valve mounted on the vacuum envelope. The assembly will have a 2½" Tee or Cross Conflat fitting with an 1½" roughing valve on one end and the RGA on the other. A cross fitting is recommended so that a high vacuum gauge can be mounted on the fitting to serve as the pressure protection device for the RGA.
Isolate the 2½ UHV valve from the vacuum envelope and connect the aux. cart to the RGA to pumpdown the RGA assembly for RGA checkout.
Refer to: RGA Operating Manual

4.3.2 Pressure gauges: Pirani and High vacuum gauge

In order to monitor pressure during the bake, a high operating temperature vacuum gauge is required. The gauge pair can be mounted on the RGA assembly.
Do not start warmup of pressure gauges until a pressure of less than $1X10^{-4}$ Torr has been reached.
Refer to: Vacuum Gauges Operating Manuals

4.4 Bakeout Sequence

4.4.1 Pumpdown

Connect the cryotrap to the component.
Connect the main turbo to the cryotrap.
Start the QDP80 roughing back.
Pumpdown until a pressure of less 0.1 Torr is reached.
Close bypass valve and start the turbo pump.

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.
Take RGA scans for 10 minutes and turn off the RGA and remove the electronics from the head.

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.

Do not start warmup until the pressure has dropped to less 5X 10^{-5} Torr otherwise hydrocarbons will be baked onto the gauge.

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.
The pressure gauge will be use to monitor pressure during the bake.
Set ramp rate for blanket system on control carts to 5°C/hr.
Set target setpoint to 150°C.

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 below manufacturers recommended maximum (200°C)

4.4.4 Soak for 48 hours

The component will be heated to 150°C and soaked for 48 hours at 150°C±20°. The pressure gauge pairs will be operating at 150°C to monitor pressure during the bake. The RGA will soak at a temperature below 200°C. Set this temperature to 175°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 on and turned off when the system has cooled down.

4.4.6 RGA data

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

Follow procedures in document: V049-2-127 "RGA TEST" for data acquisition and analysis.

Title: SPECIFICATION FOR LEAK CHECK PLAN LIGO VACUUM EQUIPMENT

SPECIFICATION FOR LEAK CHECK PLAN
FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROCESS ENGINEER	R T [illegible]
PROJECT ENGINEER	S Motew
QUALITY ASSURANCE	Alan L Bradbrook
TECHNICAL DIRECTOR	D. O. McWilliams
PROJECT MANAGER	Richard Bagley

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

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

1.0 PURPOSE

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

2.0 GENERAL

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

3.0 RESPONSIBILITY

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

4.0 PROCEDURE

4.1 Joint Categories:

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

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

Category III
CF flange joint.

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

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

4.2 Leak Checking Welded Joints

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

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

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

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

4.3 Leak Checking Conflats

Category III
Conflats.

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

4.4 Leak Checking O-rings

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

Leak checking method

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

Possible candidates for tracer gases:

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

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

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

Leak checking method

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

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

Optional Leak Detection Methods

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

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

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

Outgassing of O-Rings

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

LEAK TEST DATA SHEET

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

Remarks : ____________________

____

BSC LEAK TEST SUMMARY SHEET

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

HAM LEAK TEST SUMMARY SHEET

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

Comments

Witnessed
Signature
Title
Date

SPOOL SECTION LEAK TEST SUMMARY SHEET

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

Title: PROCEDURE FOR CLEAN ROOM ACTIVITIES

PROCEDURE FOR

CLEAN ROOM ACTIVITIES

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: Alan J. Bradbury

MANUFACTURING ENGR: [signature]

TECHNICAL DIRECTOR: D. G. McWilliams

PROJECT MANAGER: Richard Bagly

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

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

Title

PROCEDURE FOR CLEAN ROOM ACTIVITIES

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

1.0 PURPOSE

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

2.0 GENERAL

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

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

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

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

Safety glasses shall be worn at all times.

3.0 RESPONSIBILITIES

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

4.0 PROCEDURE

4.1 *Clean Room Access*

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

4.1.2 All soiled or damaged clothing shall be discarded.

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

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

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

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

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

4.2 *Clean Room Exit*

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

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

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

Title: PROCEDURE FOR VERIFYING COMPONENT DIMENSIONAL ACCURACY

PROCEDURE FOR VERIFYING COMPONENT DIMENSIONAL ACCURACY

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY: Raymond D. Ciatto

QUALITY ASSURANCE: Alan L Birdbrook

MANUFACTURING ENGR: David McE

TECHNICAL DIRECTOR: D.O. McWilliams

PROJECT MANAGER: Richard Bayley

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

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED RCiatto DATE 5/3/96	APPROVED REB DATE 5/3/96	Number A V049-2-121	Rev. Ø

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

1.0 PURPOSE

The purpose of this procedure is to define the activities required to verify dimensional accuracy of LIGO fabricated components.

2.0 GENERAL

LIGO components shall be inspected during and after fabrication to verify dimensional accuracy. All components shall be inspected to dimensions and tolerances given on the fabrication drawings.

3.0 RESPONSIBILITY

The Quality Assurance Department is responsible for inspecting and verifying LIGO component dimensional accuracy.

LIGO vessels manufactured by outside machine shops shall be inspected at the vendor while on the N.C. machine.

PSI fabricated components will be inspected in the PSI shop to verify dimensional accuracy. An electronic surface gauge shall be used to verify and record all o-ring sealing surface finishes (32 finish).

4.0 PROCEDURE

4.1 Outside Vessel Fabrication

The fabricated vessel shall be inspected during manufacture and at the Final Acceptance as detailed in the vessel Q.A. plan. The final inspection of the vessels shall be done on the N.C. machine. The fabrication drawings shall be used as the acceptance criteria. A discrepancy report shall be prepared for all non-conformances.

A PSI Q.A. (or engineering) representative shall witness and signoff all final inspections.

LIGO shall be notified five days prior to final inspections.

4.2 PSI Shop Fabrication

PSI fabricated vessels shall be inspected during manufacturing and at final assembly as detailed in the component Q.A. plan.

A Q.A. (or engineering) representative shall witness and signoff all final assembly inspections. The fabrication drawings shall be used as the acceptance criteria. A discrepancy report shall be prepared for all non-conformances.

Title: COMPONENT PACKAGING, HANDLING AND SHIPPING

COMPONENT PACKAGING, HANDLING AND SHIPPING

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington

and

Livingston, Lousiana

PREPARED BY:	DAVID EVERS / REB
MANUFACTURING ENGR:	N/A
QUALITY ASSURANCE:	ALAN BRADBROOK / REB
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	D.E. 5/6/96	REB 5/6/96	RELEASE PER DEO 176
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.		SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE D. E. 5/6/96	APPROVED DATE REB 5/6/96	Number A V049-2-123	Rev. Ø

TABLE OF CONTENTS

1.0 Purpose

2.0 Shipping

3.0 Handling

ATTACHMENTS

1. Typical Module Weight And Center Of Gravity

Number

Rev.

1.0 PURPOSE

The purpose of this procedure is to provide basic guidelines for the safe transfer of vacuum equipment and components to the customer sites.

2.0 GENERAL

The primary objective of this procedure is to:

1. Provide sufficient supports to prevent damage to vacuum equipment and system components.
2. Provide protective closers on spools and valves.
3. Assure that the crates are strong enough to stand shipping and handling hazards.
4. Assure that the crated equipment and components are properly packed and fastened, and that the contents of each container is properly identified on a packing list.
5. Make packages and crates water tight and gas tight to prevent damage from the elements.
6. Provide identification of the equipment and parts shipped including warning notes on crates and boxes.

Crates And Crating

Crates shall be designed and constructed to comply with the military specification MIL-C-104B, Crates, Wood; Lumber and Plywood Sheathed, Nailed and Bolted.

The above specification provides reference tables relating weight of the objects to be crated, size of the crate and size of the crate frame members. It should be noted that crates constructed to MIL-C-104 specification develop their full strength after the side panels and top are installed in place. The specification also provides ample amount of sketches of the crate construction details.

The following points should be observed in the construction of crates:

The crate fabricator should be provided with information on each crate specifying the weight of the object to be crated, the internal dimensions of the crate (the crate shall clear the object by 2" on all sides) and any special data that may useful such as the internal crossbracing of equipment.

The maximum allowable span dimension between skids and other frame members shall be avoided.

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

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

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

Visqueen polyethylene film and bags are both available in various widths and sizes and are readily from a variety of sources. This is a good choice for use as an initial layer of protection.

No ventilation holes shall be provided in the crates.

Drain holes shall be provided in the crate bases.

Crating Of Piping, Spools, Valves And Miscellaneous Items

Pipes, spools and valves with ends protected by pipe caps or blind flanges shall be secured to crates to prevent any movement during handling and shipment. In regard to large valves and automatic valve operators, each one shall be wrapped with water tight polyethylene enclosures. Small valves, bolting, and other small items can be wrapped in polyethylene bags and packed in water tight boxes. All items shall be properly marked.

Items To Be Removed And Crated Separately

Delicate items such as small automatic valves, instrumentation and automatic valve operators should be removed and crated or covered with water tight wrapping, plywood or sheet metal.

Stretch Wrapping
Stretch wrap (6 mil plastic) is available in various widths from 2" to 36" with hand applicators for wrapping of various components.

3.0 SHIPPING

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

Shipping Considerations For Components
The primary objective in the preparation of components for shipping is to minimize the chance for damage shipping can induce. Thoughtful planning is required in considering the causes of potential damage and its prevention.

The following recommendations shall be considered in preparing components for shipping:

All pipes, nozzles, flanges and so forth, shall be sealed. Various methods and materials may be used, but all must be watertight. All components shipped under vacuum shall be marked with warning labels.

Suitable lifting lugs, correctly orientated to the shipping face, shall be provided and identified as the lift and or tie down points.

At times there may be special tie-down lugs required for securing a component on particular transport, or bigger holes may be required on the lifting lugs to accommodate the lifting equipment at particular site. Such requirements will be known after the PSI Project Manager has submitted the component shipping drawings to the shipping concern, and the transporter has been selected.

