CALIFORNIA INSTITUTE OF TECHNOLOGY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

LIGO PROJECT

FINAL DESIGN REVIEW DATA PACKAGE BEAM TUBE MODULE DESIGN & QUALIFICATION TEST

CONTRACT C146

CDRL #15
DRD #9 ITEM I
MASTER DATA LISTING

CDRL #9
DRD #4
DRAFT DETAILED DESIGN

BOOK 1 OF 2

Prepared by

CBI TECHNICAL SERVICES COMPANY
PLAINFIELD, ILLINOIS

APRIL 11, 1994

CBI CONTRACT 930212

	LIGO PROJECT for CALTECH			KHF			
	Master Procedure Listing			4/8/94			
	CALTECH CONTRACT C-146, CBI CONTRACT 930212						
Document I.D.	**DESCRIPTION**	**Current Rev.**	**Proc By**	**Date**	**Status**	**Application** Qual. Test	**Application** Construction
BOOK 1 SECTION 1							
General - Plans & Manuals							
LIGPSM	Project Safety Manual	0	GLW		OK BY CALTECH		X
QAM	Quality Assurance Manual (See QAP Listings for Individual Procedures)	0	RAJ		OK BY CALTECH		X
LIGOTP	Planned Approach to Leak Testing for LIGO Project	1	CNS	6-Apr-94		X	X
LIGOCP	Planned Approach to Cleaning	0	CNS	2-Nov-93			X
	Procurement Plan for Design & Qualification Test	draft		22-Oct-93		X	
QAP	Quality Assurance Plan for Design & Qualification Test	0(draft)	PM	4-Feb-94		X	
MI	Material Traceability	0	PM	4-Apr-94		X	X
	Environmental Plan						
	Affirmative Action Program						
BOOK 1 SECTION 2							
Material Specifications							
C-240-0186	Coil Material Specification	0	SWP	3-Mar-94		X	X
C-CMBS1	Coil Material Bake Specification	0	SWP	21-Feb-94		X	X
C-240-0187	Baffle Material Specification	1	WJC	23-Mar-94		X	X
C-BMBS1	Baffle Material Bake Specification	0	WJC	23-Feb-94		X	X
C-240-0194	Expansion Joint Material Specification	0	RJW	7-Mar-94		X	X
Purchasing Specifications							
C-BT-CO	Ligo Beam Tube Sections, Construction Option	0	MLT	23-Mar-94			X
C-EJ-CO	Expansion Joints, Construction Option	1	RJW	23-Mar-94			X
C-BAF-1	Baffle Fabrication Specification	1	WJC	23-Mar-94		X	X
C-VAC-1	Vacuum Stiffener Fabrication Specification	1	WJC	7-Mar-94		X	X
C-SUPT-1	Structural Supports	1	WJC	9-Mar-94		X	X
C-SUPSTF-1	Support Ring/Baffle Ring Fabrication Specification	0	WJC	14-Mar-94		X	X
C-PORT-OP	Pump Port Fabrication Specification, Constr, Opt.	0	JGS	1-Mar-94			X
C-PORTPAD-1	Pump Port Reinforcing Pad Fabr. Specification	1	WJC	8-Mar-94		X	X
BOOK 1 SECTION 3							
Welding Procedures							
WPS-INDEX	Weld Procedure Index	2	RWP	1-Mar-94		X	X
GWPS-SMAW	General Welding Procedure	15	AEH	24-Mar-93		X	X
GWPS-GTAW	General Welding Procedure	14	AEH	24-Mar-93		X	X
GWPS-GMAW & FCAW	General Welding Procedure	15	AEH	24-Mar-93		X	X
WPS-ER308L/Circ (w/PQR 10029)	Welding Procedure for Expansion Joint to Beam Tube Can Assemblies	3	RWP	11-Mar-94		X	X
WPS-ER308L/Stiffener (w/PQR 4858)	Welding Procedure for Stiffener to Beam Tube Cans	3	RWP	11-Mar-94		X	X
WPS-ER308L/Port (w/PQR 10029)	Welding Procedure for 10"Ø Vacuum Port Nozzle to Beam Can Assemblies	3	RWP	11-Mar-94		X	X
WPS-ER308L/GMA (w/PQR 4858)	Weld Procedure, GMA Welding for 304L Materials	1	RWP	11-Mar-94		X	X
WPS-ER308L/REPAIR (w/PQR's 10029 & 4858)	Weld Procedure, GMA for Repair Welding for 304L Materials	0	RWP	10-Feb-94		X	X
WPS-E7018/STRUCT (w/PQR 8903)	Welding Procedure for Structural (Carbon to Carbon)	0	RWP	10-Feb-94		X	X
WPS-E308L/STRUCT (w/PQR 9168)	Welding Procedure for Structural (Stainless to Stainless)	0	RWP	10-Feb-94		X	X
WPS-E309/STRUCT (w/PQR 6190)	Welding Procedure for Structural (Carbon to Stainless)	0	RWP	10-Feb-94		X	X
WELDCOUP	Outgassing Test Coupons	1	RWP	17-Dec-93		X	
WMS-ER308L/COUP	Cleaning and Bake Out Procedure of ER 308L Weld Wire/Outgas Coupons	0	RWP	9-Dec-93			
WMS-ER308L	Cleaning and Bake Out Procedure of ER 308L Weld Wire	1	RWP	13-Jan-94		X	X
GR-8X	General Repair Procedure for Materials and Welds	1	RWP	9-Feb-94		X	X
CUP-8X	Plate Clean-up Procedure for Tube Modules	1	RWP	18-Feb-94		X	X
BOOK 1 SECTION 4							
Fabrication/Installation Procedures							
FABSEQ	Beam Tube Can Section Fabrication Sequence	1	GLW	5-Apr-94			X
INSTALLSEQ	Beam Tube Can Section Installation Sequence	1	GLW	5-Apr-94			X
FPCircumferential	Fitting/Purge Procedure for Circumferential Butt Welds	2	RWP	11-Mar-94		X	X