Two point loading with substantial shipping saddles evenly spaced about the center of gravity in areas of relative stiffness, such as external or internal stiffening rings, internal structural members, or near shell seams. Avoid supporting components at the mid-span of unsupported shells.

All shipments of components utilizing more than two point loading shall have the review and approval of the LIGO Project Manager.

Supports shall be as wide as required to distribute the load on the shell, but shall not be less than six (6) inches wide.

Supports shall only be the minimum height required to clear protrusions and stay within the shipping envelope.

Supports shall be attached to the vessel. If wooden saddles are used they should be banded to the vessel. If steel saddles are used, they should be bolted to rings.

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

The type of transporter used will affect the design of supports.

Protective Storage And Identification

Completed components shall be securely stored to prevent inadvertent movement (rolling). All nozzles shall be protected. Once protected, these components shall be stored indoors.

Any parts removed for shipping shall be clearly labeled. A loose parts list shall be generated and given to the person who will coordinate the delivery of these parts to the customer sites. The loose parts list shall accompany the shipping documents.

Marking and Special Instructions

Establishment of a good marking system and good records is critical.

Identification shall be durable. The use of hand embossed metal tags produced on a Dymo tape writer is recommended where space is the limiting factor. In all other cases, stencil painting or writing with unwashable ink is recommended. Use of photographs showing details of equipment before disassembly is strongly recommended. A picture of each crate should be taken prior to closing the lid and side walls where applicable.

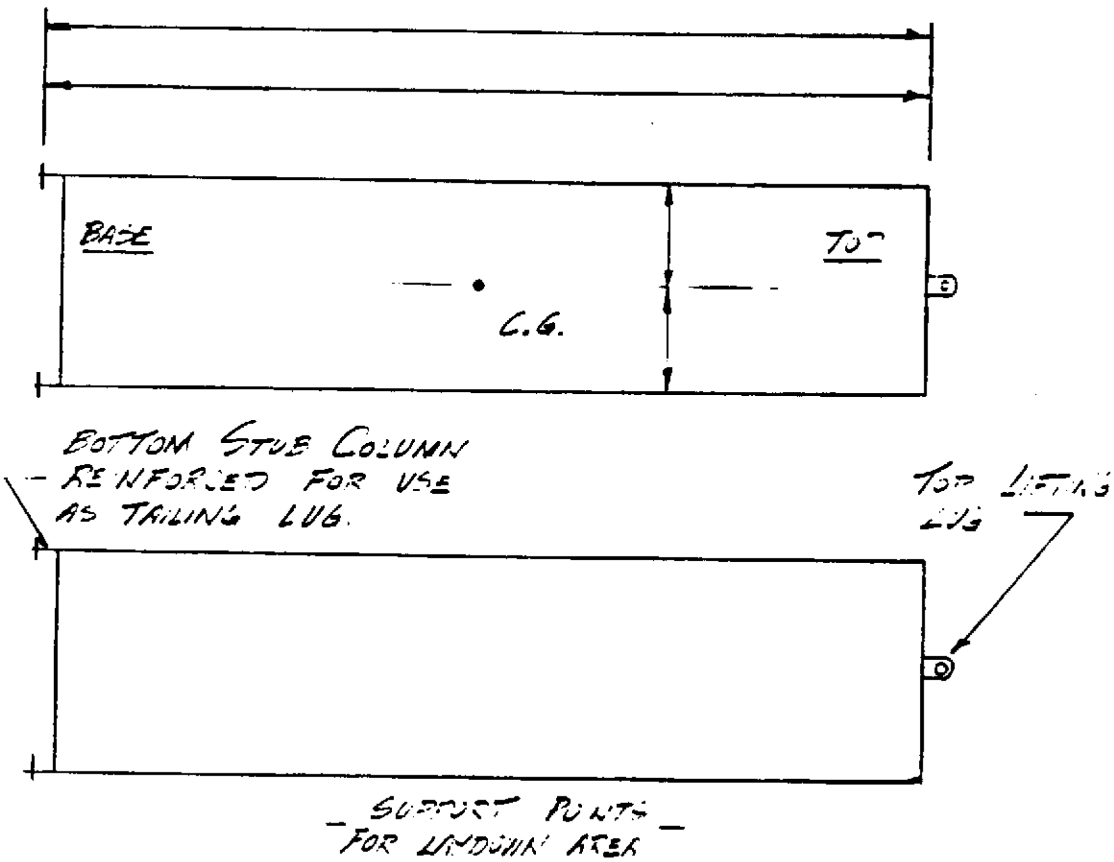
4.0 HANDLING

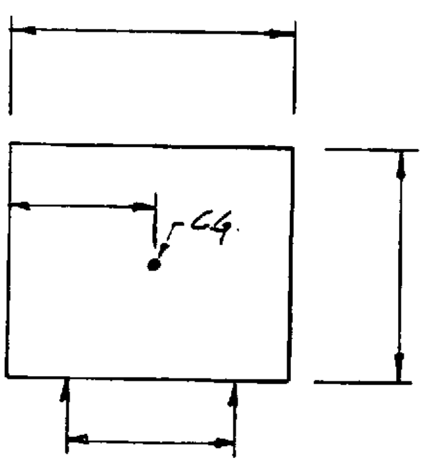
All LIGO components shall be handled (i.e. lifted, pulled, etc.) per the vessel handling data sheet. This sheet will detail weight, center of gravity, spreader beam requirements, offloading instructions, etc.

Special shipping instructions such as "USE SPREADER BAR WHEN LIFTING" or shipping weight should be painted in the proper places and detailed instructions attached to the vessel if applicable. (See Attachment 1).

SAMPLE

PROCESS SYSTEMS INTERNATIONAL INC. 20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA (508) 366-9111 / TELEX 92-0331	ENGINEERING MADE BY: ______ CHK'D ______ DATE: ______ APPV'D ______





SHIPPING WEIGHT
= ______ T

LIFTING & ERECTION
WEIGHT = ______ T

SECTION A-A.

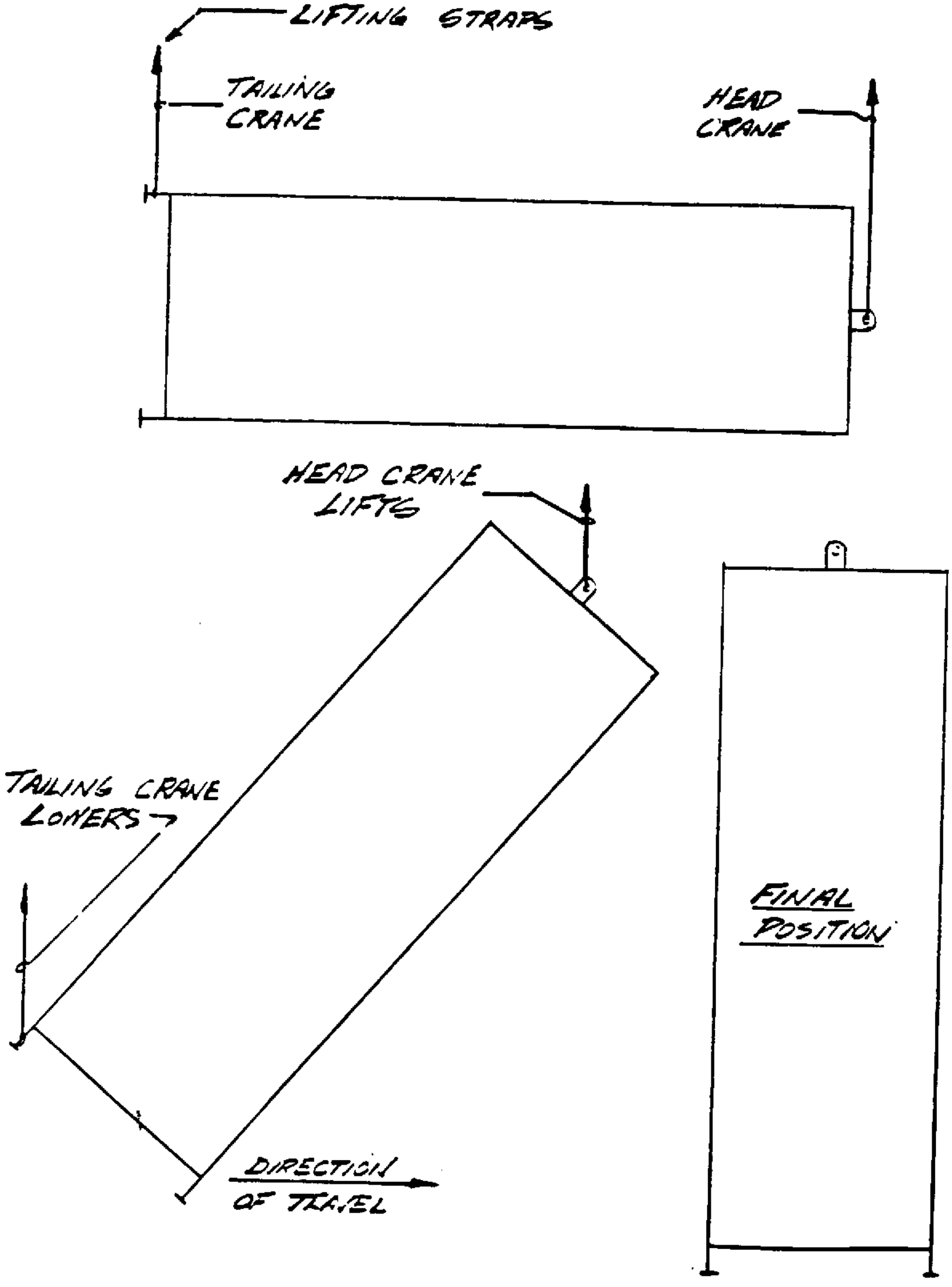
REVISION:	A	B	C	D	E	F	TITLE: MODULE WEIGHTS & CENTERS OF GRAVITY	SHEET 1 OF 3
CHK'D:								PAGE ___ OF ___
DATE:								

SAMPLE

PROCESS SYSTEMS INTERNATIONAL INC.

20 WALKUP DR WESTBOROUGH, MASSACHUSETTS 01581 USA
(508) 366-9111 / TELEX 92-0331

ENGINEERING
MADE BY: ____ CHK'D ____
DATE: ____ APPV'D ____



REVISION:	A	B	C	D	E	F
CHK'D:						
DATE:						

TITLE: ERECTION LIFTING SEQUENCE

SHEET 2 OF 3

PAGE ____ OF ____

SAMPLE

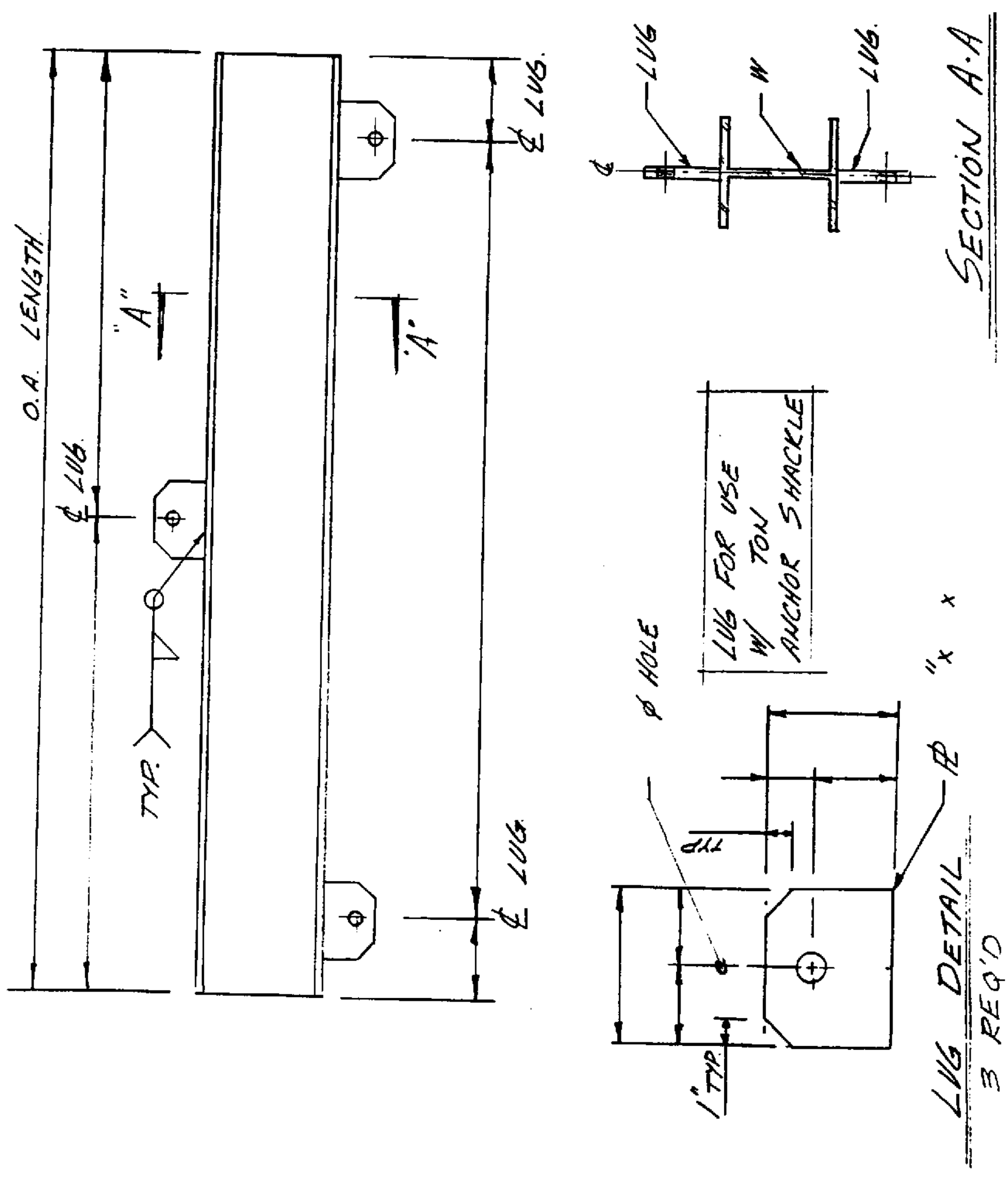
PROCESS SYSTEMS INTERNATIONAL INC.

20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA
(508) 366-9111 / TELEX 92-0331

ENGINEERING DESIGN STANDARDS

MADE BY: ______ CHK'D ______

DATE: ______ APPV'D ______



REVISION:	A	B	C	D	E	F
CHK'D:						
DATE:						

TITLE: SPREADER BAR

SHEET 3 OF 3

PAGE ______ OF ______

SPECIFICATION FOR

PROJECT QUALITY ASSURANCE PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

MANUFACTURING ENGINEER: Phillip Eclund

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D A McWilliams

PROJECT MANAGER: Richard Bayly

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 ALB	DATE 4-24-96	APPROVED REB	DATE 4/24/96	Number A V049-2-029	Rev. 0

TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

Number

Rev.

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.

Number Rev.

4.3 Material Certification

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

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

4.4 In-Process Inspection

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

4.5 Cleaning

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

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

4.6 Welding

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

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

4.7 Final Inspection

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

4.8 Testing

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

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

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

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

4.9 Documentation

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

4.10 Vendor Surveillance

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

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

4.11 Engineering Plan Review

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

4.12 Procurement Specification Review

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

Number

Rev.

Attachment 1
V049-2-029

LIGO VACUUM EQUIPMENT
FINAL DOCUMENTATION SUMMARY

Component — Date:
Model No.: — Prepared By:
Serial No.:

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

<u>Notes</u>:

Title: **PROJECT SAFETY PLAN**

PROJECT SAFETY PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

QUALITY ASSURANCE: Alan L Brodbrook

LIGO SAFETY OFFICER: [illegible]

PROJECT MANAGER: [illegible]

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 NMS 25APR96	APPROVED DATE REB 4/24/96	Number A **V049-2-023**	Rev. 0

TABLE OF CONTENTS

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

ATTACHMENTS

1. PSI Safety Manual

1.0 PURPOSE

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

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

2.0 SCOPE

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

3.0 APPLICABLE DOCUMENTS

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

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

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

c. 49 CFR Department of Transportation (DOT) Transportation

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

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

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

g. Toxic Substances Control Act (TSCA).

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

4.0 PLAN MAINTENANCE

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

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

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

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

6.0 SAFETY OBJECTIVES

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

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

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

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

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

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

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

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

6.2 Organization

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

6.3 Responsibilities

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

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

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

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

7.0 MAINTENANCE OF SAFETY CONTROLS

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

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

8.0 SITE SAFETY PLAN

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

Title: SPECIFICATION FOR VITON VACUUM BAKEOUT

SPECIFICATION FOR VITON VACUUM BAKEOUT

LIGO VACUUM EQUIPMENT

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: S Matur

QUALITY ASSURANCE: ALAN BRADBROOK / RES

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

ϕ	SM 5/4/96	REB 5/4/96	INITIAL RELEASE DEO 0162
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED SM DATE 5/4/96	Approved REB DATE 5/4/96	Number: A V049-2-122	Rev. 0

1.0 PURPOSE

The purpose of this specification is to outline the procedure to be used to vacuum bake Viton O-rings for UHV service.

2.0 GENERAL

This specification will be periodically updated as bakeout parameter data becomes available. Testing will be performed by PSI to develop a bakeout procedure that yields the best properties for Viton O-rings in UHV service,namely,low outgassing and high reliability.

3.0 RESPONSIBILITY

It shall be the responsibility of the project engineer , PSI manufacturing , and QA personell assigned to the Viton bakeout program to ensure that all procedures required by this specification are performed.Data sheets and test results for each lot of Viton that is processed will be signed and archived for future reference.

4.0 VITON BAKEOUT PROCEDURE

1.Prepare the following Viton bakeout system equipment for operation:
- Vacuum chamber
- Vacuum pumps
- Heating system
- Cryotrap and LN2 system
- Instrumentation and controls

2.Load the Viton O-rings into the vacuum chamber using clean room techniques to prevent contamination of the chamber or Viton.*Log lot no.,quanties and sizes.*

3.Close up chamber.

4.Start rough pumping chamber .*Log time and ambient temperature.*

5.Continue rough pumping until pressure reaches $\leq$ 0.1 torr.*Log time,chamber pressure.*

6.Start cryotrap LN2 supply.*Log time, chamber pressure.*

7.Start turbomolecular pump when pressure reaches 0.05 torr. *Log time,chamber pressure*

8.When chamber pressure appears to have leveled off,start heating the chamber.The initial temperature set point is 40.C. *Log time,temp.,heater power, chamber pressure.*

9.The chamber temperature must be slowly ramped up to help achieve uniform heat distribution and sample "soaking".Colder areas of the chamber (typically flanges and thicker sections) may condense vapors.The maximum temperature set point to be achieved is 150 C.The temperature set point should be ramped up at 20 C / hr. *Log time ,set point, temp.,heater power, chamber pressure* hourly and each time the temperature set point is changed.

Caution! Dangerous byproducts may be formed if Viton is heated to a temperature greater than 200C

10.Once the maximum temperature is achieved ,the goal is to maintain this temperature until the pressure decays to an asymptotic minimum. *Log time,set point,temperature,pressure every 2 hrs.*

11.Cooldown requires that the temperature is slowly ramped down at 20.C/hr. avoiding cold spots as before.Pressure may drop during cooldown *.Log time,set point,temperature,pressure every hour.*

12.Cooldown is complete when the chamber temperature is at ambient and the pressure has been stable for 1 hour.*Log* final readings when cooldown is complete.