		LIGO PROJECT for CALTECH			KHF			
		Master Procedure Listing			4/8/94			
		CALTECH CONTRACT C-146, CBI CONTRACT 930212						
	Document I.D.	**DESCRIPTION**	**Current Rev.**	**Proc By**	**Date**	**Status**	**Application Qual. Test**	**Construction**
	FPStiffener	Fitting/Purge Procedure for Beam Tube Stiffeners	2	RWP	11-Mar-94			X
	FPPumpPort	Fit-up Instructions for 10"Ø Vacuum Port Nozzle	2	RWP	11-Mar-94		X	X
	CR1TSM	Clean Room Transporting, Storage and Maintenance Instructions	1	SDH	6-Nov-93	hard copy only		X
	BDF1	Positive Blower/Dryer/Filtration System(BDF) Installation and Maintenance	1	SDH	28-Mar-94	hard copy only		X
		Machining Instructions for 10"Ø Vacuum Port Penetration		SDH				X
	IR	Receipt Inspection Procedure	0	PM	4-Apr-94		X	X
	DC	Dimensional Control Procedure	0	WLR	30-Mar-94		X	X
		Rigging, Handling & Storage Procedures					X	X
	MODSEQ	Final Alignment and Module Testing Sequence	1	GLW	14-Mar-94			X
	NDE Procedures							
	VI 5	Visual Inspection Procedure	0	RWK	20-Jun-88		X	X
	VI 8	Visual Inspection Procedure for ASME Section VIII Code Vessels	2	RWK	10-May-91		X	X
BOOK 1 SECTION 5								
	Cleaning Procedures							
	CLCOUP	Cleaning of Coupons	0	CNS	30-Mar-94		X	
	CL1N	Cleaning of Completed Beam Tube Can Assemblies	1	CNS	5-Apr-94			X
	CL2N	Maintenance of Partially Completed Beam Tube Modules	0	CNS	3-Nov-93			X
	CL3N	Final Cleaning & Inspection of Beam Tube Module Inner Surfaces	1	SDH	21-Mar-94			X
	CRWA-1	Clean Room Wearing Apparel for Beam Tube Access during Construction Inspection Activity	0	SDH	3-Mar-94			X
	CLCOUP	Cleaning of Welded & Plain Coupons	3	CNS	28-Dec-93		X	
	CLCOUPA	Cleaning of Welded & Plain Coupons W/ Oil Contamination	0	CNS	22-Feb-94		X	
	CLCOUPA0	Cleaning of Plain Coupons, Alternate Method #0	2	CNS	22-Feb-94		X	
	CLCOUPA1	Cleaning of Plain Coupons, Alternate Method #1	1	CNS	22-Feb-94		X	
	CLALT	Method of Qualifying Alternate Cleaning Approaches for Final Cleaning	0 (draft)	CNS	3-Nov-93		X	
	CLCOUPQT	Cleaning of Coupons for Outgassing Tests for Qualification Test	0	CNS	30-Mar-94		X	
BOOK 1 SECTION 6								
	Leak Testing Procedures							
	HMST1N	Helium Mass Spectrometer Hood Test of Beam Tube Can Assemblies	0	CNS	15-Mar-94			X
	HMST2N	Helium Mass Spectrometer Test of Circumferential Beam Tube Weld	0	CNS	15-Mar-94			X
	HMST3N	Helium Mass Spectrometer Test of 10"Ø Valve and Blind Flange Seals	0	CNS	15-Mar-94			X
	HMST4N	Helium Mass Spectrometer/Performance Test Beam Tube Module	2	CSN	7-Apr-94			X
	HMST5N	Helium Mass Spectrometer Hood Test of Beam Tube Module	0	CSN	15-Mar-94			X
	Outgas Testing Procedures							
	COUP-01	Coupon Outgassing Test Procedure for Option Phase	1	WAC	3-Feb-94			X
BOOK 1 SECTION 7								
	Alignment Procedures							
	ALI-1	Initial & Final Alignment During Installation of LIGO Beam Tube Modules Using GPS System	4	SDH	31-Mar-94	hard copy only		X
	ALM-B	Procedure for Alignment Maintenance Using the Global Positioning System (GPS) Technique	1	SDH	29-Dec-93			X
	QP-GPS-1	Alignment Procedure Using Real Time Kinematic Global Positioning (GPS)	2	SDH	31-Jan-94		X	
	AQT	General Alignment Procedure for LIGO Qualification Test Module Addenda	0	SWP	5-Apr-94		X	