13.Isolate chamber and shutdown vacuum pumps.

14.Cryotrap remains cold until serviced.

15.Vent chamber with dry air or GN2.

16.Vent vacuum pumps with dry air or GN2.

17.Remove Viton O-rings from the chamber using clean room procedures.Visually inspect , bag and label the O-rings. Prepare a sample for durometer testing.

18.Service cryotrap.

Caution! Contents frozen in cryotrap should be considered hazardous waste and must be handled and treated accordingly.

19.Clean the vacuum chamber in preparation for the next lot.

Caution! Deposits found in the chamber should be considered hazardous waste and must be handled and treated accordingly.

Title: SPECIFICATION FOR VITON VACUUM BAKEOUT

VITON BAKEOUT DATA SHEET

Lot no. ___________ Size ___________ Quan. ___________ Size ___________ Quan. _______ __
Date ___________ Size ___________ Quan. ___________Size ___________ Quan. _______
By ___________ Size ___________ Quan. ___________ Size ___________ Quan. _______

	1	2	3	4	5	6	7
Date/Time							
Pressure							
Temperature							
Set Point							
Htr.Power							
LN2 level							
Turbo Pump							
Rough Pump							

Remarks ____

____

____

SPECIFICATION

Number: **A** V049-2-122 Rev.0

Title: SPECIFICATION FOR COMPONENT SHOP CONDITIONING/TEST PLAN

SPECIFICATION FOR COMPONENT SHOP CONDITIONING / TEST PLAN
FOR LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROCESS ENGINEER R Thew

PROJECT ENGINEER S. Moten

QUALITY ASSURANCE Alan L Bradbook

TECHNICAL DIRECTOR DA McWilliams

PROJECT MANAGER Richard Bayly

Φ	SM 5/3/96	REB 5/3/96	INITIAL RELEASE DEO 0166 FOR FDR
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				**SPECIFICATION**	
INITIAL APPROVALS	PREPARED SM	DATE 5/3/96	Approved REB DATE 5/3/96	Number: **A V049-2-047**	Rev. 0

1.0 PURPOSE

This specification outlines the basic sequence of vacuum equipment conditioning processes and test procedures that will be used during the manufacturing cycle for all vacuum vessels and components.These vessels and components include BSC's ,HAM's,80KCryopumps, Adapters,Spools,and Bellows.

2.0 GENERAL

Reference will be made to specifications covering cleaning,bakeout,leak checking,RGA ,dimensional inspection and shipping.A flow diagram is included as part of this specification.

3.0 RESPONSIBILITY

The procedures referenced in this plan will be performed at PSI upon completion of the fabrication of the component.Fabrication will be done either by PSI or subcontractor.

4.0 PROCEDURE

Reference Attachment "A", Conditioning / Test Plan Flow Diagram.
The following is a description of each step shown on the Flow Diagram;

100-110

Fabrication of the vessel or component is complete.Final dimensions and tolerences have been checked and certified in accordance with PSI specification V049-2-121,latest revision.
The vessel or component is completely assembled and has been steam cleaned during the fabrication cycle.The component is now ready for evacuation and initial leak checking.The purpose of the initial leak check is to find and repair leaks in the welded joints and CF (metal gasket) flanged joints before final cleaning and baking.

110-120-130
Refer to PSI specification V049-2-014,latest revision. for leak checking catagories I,II,III joints.The joint catagories are defined as follows:

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.)

After successful completion of the initial leak check of catagory I,II,III joints,the component is ready for full cleaning.

130-200
Refer to PSI specification V049-2-015,latest revision,for the cleaning procedure.
After full cleaning,the component is reassembled and prepared for final leak checking.

200-220
Refer to PSI specification V049-2-014,latest revision. for final leak checking procedures.Final leak checking includes joint catagories I,II,III,IV,V. After successful completion of the final leak check of catagory I,II,III,IV,V joints,the component is ready for a pre-baked RGA scan.

220-240
Refer to PSI specification V049-2-127,latest revision,for component RGA test procedure.
The purpose of the pre-baked RGA scan is to verify that the component is ready for bakeout and final testing.Any problems identified at this time will be corrected before bakeout is allowed.After the RGA scan is completed, the component is prepared for bakeout.

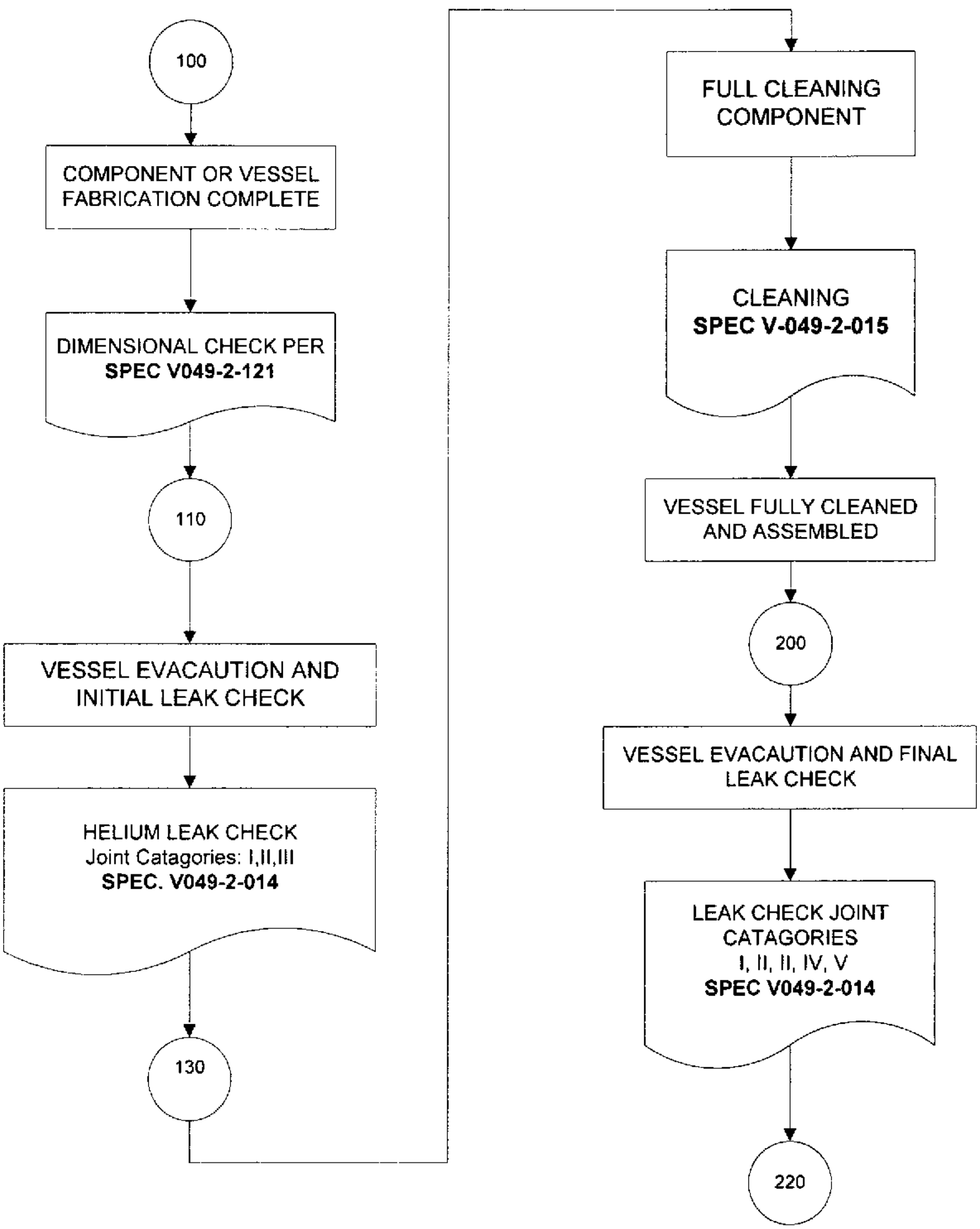
240-250
Refer to PSI specification V049-2-019,latest revision, for bakeout procedure.After bakeout,the component is prepared for final RGA testing.

250-260
Refer to PSI specification V049-2-127,latest revision,for component RGA test procedure.The final RGA test will certify that the component's vacuum performance is acceptable for installation.

260-280
A final test report is prepared and the component documentation package is assembled. The component is prepared for transport to the installation site.Refer to PSI specification V049-2-123,latest revision, for packaging,handling and shipping procedures.

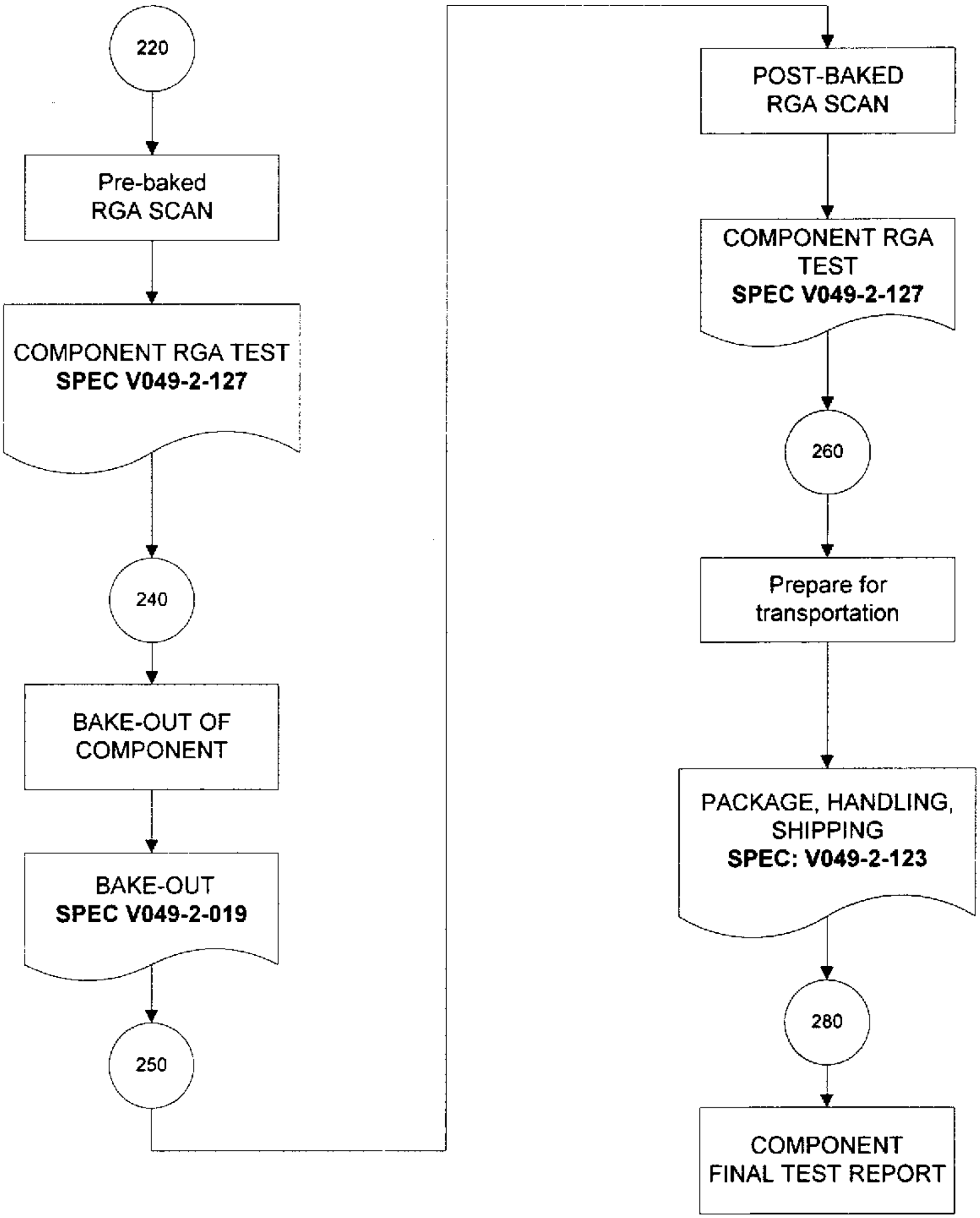
Title: SPECIFICATION FOR COMPONENT SHOP CONDITIONING/TEST PLAN

ATTACHMENT A: CONDITIONING / TEST FLOW DIAGRAM, PAGE -1



SPECIFICATION	
Number: V049-2-047 **A**	Rev.0

ATTACHMENT A: CONDITIONING / TEST FLOW DIAGRAM PAGE-2



Title: CONTAMINATION CONTROL PLAN

CONTAMINATION CONTROL PLAN

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PROJECT ENGINEER: Thomas M. Stan

QUALITY ASSURANCE: ALAN BRADBROOK /RBB

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

0	TMS 5-4-96	REB 5/4/96	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 REB	DATE 5/4/96	Number A V049-2-119 / Rev. 0

TABLE OF CONTENTS

1.0 Purpose
2.0 Responsibilities
3.0 Reference Documents
4.0 General
5.0 Hydrocarbon Control
6.0 Particulate Control

1.0 PURPOSE

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

2.0 RESPONSIBILITIES

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

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

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

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

3.0 REFERENCE DOCUMENTS

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

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

4.0 GENERAL

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

5.0 HYDROCARBON CONTROL

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

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

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

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

6.0 PARTICULATE CONTROL

6.1 Material Protection

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

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

6.1.2 Materials shall not be stored in direct contact with materials of different composition, but shall be separated by means such as wooden spacers or paper sheeting.

6.1.3 Stored materials (raw materials or work in process) shall be protected from the shop atmosphere when not being handled (or worked on) by plastic sheets or similar protective covers.

6.1.4 During transportation, components shall be shrink wrapped in plastic and shipped in closed trucks or under tight fitting tarpaulins.

6.1.5 Finished components shall be shipped to the sites under vacuum.

5.2 Cleanrooms

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

5.2.1 During Assembly

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

5.2.2 During Installation

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

Title: SPECIFICATION FOR MATERIAL CONTROL

SPECIFICATION FOR

MATERIAL CONTROL

PREPARED BY: ALAN BRADBROOK

PROJECT ENGINEER: N/A

QUALITY ASSURANCE: Alan R Bradbrook

MANUFACTURING ENGR: Phillip Farland

TECHNICAL DIRECTOR: D. A. [illegible]

PROJECT MANAGER: [illegible signature]

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

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED A Bradbrook	DATE 5/1/96	APPROVED REB	DATE 5/1/96	Number A V049-2-125	Rev. Ø

Title

SPECIFICATION FOR MATERIAL CONTROL

TABLE OF CONTENTS

1.0 Scope

2.0 General Procedure

2.1 Procurement

2.2 Receiving Inspection

2.3 Material Identification

Exhibit 1 Dock Receipt

Exhibit 2 Purchase Order

Exhibit 3 Tag

Number

Rev.

1.0 SCOPE

This specification covers the minimum requirements for the control of LIGO materials at PSI. The purpose of this specification is to define the method employed by PSI to purchase materials, receipt inspect materials and items and to identify and control materials and items during manufacturing.

2.0 GENERAL PROCEDURE

2.1 Procurement

2.1.1 Materials are purchased to either ASTM or ASME material specification.

2.1.2 Materials listed on the Bill of Material are reviewed during the final drawing review. The Bill of Material is then entered and electronically released to Purchasing through MRP II (EMS) computer system. The requirements for material test reports (MTR's) are included in the material description and the material part number assigned to each part on the Bill of Material.

2.1.3 Once the Bill of Material is entered into the MRP II (EMS) computer system, the system sets up a demand for the Buyer to procure the materials or items.

2.1.4 Materials specified on the Bill of Materials and/or on the Purchase Order cannot be substituted without prior approval of the Design Engineer. The Design Engineer is responsible for reviewing the Design Calculations, reconcile the substitution of material and revise the calculations as necessary.

2.2 Receiving Inspection

2.2.1 LIGO material requires special handling to prevent material contamintion. See PSI V049-2-120 "Raw Material Handling Procedure" and V049-2-119 "Contamination Control Plan".

The shipper/receiver off-loads the material, inspects the packaging for damage, verifies the shipment against the packing slip, prints a Dock Report (Exhibit I) from the MRP II (EMS) computer system and forwards the dock receipt and the material or time to Quality Control Receiving Inspections.

2.2.3 The Receiving Inspector verifies the identification markings on the material, size, thickness, evidence of damage and conformance of the Material Test Reports to the applicable material specification.

2.2.4 Material that is found to be discrepant shall be processed in accordance with the Control of Nonconformance procedure.

2.2.5 When material test reports are required on the purchase order, a Material Identification Code (MIC) number. The receiving inspector shall assign a MIC No. to each lot of material and mark each piece of material with the assigned MIC NO., PO No., Job No., and the Part No.

2.2.6 When the material or item has been accepted, the Receiving Inspector will attach a green tag (Exhibit 3) and forward the material or item to the stockroom with the dock receipt.

2.3 Material Identification

2.3.1 It is the responsibility of the Stockroom Attendant to assure that only the intended material purchased for a specific order be released to the shop operation department and that all the required materials are properly marked prior to release.

2.3.2 Material such as plate, pipe or bar issued to the shop operation department that has to be subdivided by cutting, sawing or shearing shall be appropriate marked with MIC No., Job No., and the assembly No. or Spool No. All material shall be identified prior to subdividing or cutting to maintain traceability (when traceability is required).

2.3.3 Vibro-etching on the external surface is the only acceptable marking means. No marking is allowed on the interior surfaces or on flange vacuum surfaces.

2.3.4 It material is found to be suspect or traceability of material is lost, further material testing shall be required to be performed. A sample of the suspect material shall be sent to an outside lab to verify complete compliance to the material specification. The results of the testing willbe verified through Receiving Inspection.

Purchasing - Receipts PO#: 553647-00 Type:N Sts:P

Vendor: 40648 Buy-From: 40648
STAINLESS PIPE & FITTINGS
128 YORK AVE.
RANDOLPH, MA 02368

Ship to location:01
PROCESS SYSTEMS INTERNATIONAL
20 WALKUP DRIVE
WESTBORO, MA 01581-5003

Buyer: 03
Terms: 1
Col/Ppd: C
Chg/Cnc: N

ATTN: BARRY

Line: 003 Item:C222240-01 1 Vendor Item: Comm:M6
FLANGE,SST F304L,SA182 CMTR, BLIND ,1" 150#, RF
Job#:N00581 Qty Ord: 2 EA Received to date: 0
Notify: PUR Request: 05/30/1995 Rejected: 0
Move to:STK Promise: 05/30/1995 Due: 2

1. Qty Received: 2 UM:EA
2. Qty Rejected: 0
3. User Comment:
4. Received By: CEW
5. Receipt Date: 05/30/1995
6. Receiver:

Field to change __

EXHIBIT 1

PURCHASE ORDER

PROCESS SYSTEMS INTERNATIONAL, INC.

20 Walkup Drive • Westborough, Massachusetts 01581-5003

508 / 366-9111 • Fax 508 / 870-5930

P/O NUMBER	PAGE
553037-00	01

P/O DATE	CHANGE/CANCEL
02/17/1995	

(Ship to the above address unless specified below.)