		LIGO PROJECT for CALTECH			KHF			
		Master Procedure Listing			4/8/94			
		CALTECH CONTRACT C-146, CBI CONTRACT 930212						
	Document	**DESCRIPTION**	**Current**	**Proc**	**Date**	**Status**	**Application**	
	I.D.		**Rev.**	**By**			**Qual. Test**	**Construction**
	ALIGNMENT PROCEDURES DEVELOPED FOR CONSIDERATION (USE YET TO BE DETERMINED)							
	ALI-A	Procedure for Initial Layout & Final Alignment Using Standard Optical & Surveying Techniques	0	SDH	28-Dec-93			X
	ALM-A	Procedure for Alignment Maintenance Using Standard Optical & Surveying Techniques	1	SDH	28-Dec-93			X
	ALI1	Initial and In-process Inspection of Beam Tube Alignment Instructions	0	SDH	6-Nov-93			X
	ALM1	Final Alignment and Maintenance of Beam Tube Modules	0	SDH				X
	ALI-C	Procedure for Initial Layout & Final Alignment Optical & Laser Techniques	0	SDH	28-Dec-93			X
	ALM-C	Procedure for Alignment Maintenance Using Optical & Laser Techniques	1	SDH	28-Dec-93			X
BOOK 2 SECTION 1								
Detailed Schedule								
		Hanford Livingston Summary Barchart						
		Hanford Mobilization Logic Chart						
		Beam Tube Module Logic Chart						
		Hanford Final Inspection & Testing Logic Chart						
BOOK 2 SECTION 2								
		Detailed Hanford Schedule Activity List						
BOOK 2 SECTION 3								
		Detailed Livingston Schedule Activity List						
BOOK 2 SECTION 4								
		Proposal For Differential GPS For The LIGO Project						
		CBI Report on Tremble Navigation Site Survey System						
		Tremble Navigation Product Information						
BOOK 2 SECTION 5								
Configuration Drawings								
	See Configuration Drawing Summary "0" Sheet for listing							
Erection Drawings ("ER")								
	See ER Drawing Summary "0" Sheet for listing							
NOT INCLUDED, CONTAINED IN QA MANUAL								
Qualilty Assurance Procedures (QAP's) - Construction Option, Listing for Reference Only, See QA Manual for QAP's								
	QAP 1.1	Management Responsibility	REK	0	19-Aug-92			X
	QAP 2.1	Quality System	REK	0	19-Aug-92			X
	QAP 2.2	Quality Plan	REK	0	19-Aug-92			X
	QAP 2.3	Contract QAP's	REK	0	19-Aug-92			X
	QAP 3.1	Pre-Contract Review	ALD	0	19-Aug-92			X
	QAP 3.2	Post-Award Review	ALD	0	19-Aug-92			X
	QAP 4.1	Preparation of Detail Drawings, Written Requisitions and Procurement Specifications	JGS	0	19-Aug-92			X
	QAP 5.1	Document Control	JGS	0	19-Aug-92			X
	QAP 5.2	Distribution of Detail Drawings, Written Requisitions and Procurement Specifications	JGS	0	19-Aug-92			X
	QAP 5.3	CBI Standards	JGS	0	4-Sep-92			X
	QAP 5.4	Contract QA Documents	ALD	0	19-Aug-92			X
	QAP 5.5	Customer Drawings	RGL	0	19-Aug-92			X
	QAP 6.1	Purchase Orders	RGL	0	9-Dec-92			X
	QAP 6.2	Vendor Survey	RGL	0	19-Aug-92			X
	QAP 6.3	Vendor Assignment & Surveillance	RGL	0	9-Dec-92			X
	QAP 7.1	Receipt of Customer Supplied Material	RGL	0	9-Dec-92			X
	QAP 8.1	Material Control	RAJ	0	9-Dec-92			X
	QAP 9.1	Process Control	ALD	0	9-Dec-92			X
	QAP 9.2	Welding Control	ALD	0	9-Dec-92			X
	QAP 9.3	Heat Treating	ALD	0	9-Dec-92			X
	QAP 9.4	Miscellaneous Process Control	ALD	0	9-Dec-92			X
	QAP 10.1	Receiving Inspection	ALD	0	9-Dec-92			X
	QAP 10.2	NDE, Inspection and Testing	ALD	0	9-Dec-92			X