ORDERED FROM
TIERNEY DALTON
43 HOPKINTON ROAD
WESTBORO, MA 01581
ATTN: STEVE

SHIP TO
PROCESS SYSTEMS INTERNATIONAL
20 WALKUP DRIVE
WESTBORO, MA 01581-5003

ORDER TYPE	BUYER	ACKNOWLEDGE	CONFIRM	TERMS	F.O.B.	SHIP VIA	COL
NORMAL	LARRY MAURIELLO	YES	YES	NET 30	SHIPPING	BEST WAY	CO

LINE NUMBER	QUANTITY ORDERED / BLANKET TYPE	U/M	OUR ITEM NUMBER DESCRIPTION/NOTES	YOUR ITEM NUMBER	PRICE/UNIT	REQUESTED DATE	CHAN CANC
001	1	EA	C025111-D ELBOW,STL,A105,90 LR , 0.500" 3000# THD. JOB NUMBER: T55100		2.780	02/24/1995	
002	C.W 2-24-95 1	EA	C085102-06 1 FLANGE,STL,SA105 CMTR WN , 6" 150#, RF SCH 40 MATERIAL MANUFACTURER'S CERTIFIED MILL TEST REPORT TO APPLICABLE ASME II SPECIFICATIONS ARE REQUIRED AND MUST ACCOMPANY SHIPMENT. IDENTIFY MATERIAL WITH TYPE, GRADE AND HEAT NUMBERS. JOB NUMBER: N00581	HT-EKW	26.250	02/24/1995	
003	1	EA	C025109-F ELBOW,STL,A105,90 LR , 0.750" 3000# SW, JOB NUMBER: N00581		3.060	02/24/1995	
004	2	EA	C045109-F TEE,STL,A105,STR , 0.750" 3000# SW, JOB NUMBER: N00581		4.280	02/24/1995	
005	2	EA	C145119-01 COUPLING,STL,A105,STR FULL , 1" 3000# SW		2.110	02/24/1995	

EXHIBIT 2

INSTRUCTIONS TO VENDORS:
PARTIAL SHIPMENTS ARE ACCEPTABLE UNLESS OTHERWISE INDICATED.
A COPY OF THE BILL OF LADING AND THE PACKING LIST MUST BE SENT TO PROCESS SYSTEMS INTERNATIONAL, INC.

INVOICE TO: ACCOUNTS PAYABLE
PROCESS SYSTEMS INTERNATIONAL, INC.
20 WALKUP DRIVE
WESTBOROUGH, MASSACHUSETTS 01581-5003

MASS. SALES TAX: EXEMPT # 043126695

THIS PURCHASE ORDER IS BUYER'S OFFER TO SELLER AND ACCEPTANCE IS EXPRESSLY LIMITED TO ITS TERMS CONDITIONS AS SET FORTH ON THIS AND THE REVERSE SIDE HEREOF AND TO THE GENERAL AND SUPPLEMENT TERMS, CONDITIONS AND PROVISIONS, IF ANY, ATTACHED HERETO OR INCORPORATED BY REFERENCE, ALL OF W ARE MADE A PART OF THIS OFFER.

ORDERED BY ____

PO 553037 JOB V59049-
PN C02S111-D HT# EKW
SIZE 1/2" SCH 3000#
SA 105 GR —

COLOR GREEN

CMTR ☒
C of C ☐

EXHIBIT 3

Title: SPECIFICATION FOR COMPONENT RGA TEST PROCEDURE

PROCEDURE FOR COMPONENT RGA TEST

LIGO VACUUM EQUIPMENT

Hanford, Washington and Livingston, Louisiana

JOB NO. V59049

PREPARED BY: Roberto Than

QUALITY ASSURANCE: ALAN BRADBROOK /REB

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

		REB 5/4/96	INITIAL RELEASE PER DEO 166
REV LTR	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.			SPECIFICATION	
INITIAL APPROVALS	PREPARED DATE	Approved DATE REB 5/4/96	Number: V049-2-127 A	Rev.0

1.0 PURPOSE

The purpose of this procedure is to define the steps necessary to carry out an RGA scan on a vacuum vessel.

2.0 GENERAL

This procedure is generally applicable for any RGA, but specific reference will made to the Balzers Quadstar software for the PRISMA RGA.

3.0 REFERENCE DOCUMENTS

Balzers QUADSTAR 421 SOFTWARE MANUAL.

4.0 RESPONSIBILITY

The procedure is applicable to PSI Personnel.

5.0 RGA CONDITION

5.1 Bake out

For measurements on a clean chamber the RGA must be baked before use on the clean chamber. For the Balzers PRISMA RGA, the detector head can be baked to 200°C with the electronics package removed.
Requirements for bakeout is that warmup shall not occurs until the pressure is below 10^{-4} Torr to prevent bakeon of contaminants

6.0 Readings

Readings can be taken once the Vacuum vessel has cooled to ambient and the pressure is below 10^{-6} Torr.

6.1 Setup

Connect the RGA electronics package to the RGA detector head and the communications cable to the computer.

Data acquisition
Data will be taken by three methods: A complete 1-200 AMU Scan in SCAN mode. An ion current scan in the Multiple Ion Detection (MID) mode using all available channels. And a concentration scan using the Quantitative Analysis Module: Multiple Concentration Detection (MCD) mode to get partial pressures from solving the raw data with known cracking patterns. The scans shall be made with the Faraday cup only and another set of scan shall be made with the Electron Multiplier on.

Summary of the reading sequence

FARADAY CUP ONLY
Perform offset calibration
Perform Full AMU scan in SCAN and save data.
Perform Ion current scan in MID mode and save to file
Perform Concentration scan in MCD mode and save to file

Switch on Electron Multiplier

WITH EM ON
Perform offset calibration
Perform Full AMU scan in SCAN and save data.
Perform Ion current scan in MID mode and save to file
Perform Concentration scan in MCD mode and save to file

Dwell Time should be set to slow: 60 ms.

6.2 FARADAY CUP ONLY

Perform offset calibration. Follow instruction in the Manual for performing a offset calibration. This is recommended if the dwell time is changed or when switching between the Faraday cup and Channeltron.

6.2.1 SCAN

Perform a full range AMU scan to record intensities over the AMU range.
To check for hydrocarbons, the data shall be taken over the range from 1 to 200 AMU.
Take data for 10 cycles.

6.2.2 MID

Perform Ion current scan in MID mode and save to file
Follow instruction in the Manual for performing a MID scan
This gives the ion current intensities,same as the SCAN, for selected AMU's
Take data for 10 cycles.

6.2.3 MCD

Perform Concentration scan in MCD mode and save to file
Follow instruction in the Manual for performing a MCD scan
Take data for 10 cycles.
This will give concentration of the selected gasses by solving the raw data by matrix inversion using the spectra library of the RGA.

Gas species selection for Multiple Concentration Detection mode (MCD)

GAS SPECIES	
H2	N2
He	NO
CH4	O2
H2O	AR
NE	CO2
CO	CnHm

6.3 WITH ELECTRON MULTIPLIER ON

Switch on Electron Multiplier
Perform offset calibration. Follow instruction in the Manual for performing a offset calibration. This is recommended if the dwell time is changed or when switching between the Faraday cup and Channeltron. It is recommended to use the same SEM voltage for all readings. This can be set during the parameter setup process.

6.3.1 SCAN

Perform a full range AMU scan to record intensities over the AMU range.
To check for hydrocarbons, the data shall be taken over the range from 1 to 200 AMU.

6.3.2 MID

Perform Ion current scan in MID mode and save to file
Follow instruction in the Manual for performing a MID scan
This gives the ion current intensities,same as the SCAN, for selected AMU's

6.3.3 MCD

Perform Concentration scan in MCD mode and save to file
Follow instruction in the Manual for performing a MCD scan
This will give concentration of the selected gasses by solving the raw data by matrix inversion using the spectra library of the RGA.

Perform offset calibration
Perform Full AMU scan in SCAN and save data.
Perform Ion current scan in MID mode and save to file
Perform Concentration scan in MCD mode and save to file

Dwell Time should be set to slow: 60 ms.

6.5 Leak Detection by air signature method.

Finding a leak by an air signature method may be more difficult because of the presence of o-ring. The outgassing and permeation of the o-rings may be dominated by the same gas species found in air. For very small leaks in a large vessel with o-rings this may not be practical. Outgassing from o-ring after baking is expected to be dominated by H_2O, CO and CO_2.

Tests using a calibrated air leaks at 10^{-7} Torr-L/s, 10^{-8} Torr-L/s, 10^{-9} Torr-L/s will be performed on the BSC prototype to determine feasability of this method for a chamber with many o-ring joints.

6.6 Cleaniless and hydrocarbon contamination

Fore a scan after bake-out:
Inspect the full analog scan obtained in the SCAN mode for hydrocarbon contamination.
This is represented by ion current intensities throughtout the spectrum up to 200AMU.
For a well cleaned and well baked system the intensities above mass 44 should be very low.

Criteria for cleaniless

RGA intensities values or partial pressures for determining acceptable cleaniless

SPECIES	Partial Pressure	CRITERIA
	Torr	
H2		
He		
CH4		
NE		
H2O		
CO		
N2		
NO		
O2		
AR		
CO2		
CnHm		TBD
TOTAL		

6.7 Conversion

Ion current to mass species partial pressure

Very Rough conversion

An approximate partial pressure can be obtained by knowing the instrument sensitivity and by apply the following formula.

$$PP_{gas} = \frac{I}{SF}$$

where PP_{gas}: Partial pressure of gas
I: Ion current in Amperes
SF: Sensitivity factor instrument

The Balzers sensitivity is factory determined using Argon and a certificate is supplied with the unit Without the Faraday cup operating only, the sensitivity is for example $6X10^{-4}$ A/mbar. and with the Electron Multiplier operating it is for example 2.1A/mbar at a SEM Voltage of 1300 V.

More Accurate Conversion

$$PP_a = I_b \bullet \frac{FF_{N28}}{S} \bullet FF_{ab} \bullet XF \bullet TF \bullet DF$$

where
PP_b: partial pressure of a given molecular species

FF_{N28} : Fragmentation factor for N2+ ions from nitrogen

S: Sensitvity for nitrogen (unit current /unit pressure) A/mbar

TF: transmission factor relative to N2 Typically TF=28/M

DF: Detection factor Relative current per ion at mass b compared to current at mass N2
Typically DF=1

FF_{N28} / S , the basic instrument sensitvity is typically independent of gas species.

thus a basic instrument sensitivity can be used: SI

For this example RGA from the Factory test sheet the SI (Faraday cup) =1666 mbar/A
and SI (with EM) = 0.476 mbar/A

The conversion of to partial pressure with these formulas is only useful if the components in the vacuum chamber do not have many overlaps e.g when there is a lot of hydrocarbon present.