		LIGO PROJECT for CALTECH			KHF			
		Master Procedure Listing			4/8/94			
		CALTECH CONTRACT C-146, CBI CONTRACT 930212						
	Document	**DESCRIPTION**	**Current**	**Proc**	**Date**	**Status**	**Application**	
	I.D.		**Rev.**	**By**			**Qual. Test**	**Construction**
	QAP 10.3	Documentation Review and Final Visual Inspection	ALD	0	9-Dec-92			X
	QAP 11.1	Calibration	RAJ	0	19-Aug-92			X
	QAP 12.1	Inspection and Test Status	RAJ	0	19-Aug-92			X
	QAP 13.1	Nonconformities	REK	0	19-Aug-92			X
	QAP 14.1	Corrective Action	REK	0	19-Aug-92			X
	QAP 15.1	Handling, Storage, Packaging and Shipping	REK	0	19-Aug-92			X
	QAP 16.1	Quality Records	REK	0	19-Aug-92			X
	QAP 17.1	Internal Auditing	RGL	0	9-Dec-92			X
	QAP 18.1	Training	RGL	0	19-Aug-92			X

CBI

TITLE	IDENTIFICATION LIGOTP			
PLANNED APPROACH TO LEAK TESTING FOR LIGO PROJECT - CALTECH	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 04/07/94	DATE	DATE	DATE

1.0 SCOPE:

This planned approach to leak testing LIGO (in chronilogical order of performance) covers:

1.1 The helium mass spectrometer hood test of each beam tube can section in accordance with the current approved revision of procedure HMST1N.

1.2 The helium mass spectrometer hood test of the closing weld joint between beam tube can sections in accordance with the current approved revision of procedure HMST2N.

1.3 The helium mass spectrometer hood test of all pump port assemblies with the isolation valve, LN_2 pump, RGA head connection, cold cathode gauge head connection and flange seals in accordance with the current approved revision of procedure HMST3N.

1.4 The ~~helium mass spectrometer~~ Other gases/performance test of each beam tube module in accordance with the current approved revision of procedure HMST4N.

1.5 The helium mass spectrometer hood test of beam tube modules in accordance with the current approved revision of procedure HMST5N.

2.0 PERSONNEL:

Qualified leak testing personnel shall perform and supervise all helium mass spectrometer leak testing conducted in accordance with this planned approach and all the leak testing procedures referenced within this plan.

3.0 REFERENCE:

3.1 1992 ASME Boiler & Pressure Vessel Code, Section V, Article 10, with 1992 Addenda as a guide.

3.2 ASTM 498 as a guide.

3.3 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules.

3.4 Paper titled "RGA Air Signature Analysi" dated July 11, 1992 by R. Weiss of MIT.

3.5 Nondestructive Testing Handbook, Second Edition, Volume One, Leak Testing; published by the American Society of Nondestructive Testing; Sections 3 and 8.

CBI	IDENTIFICATION LIGOTP			
TITLE PLANNED APPROACH TO LEAK TESTING FOR LIGO PROJECT - CALTECH	REFERENCE NO. 930212		SHT 2 OF 3	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 04/07/94	DATE	DATE	DATE

4.0 LEAK TESTING EQUIPMENT USED IN ALL LEAK TEST PROCEDURES:

4.1 Helium mass spectrometers (HMSs) with a high vacuum turbomolecular pump or a diffusion pump with a cold trap and an internal auxilary mechanical vacuum pump. Instruments must be capable of direct flow operation and may have the option of indirect flow operation. Specific models and sensitivity limitations will be given in each of the applicable leak test procedures. Each HMS shall be on a separate 110 Vac 30 ampere electrical breaker circuit.

4.2 Permeation (quartz) helium standard leaks with leakage rates in the range of 10^{-8} atm. cc/sec. or smaller.

4.3 Commercial grade helium supplied from an on-site storage trailer or container.

4.4 Helium regulators.

4.5 Helium tracer probes and hoses.

4.6 Liquid nitrogen supplied from an on-site cryogenic storage container.

4.7 Electrical power for all electrical leak testing equipment such as mechanical vacuum pumps, turbomolecular pumps, helium refrigeration compressors, vacuum gauges, helium mass spectrometers (see item 4.1) and a PC with a printer.

4.8 Cleaning solvents such as electronic grade 99% mol isopropyl alcohol.

4.9 Clean lint free cloths or paper towels.

5.0 DECISION TREE:

The following Leak Detection Decision Tree provides a condensed view of the leak testing to be performed on LIGO.

6.0 DOCUMENTATION:

6.1 Sign-off and date the beam tube module checklist for each item after the leak test for that item has been successfully completed.

6.2 Maintain a log book for each beam tube module and make entries of all note worthy leak testing events, such as leaks repaired, as they occur during the leak testing of each can section and closing weld joints between can sections of that module.

6.3 Prepare a brief test report of the results of each leak test as it is completed with all information of importance to the outcome of the test listed in the report.

6.4 As a backup to the data from items 6.1 through 6.3, enter on a daily basis all the data from items 6.1 through 6.3 on a computer as text only. This will result in being the same as ASCII. When text is entered, it shall be prefixed with the entry date year, month and day and daily sequence number for easy retrieval. Examples of prefix numbers for entries are 940124.3, 940126.5, and 940128.1. These enties are respectively the third entry made on January 24, 1994, the fifth entry made on January 26, 1994 and the first entry made on January 28, 1994.

6.5 Provide a log at each HMS station. Make entries in each of these logs for all:

6.5.1 Maintenance on done on the HMS either by CBI or by others and whether it was scheduled or necessary maintenance due to problems with the instrument.

6.5.2 Electrical problems encountered with the HMS circuit such as power outages and/or abnormal voltage fluctuations.

LIGO
CAN SECTION
HMS LEAK TEST REPORT

Hanford/Livingston — LOCATION (Circle One)

930212 — CONTRACT

__________ CAN SECTION I.D. NO.

Customer	Procedure and Rev.
HMS Leak Detector (Mfg., Type & Model)	Standard Leak ID
HMS Sensitivity atm. cc/sec./div.	Standard Leak Helium Leakage Rate atm. cc/sec.
Basis for HMS Leak Indicator Division Unit of ________ on Scale	System Sensitivity atm. cc/sec./div./time
System Absolute Pressure During Test Torr	D.P. Foreline Absolute Pressure During Test Torr
HMS Element Pressure During Test	During System Calibration Throttling/Accumulating

Instrument Calibration Calculation

$$\text{HMS Sensitivity} = \frac{\text{Leakage Rate of Std. Leak} \times \text{Division Unit}}{\text{Net Signal in Divisions}}$$

HMS Sensitivity = ____________________ = atm. cc/sec./div.

Instrument Calibration Calculation

$$\text{System Sensitivity} = \frac{\text{Leakage Rate of Std. Leak} \times \text{Division Unit}}{\text{Net Signal in Divisions}}$$

System Sensitivity = ____________________ = atm. cc/sec./div./time

Check Applicable Box(es):

☐ Weld repairs were made during leak testing and have been visually inspected and re-tested and found acceptable.
See VT Report No. ________

☐ No welded repairs made during leak testing.

Tests were performed and all leakage was evaluated in accordance with the referenced procedure.
Defects not repaired and retested during testing are recorded above as to location and recommended disposition.
All other tested areas included in this report were found acceptable.

COMMENTS: ______________________________________

____

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____________________ OPERATOR/EVALUATOR   __________ DATE

Report results reviewed and accepted by: ____________________ __________ DATE

LIGO CIRCUMFERENTIAL WELD HMS LEAK TEST REPORT

CBI

Hanford/Livingston
LOCATION (Circle One)

930212
CONTRACT

____
CAN SECTION I.D. NO.

Customer	Procedure and Rev.
HMS Leak Detector (Mfg., Type & Model)	Standard Leak ID
HMS Sensitivity atm. cc/sec./div.	Standard Leak Helium Leakage Rate atm. cc/sec.
Basis for HMS Leak Indicator Division Unit of ________ on Scale	System Sensitivity atm. cc/sec./div./time
System Absolute Pressure During Test Torr	D.P. Foreline Absolute Pressure During Test Torr
HMS Element Pressure During Test	During System Calibration Throttling/Accumulating

Instrument Calibration Calculation

$$\text{HMS Sensitivity} = \frac{\text{Leakage Rate of Std. Leak x Division Unit}}{\text{Net Signal in Divisions}}$$

HMS Sensitivity = ______________________ = atm. cc/sec./div.

Instrument Calibration Calculation

$$\text{System Sensitivity} = \frac{\text{Leakage Rate of Std. Leak x Division Unit}}{\text{Net Signal in Divisions}}$$

System Sensitivity = ______________________ = atm. cc/sec./div./time

Check Applicable Box(es):

☐ Weld repairs were made during leak testing and have been visually inspected and re-tested and found acceptable.
See VT Report No. ________

☐ No welded repairs made during leak testing.

Tests were performed and all leakage was evaluated in accordance with the referenced procedure.
Defects not repaired and retested during testing are recorded above as to location and recommended disposition.
All other tested areas included in this report were found acceptable.

COMMENTS:____

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______________________________ ______________
OPERATOR/EVALUATOR DATE

Report results reviewed and accepted by:______________________ ______________
DATE

LIGO
PUMP PORT ASSEMBLY
HMS LEAK TEST REPORT

Hanford/Livingston	930212	
LOCATION (Circle One)	CONTRACT	CAN SECTION I.D. NO.