In order to get a more accurate composition the raw data is transformed into partial pressures for each mass species and using the spectra library of the desired gasses for that RGA a solution is found for composition of each gas. In the Balzers software, the solution of the matrix is done using the technique by *Givens,* which allows for super-determinate matrices (A least square fit is employed to find the best solution).

Since the sensitvity for each mass species differs between RGAs, as a results the cracking pattern for a gas will differ from the actual cracking pattern. The pattern as measured by the RGA is stored as a spectra library.

RGA DATA POST BAKE

RESULTS OF THE RGA TEST	
RGA TEST :	
DATE:	
TIME:	
TESTI.D.:	
PSI TEST ENGINEER:	
QUALITY ASSURANCE:	

SPECIES	MEASURED ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		
etc to 200		

RGA DATA POST BAKE

RESULTS OF THE RGA TEST	
RGA TEST :	POST BAKE
LOCATION OF RGA	
COMPONENT NAME:	
COMPONENT SERIAL #:	
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
QUALITY ASSURANCE:	

SPECIES	Partial Pressure	ACCEPTANCE
	Torr	
H2		
He		
CH4		
NE		
H2O		
CO		
N2		
NO		
O2		
AR		
CO2		
CnHm		
TOTAL		

	ENGINEER NAME & TITLE	SIGNATURE
	TEST ENGINEER	
	QUALITY ASSURANCE	

RGA DATA PRE BAKE

RESULTS OF THE RGA TEST	
RGA TEST :	
DATE:	
TIME:	
TESTI.D.:	
PSI TEST ENGINEER:	
QUALITY ASSURANCE:	

SPECIES	MEASURED ION CURRENT	Partial Pressure
	A	Torr
2		
4		
12		
13		
14		
15		
16		
17		
18		
19		
20		
21		
22		
24		
25		
26		
27		
28		
29		
30		
31		
32		
etc to 200		

Title: SPECIFICATION FOR COMPONENT RGA TEST PROCEDURE

RGA DATA PRE BAKE

RESULTS OF THE RGA TEST	
RGA TEST :	PRE BAKE
LOCATION OF RGA	
COMPONENT NAME:	
COMPONENT SERIAL #:	
DATE:	
TIME:	
TEST I.D.:	
PSI TEST ENGINEER:	
QUALITY ASSURANCE:	

SPECIES	Partial Pressure	ACCEPTANCE
	Torr	
H2		
He		
CH4		
NE		
H2O		
CO		
N2		
NO		
O2		
AR		
CO2		
CnHm		
TOTAL		

	ENGINEER NAME & TITLE	SIGNATURE
	TEST ENGINEER	
	QUALITY ASSURANCE	

SPECIFICATION

Number: V049-2-127 A	Rev.0

APPENDIX A

TABLES

TESTSHEET

balzers

Prisma

QUADRUPOL MASS-SPEKTROMETER

Order No. 409190

QMS 200	BK M25	002	I
QME 200	BG D28	501	1.062528 V008
QMA 200	BK M25	252	1.074762 V015
SP 200	B 5181 408 K		I

P_{Argon}: 5·10⁻⁷ mbar

Sensitivity for Argon without SEM .... $6 \cdot 10^{-4} \frac{A}{mbar}$

Sensitivity for Argon with SEM by HV 1300 .... $2{,}1 \frac{A}{mbar}$

Resolution Cal.

M 84 $\frac{M}{\Delta M}$ = 84

Balzers 14.7.95 BEHA

Table 16:
Fragmentation Factor (Fraction of Total Ions) For Major Peaks of Selected Materials

MASS	FF	MASS	FF	MASS	FF
Acetone $(CH_3)_2CO$		Helium He		Oxygen O_2	
43	.63	4	1.00	32	.95
58	.23			16	.05
42	.04	Hydrogen H_2			
27	.03	2	.98	Toluene $C_6H_5CH_3$	
		1	.02	91	.46
Argon Ar				92	.34
40	.88	Krypton Kr		39	.07
20	.12	84	.57	65	.05
		86	.18		
Benzene C_6H_6		82	.11	Trichlorethylene C_2HCl_3	
78	.53	83	.11	95	.22
51	.11			130	.22
52	.11	Methane CH_4		132	.21
50	.10	16	.46	97	.14
		15	.40	60	.13
Carbon Dioxide CO_2		14	.07		
44	.85	13	.04	Water H_2O	
28	.05			18	.75
16	.05	Methanol CH_3OH		17	.19
12	.02	31	.43	1	.05
		32	.31	16	.02
Carbon Monoxide CO		29	.18		
28	.91	28	.04	Xenon Xe	
12	.05			132	.26
16	.02	Neon Ne		129	.25
		20	.90	131	.20
Ethanol C_2H_5OH		22	.10	134	.10
31	.49			136	.08
45	.21	Nitrogen N_2			
27	.09	28	.94		
29	.07	14	.05		
		29	.01		

FF = fraction of total ions that occur at the indicated mass

N.B. This table should not be confused with a spectrum library. The spectra displayed by an instrument are influenced by the mass discrimination of the quadrupole filter. Typically ions of low mass will be emphasized and ions of high mass will be diminished, relative to the abundances given in Table 16. A spectrum library lists the relative abundances as the instrument shows them.

Table 17:
Ionization Probability Table

Substance	Formula	Relative Ionization Gauge Sensitivity, S/S_{n}
Acetone	$(CH_3)_2CO$	3.6
Air		1.0
Ammonia	NH_3	1.3
Argon	Ar	1.2
Benzene	C_6H_6	5.9
Benzoic acid	C_6H_5COOH	5.5
Bromine	BR	3.8
Butane	C_4H_{10}	4.9
Carbon dioxide	CO_2	1.4
Carbon disulfide	CS_2	4.8
Carbon monoxide	CO	1.05
Carbon tetrachloride	CCl_4	6.0
Chlorobenzene	C_6H_5Cl	7.0
Chloroethane	C_2H_5Cl	4.0
Chloroform	$CHCl_3$	4.8
Chloromethane	CH_3Cl	3.1
Cyclohexane	C_6H_{12}	6.4
Deuterium	D_2	0.35
Dichlorodifluoromethane	CCl_2F_2	2.7
Dichloromethane	CH_2Cl_2	3.7
Dinitrobenzene	$C_6H_4(N_2O_4)$	7.8
Ethane	C_2H_6	2.6
Ethanol	C_2H_5OH	3.6
Ethylene oxide	$(CH_2)_2O$	2.5
Helium	He	0.14
Hexane	C_6H_{14}	6.6
Hydrogen	H_2	0.44

Substance	Formula	Relative Ionization Gauge Sensitivity, S/S_{n}
Hydrogen chloride	HCl	1.6
Hydrogen floride	HF	1.4
Hydrogen iodide	HI	3.1
Hydrogen sulfide	H_2S	2.2
Iodine	I_2	
Krypton	Kr	1.7
Lithium	Li	1.9
Methane	CH_4	1.6
Methanol	CH_3OH	1.8
Neon	Ne	0.23
Nitrogen	N_2	1.0
Nitric oxide	NO	1.2
Nitrous oxide	N_2O	1.7
Oxygen	O_2	1.0
n-Penthane	C_5H_{17}	6.0
Phenol	C_6H_5OH	6.2
Phosphine	PH_3	2.6
Propane	C_3H_8	3.7
Silver perchlorate	$AgClO_4$	3.6
Stannic iodide	SnI_4	6.7
Sulfur dioxide	SO_2	2.1
Sulfur hexafloride	SF_6	2.3
Toulene	$C_6H_5CH_3$	6.8
Trimitrobenzene	$C_6H_3(NO_2)_3$	9.0
Water	H_2O	1.0
Xenon	Xe	3.0
Xylene	$C_6H_4(CH_3)_2$	7.8

Scanning Characteristics—Constant M versus Constant Transmission

Table 18:
Spectra Interpretation Guide

F = Fragment
P = Parent Ion
DI = Doubly Ionized

AMU NO.	CHEMICAL SYMBOL	SOURCES	
1	H	Water F or Hydrogen F	
2	H_2, D	Hydrogen, Deuterium (H^2)	
3	HD, H^3	Hydrogen-Deuterium, Tritium (H^3)	
4	He	Helium	
5		No known elements	
6	C^{++}	Doubly Ionized C^{12}	Rare
7	N^{++}	DI N^{14}	Rare
8	O^{++}	DI O^{16}	Rare
9		No known elements	
10	Ne^{++}	DI Ne^{20}	Rare
11	Ne^{++}	DI Ne^{22}	Rare
12	C	Carbon, Carbon Monoxide F, Carbon Dioxide F	
13	CH, C^{13}	Methane F, Carbon Isotope	
14	N, CH_2	Nitrogen, Methane F or Note 1	
15	CH_3	Methane F or Note 1	
16	O, CH_4, NH_2	Oxygen or Carbon Monoxide F, Methane P, Ammonia F	
17	OH, NH_3	Water F, Ammonia P	
18	H_2O	Water P	
19	F	Fluorine or Freon F	
20	Ar^{++}, Ne, HF	DI Argon, Neon Hydrofluoric acid	
21			
22	Ne^{22}	Neon isotope	
23		See Note 1	
24	C_2	See Note 1	
25	C_2H	See Note 1. Hydrogen Cyanide F	
26	C_2H_2CN	See Note 1. Aluminum, Hydrogen Cyanide	
27	C_2H_3, Al, HCN	Nitrogen, Carbon Monoxide, Ethylene P, Silicon	
28	N_2, CO, C_2H_4, Si	Ethane F or Ethanol F or Isopropyl alcohol F	
29	CH_3CH_2	Ethane P, Nitric Oxide	
30	C_2H_6, NO	Phosphorus, Methanol F, Ethanol F, Freon F	
31	P, CH_2OH, CF	Oxygen, Methanol P, Sulfur	
32	O_2, CH_3OH, S	Hydrogen Sulfide F	
33	HS	Hydrogen Sulfide P, Sulfur isotope	
34	*H_2S, S^{34}	Chlorine isotope. See Note 2	
35	*Cl	Hydrochloric acid, Argon isotope	
36	*HCl, Ar^{36}	Chlorine isotope. See Note 2	
37	*Cl^{37}	Hydrochloric acid or See Note 2	
38	HCl^{37}	See Note 3	
39	C_3H_3	Argon. See Note 1	
40	Ar, C_3H_4	See Note 1	
41	C_3H_5	See Note 1	
42	C_3H_6	Note 1. Acetone F or Methyl Ethyl Ketone F	
43	C_3H_7, CH_3CO	Carbon dioxide. See Note 3	
44	CO_2, C_3H_8	Ethanol F or Isopropyl alcohol F	
45	CH_3CH_2O	Ethanol P	
46	CH_3CH_2OH	See Note 2	
47	CCl^{35}	See Note 2, Sulfur Dioxide F	
48	$HCCL^{35}$, SO	See Note 2, pump oil F	
49	CCl^{37}, SiOH	See Note 2, Freon F, Note 3	
50	CCl^{37}, CF_2, C_4H_2		