Customer	Procedure and Rev.
HMS Leak Detector (Mfg., Type & Model)	Standard Leak ID
HMS Sensitivity atm. cc/sec./div.	Standard Leak Helium Leakage Rate atm. cc/sec.
Basis for HMS Leak Indicator Division Unit of ________ on Scale	System Sensitivity atm. cc/sec./div./time
System Absolute Pressure During Test Torr	D.P. Foreline Absolute Pressure During Test Torr
HMS Element Pressure During Test	During System Calibration Throttling/Accumulating

Instrument Calibration Calculation

$$\text{HMS Sensitivity} = \frac{\text{Leakage Rate of Std. Leak x Division Unit}}{\text{Net Signal in Divisions}}$$

HMS Sensitivity = ____________________ = atm. cc/sec./div.

Instrument Calibration Calculation

$$\text{System Sensitivity} = \frac{\text{Leakage Rate of Std. Leak x Division Unit}}{\text{Net Signal in Divisions}}$$

System Sensitivity = ____________________ = atm. cc/sec./div./time

Check Applicable Box(es):

☐ Weld repairs were made during leak testing and have been visually inspected and re-tested and found acceptable.
See VT Report No. ________

☐ No welded repairs made during leak testing.

Tests were performed and all leakage was evaluated in accordance with the referenced procedure.
Defects not repaired and retested during testing are recorded above as to location and recommended disposition.
All other tested areas included in this report were found acceptable.

COMMENTS:____

____

____

OPERATOR/EVALUATOR DATE

Report results reviewed and accepted by:______________________ ____________
DATE

CBI	IDENTIFICATION LIGOCP			
TITLE PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO PROJECT FOR CALTECH	REFERENCE NO. 930212		SHT 1 OF 2	
	OFFICE		REVISION 0	
PRODUCT	MADE BY cns	CHKD BY	MADE BY	CHKD BY
	DATE 11/02/93	DATE	DATE	DATE

1.0 SCOPE:

This planned approach to cleaning covers

1.1 Offsite cleaning requirements for manufacturers of purchased components or subassemblies.

1.2 Cleanliness maintenance requirements for the manufacturer of the beam tube can sections.

1.3 Onsite initial spot cleaning followed by final cleaning using procedure number CL1N for completed beam tube can sections after they are helium mass spectrometer leak tested, but before they are installed and welded in final position.

1.4 Cleaning maintenance procedure number CL2N for maintaining the cleanliness integrity of partially completed beam tube modules during construction. Included as an integral part of this procedure is the spot cleaning requirements of the closing weld joints between can sections after welding of those joints is complete.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning and cleaning maintenance performed in accordance with this planned approach and the cleaning and cleaning maintenance procedures referenced within this plan.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specifications Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

4.0 MATERIALS USED IN ALL CLEANING PROCEDURES:

4.1 Potable tap water with a chlorine content in the range of 0.02 to 200 ppm.

4.2 Technical grade solvents such as acetone or alcohol.

4.3 Lint free cloths or paper towels.

4.4 100 Watt blacklights with 3650 Angstrom unit wavelength.

4.5 Blacklight meters capable of measuring at least 800 uw/cm^2.

5.0 DOCUMENTATION:

5.1 On a checklist of all purchase items for a beam tube module, sign-off and date the entry for each purchase item indicating that the item was received in a clean condition. Note each purchase item received in a non-clean condition. List them on a separate checklist of items still to be cleaned or on a checklist of items returned to the manufacturer for cleaning or recleaning

5.2 Maintain a cleaning log book for each beam tube module listing the sign-offs and dates of entry for:

5.2.1 Satisfactory completion of the initial spot cleaning followed by the satisfactory completion of the final cleaning per procedure CL1N for each beam tube can section.

5.2.2 Satisfactory cleaning maintenance during construction per procedure CL2N of each partially completed beam tube module. This covers the local cleaning of closing weld joints after successful completion of the local HMS leak testing of those weld joints.

1.0 PURPOSE

This plan describes the procurement procedures and documentation to be used by CBI in the execution of the LIGO Beam Tube Module Design and Qualification Test.

2.0 SCOPE

This plan covers the procurement of all materials and equipment required to develop the beam tube module detailed design and required to execute the qualification test.

3.0 CLASSIFICATION OF PROCUREMENT ITEMS

The material and equipment procured for the LIGO Beam Tube Module Design and Qualification Test will be classified according to its use.

3.1 Beam Tube Module Components

All items which physically represent components is the beam tube modules are classified as "Module Components". Module components are considered to be contract material even though CBI retains ownership of all module components in the design and qualification test. Module components are subject to all ASME code and CBI procurement and material controls and procedures for contract material. The following items are module components:

- Spiral welded beam tube sections
- Beam tube stiffeners
- Beam tube expansion joints
- Beam tube supports and adjustment mechanisms
- Beam tube baffles
- 10" diameter pumping port
- Welding material

3.2 Demonstration Components

All items used in the development of the procedures for the design and qualification test and for the option which may be representative of option activities are classified as demonstration components. Items should be considered to be demonstration components as long as they potentially represent option activities or configurations. The demonstration components include, but are not necessarily limited to the following items:

- Alignment equipment
- Welding equipment and prototype
- Cleaning equipment
- Leak testing equipment
- Outgas testing equipment

3.3 Qualification Test Construction Equipment

All items used in the execution of the design and qualification which are not representative of the option are considered to be QT Construction Equipment. The QT construction components include the following items:

- ~~Bake out equipment~~ — Hopefully to be changed to direct heating
- Temporary supports
- Thrust blocks or end supports
- Qualification test pumping equipment

4.0 PROCUREMENT DOCUMENTATION

4.1 Module Components

Module components will be procured and identified in accordance with CBI's practice for ASME Section VIII Division 1 structures. CBI's practice for these structures is described in CBI's ASME QCS Manual.

4.1.1 Module component items and services shall be purchased in accordance with written requisitions.

4.1.2 To assure item and service conformance's, the following steps shall be implemented:

A. Purchase orders shall contain all technical and QA information needed to satisfy the LIGO Beam Tube Module Design and Qualification Test contract. The Project Services Department shall prepare a LIGO Project Procurement Specification which contains all LIGO pass through requirements. The responsible design groups shall prepare Technical Specifications for all purchased module components which completely describe the physical, material, inspection and documentation requirements. The Procurement Specification and the Technical Specification shall accompany all requests for quotation and purchase orders.

B. Purchased items shall be inspected at the source or upon receipt for identity, compliance with the P.O. and shipping damages.

C. The result of the receiving inspection shall be documented on a Receiving Inspection Report, RIR.

D. Accompanying documentation shall be reviewed by the Purchasing Manager or the Qualification Test Manager for completeness, correctness and compliance with the requirements of the P.O.

E. The user of the service is responsible for verifying its compliance with the P.O.

4.2 Demonstration Components and Construction Equipment

Demonstration components and construction equipment will be procured by Houston Corporate Welding and Plainfield Research & Development in accordance with the attached "Procurement Procedure" for the respective departments.

5.0 PRODUCT IDENTIFICATION AND TRACEABILITY

Product identification and traceability shall be maintained for all Module Components fabricated by CBI or supplied by others.

5.1 CBI Fabricated Module Components

CBI fabricated module components are those components manufactured in CBI shops.

5.1.1 Engineering-Assigned shall prepare contract drawings, procurement specifications and bill sheets which identify the material and items required. The bill sheets shall indicate the material identification (ID) required for each item. This ID will indicate the traceability required for the item.

5.1.2 The Superintendent shall identify all material and items with a contract number and piece mark and, when required, with a serial number which can be related to a mill marking so that traceability can be maintained throughout the fabrication and installation processes. Identification shall be made in the form of a mark, label or hardstamp. The marking or labeling shall be legible, durable and in accordance with any application procedures or instructions. CBI Standards shall be followed for material identification coding systems.

5.1.3 The Superintendent shall prepare a "Daily Fabrication or Stores Release Report" (DFR). The DFR identifies the material and provides a tie between the CBI piece mark and serial number and supplier heat and lot number. The completed DFR is used for material verification.

5.2 Vendor Supplied Module Components

5.2.1 Material supplied by vendors shall be inspected upon receipt for proper identification, shipping damage and any special contract requirements.

5.2.2 Any products that are lost, damaged, rendered unusable, received without proper documentation or inadequate identification shall be documented and immediately reported to the vendor for disposition.

5.2.3 When the vendor supplies material, the vendor identification system may be used. Alternately, the CBI identification system may be used.

6.0 PROCUREMENT PROCEDURES

6.1 Module Components

6.1.1 Only module components for the qualification test are within the scope of this plan. Purchasing documents prepared by Engineering and Project Services shall be assembled and issued to potential suppliers by the Project Services department. Project Services shall receive all quotations and proposals. Proposals shall be reviewed by all relevant departments and by the Engineering Project Manager.

6.1.2 After review and approval of the Engineering Project Manager, the Project Services department shall issue written requisitions or purchase orders to the selected supplier. To assure item and service conformance, purchase orders, including any referenced attached procurement specification, shall contain all the technical and QA information needed to satisfy the requirements of the contract.

6.1.3 The Engineering Project Manager shall obtain Caltech's review and comments prior to issuing any module component purchase order.

6.2 Demonstration Equipment and Construction Equipment

6.2.1 Purchasing documents shall be prepared and issued by the responsible department in accordance with the attached procurement procedures. Proposals shall be received by the issuing department and reviewed by all relevant departments and by the Engineering Project Manager.