NOTE 1
Fragments of several hydrocarbons, such as mechanical pump oil, diffusion pump oil, vacuum grease, cutting oil, and organic solvents.

NOTE 2
Fragments of several chlorinated hydrocarbons, such as carbon tetrachloride, trichloroethylene and many Freons.

NOTE 3
Fragments for both straight chain hydrocarbons and benzene ring hydrocarbons.

*See Isotopic Ratio Chart in Table 19.

Title: LIGO VISUAL INSPECTION PROCEDURE

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 Fitzford

TECHNICAL DIRECTOR: D.O. McWilliams

PROJECT MANAGER: Rudolf Bayly

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
Ø	ALB 5/3/96		ISSUED PER DEO 0168 FOR PDR

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED: ALBradbrook	DATE: 5/3/96	APPROVED: RGB DATE: 5/3/96	Number A V049-2-128	Rev. Ø

TABLE OF CONTENTS

1.0 Scope

2.0 General Procedure

2.1 Control of Documents, Codes and Standards

2.2 Technical Requirements

2.3 Examination Requirements

2.4 Acceptance Standards

1.0 SCOPE

This document contains the methods and acceptance criteria for visual inspection for the LIGO project.

2.0 GENERAL PROCEDURE

2.1 Control of Documents, Codes and Standards

2.1.1 The Quality Plan, the fabrication drawings and other procedures specify the required visual inspection and physical dimensions. It is not the intent of this procedure to duplicate those requirements. It is however, the intent of this procedure to provide a consistent method of performing visual inspection.

2.2 Technical Requirements

2.2.1 Illumination - lighting, natural or artificial shall be sufficient to illuminate the area being examined.

2.2.2 Personnel - Personnel performing visual examination shall be familiar with the welding technique being used, welding procedure requirements, machining operations, liquid penetrant testing, and the type of discontinuities that may occur in the weld or base material being examined.

2.2.3 Direct visual examination shall be used when access is sufficient to place the eye within 24 inches of the surface to be examined and at an angle not less than 30 degrees to the surface to be examined. Mirrors may be used to improve the angle of vision, and aids such as a magnifying lens may be used to assist examinations.

NOTE: Unless impossible, direct visual examinations will be used for all visual examinations performed to this procedure.

In some cases, remote visual examinations may have to be substituted for direct examination. Remote visual examinations may use visual aids such as mirrors, borescopes, cameras, or other suitable instruments.

2.3 Examination Requirements

2.3.1 Visual Examination of Welding

A. Equipment

1. Artificial Light Source
2. Mirrors
3. Magnifiers
4. Straight Edges or Rules
5. Weld Gages

B. Visual Inspection and Identification of Base Material and Joint Preparation as follows:

1. Base material type compatible with the detailed weld procedure.

2. Weld being made in accordance with drawing.

3. Weld preparation and adjacent base material clean free of paint, scale, rust, oil, grease and any other foreign material that would be deleterious to the process.

4. Weld preparation has fairly smooth surfaces free from deep notches, grooves, nicks, and other gross irregularities.

5. Weld preparation free from base material defects such as laminations, laps, non metallic inclusions, pin holes, porosity, that are open to the surface.

C. Visual Inspection of Weld Preparation Geometry as follows:

1. Alignment of parts to be welded.

2. Size of root face (land) and root gap.

3. Groove angle.

4. I.D. mismatch of Butt Joints.

D. Visual Inspection of Tack Welds as follows:

1. Tack welds are properly prepared to be incorporated into the weld or completely removed. When left in place, each end should be feathered.

2. Examine tacks for discontinuities.

3. Check for cleanliness.

E. Visual Inspection of Intermediate Weld Passes as follows:

1. Cleanliness

2. Weld spatter

3. ARC strikes

4. Slag

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

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

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

1. Surface Finish
2. Discontinuities
3. Cleanliness

2.4 Acceptance Standards

2.4.1 Cleanliness

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

Prior To Welding

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

After Welding

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

2.4.2 Tack Welds

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

2.4.3 Final Weld Condition

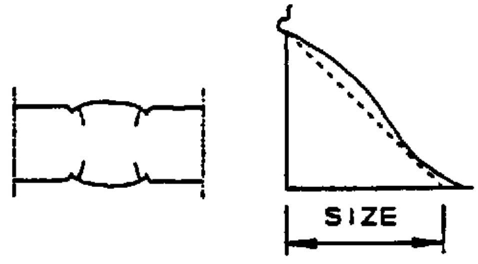
A. As welded, as-cast or as-forged surfaces are permitted, provided the surface of welds are sufficiently free form coarse ripples, overlaps and abrupt ridges and valleys.

B. Cracks or other linear indications are unacceptable.

C. Porosity open to the surface is unacceptable.

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

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



EXCESSIVE UNDERCUT

F. Concavity on the root side of a single side welded circumferential butt weld is permitted when the resulting thickness of the weld is at least equal to the thickness of the thinner member of the two (2) sections being joined and the contour of the concavity is smooth.

G. Offset of final butt welded joints shall not be greater than the following:

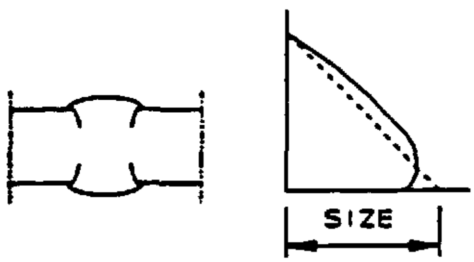
Nominal Wall Section Thickness. in. (mm)	Maximum Offset, in. (mm) All LIGO Project Joints
0.060" Thru 0.500"	1/4t

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

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

2.4.4 Examples Of Conditions That Are Unacceptable.

OVERLAP
Welds shall be free from overlap.



OVERLAP

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

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

SLAG INCLUSIONS

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

INCOMPLETE FUSION

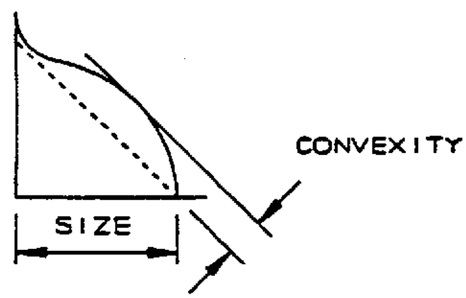
Acceptability requirements are the same as those for slag inclusions.

MISALIGNMENT AND WARPING

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

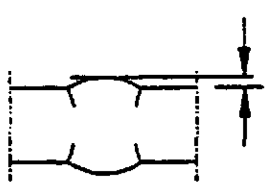
CONVEXITY FILLET

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



CONVEXITY, GROOVE WELDS

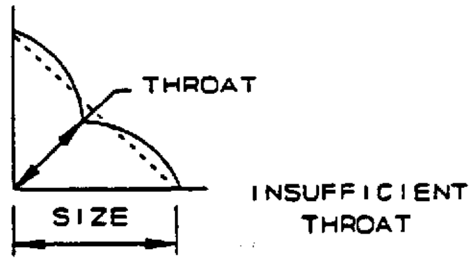
Reinforcement to be 1/8" max, and shall have a gradual transition to the plane of the base metal surface when the thinner base metal is less than 1/2" thick.



REINFORCEMENT

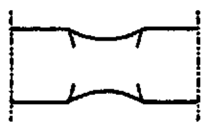
INSUFFICIENT THROAT, *FILLETS*

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



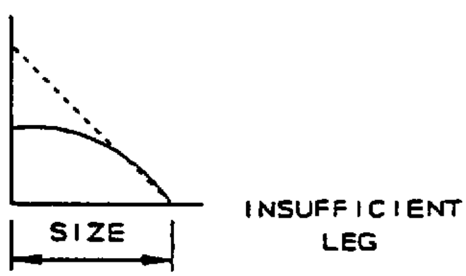
INSUFFICIENT THROAT, GROOVE WELDS

The weld shall be slightly convex.



INSUFFICIENT 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.



SPECIFICATION FOR

BLACK LIGHT INSPECTION PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

QUALITY ASSURANCE: ALAN BRADBROOK/REB

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bayly

0	TMS 5-5-96	REB 5/5/96	INITIAL RELEASE PER DEO # 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 REB	DATE 5/5/96	Number V049-2-130	Rev. 0

SPECIFICATION TABLE OF CONTENTS

1.0 Purpose

2.0 General

3.0 Responsibilities

4.0 Procedure

5.0 Required Documentation

1.0 PURPOSE

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

2.0 GENERAL

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

2.2 Inspection shall be done in a darkened area.

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

3.0 RESPONSIBILITIES

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

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

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.