6.2.2 After review and approval of the Engineering Project Manager, the issuing department shall issue a written requisition or purchase order to the selected supplier. To assure item and service conformance, purchase orders, including any referenced attached procurement specification, shall contain all the technical and QA information needed to satisfy the requirements of the contract.

6.2.3 The Engineering Project Manager shall obtain Caltech's review and comments prior to issuing major equipment purchase orders.

6.3 Verification of Items and Services

6.3.1 Purchased items shall be inspected at the source or upon receipt for identity, compliance with the P.O. and shipping damage.

6.3.1.1 The result of receiving inspection shall be documented on a Receiving Inspection Report (RIR) for all module components.

6.3.1.2 Accompanying documentation (CMTR, COC, etc.) shall be reviewed by the Purchasing Manager or Welding and QC Manager for completeness, correctness and compliance with the requirements in the P.O.

6.3.2 The user of the service is responsible for verifying its conformance with the P.O.

6.3.3 Beam tube module sections shall be inspected at the point of fabrication prior to releasing sections for shipment.

7.0 CALTECH NOTIFICATION

7.1 Module Components

7.1.1 Copies of all RFP's for module components shall be sent to Caltech when issued to potential vendors.

7.1.2 Caltech shall be notified of all visits to vendors or potential vendors of LIGO module components.

7.1.3 In addition to those requirements contained in Contract No. C146, CBI shall notify Caltech of any module component vendor selection prior to issuing the P.O. to enable Caltech to review and comment.

7.1.4 Caltech or their representatives shall have non-escort privileges to all areas of CBI's or CBI's subcontractor's facilities where work in being performed under the Beam Tube Module contract. All purchase orders shall include notification to vendors and subcontractors to this effect.

7.2 Demonstration Components

7.2.1 In addition to those requirements contained in Contract No. C146, CBI shall notify Caltech of the purchase of any potential demonstration component when the component is purchased.

7.3 Construction Equipment

7.3.1 No special notification is required for construction equipment. Notification shall be in accordance with Contract No. C146.

1.0 POLICY AND AUTHORITY

This Quality Assurance Plan is issued by CBI Technical Services, Inc. to specify the responsibilities and controls required of the Project Team and CBI corporate groups during the design, procurement, construction and testing of the LIGO Beam Tube Module Design and Qualification Test at CBITS's Plainfield Research and Development Center.

All persons performing quality control functions have the freedom to identify quality control problems and to recommend solutions through designated channels.

The management of CBITS is committed to follow the requirements of this Project Quality Assurance Plan.

J. Hagstrom
President, CBITS

2.0 SCOPE OF QA PLAN

2.1 Introduction

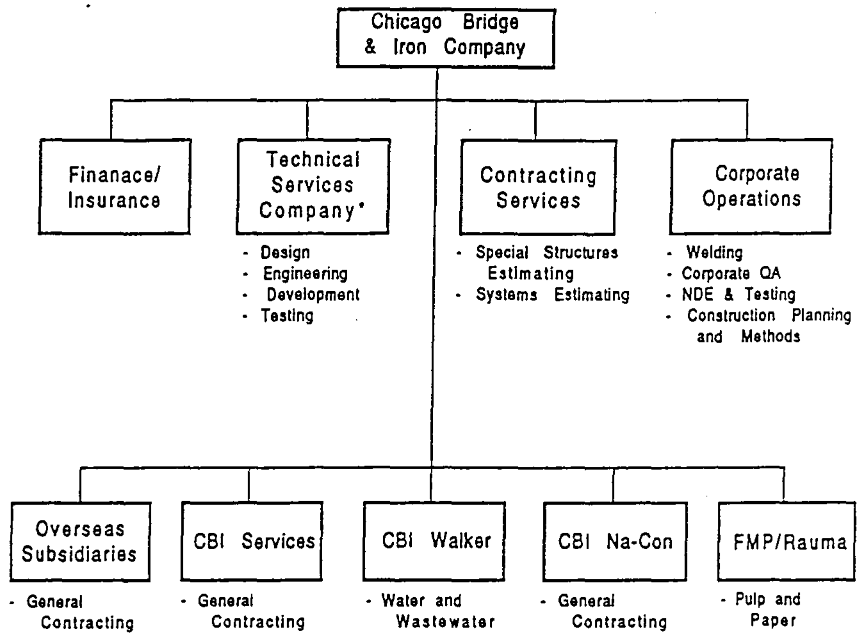
The Quality Assurance Plan summarizes the system used by CBI to complete the Beam Tube Module Design and Qualification Test Contract with California Institute of Technology (Caltech Contract No. C146). This plan describes CBI's quality assurance policy through implementation of quality controls invoked by CBI's Manual for ASME Quality Control System (ASME QCS).

The CBI ASME QCS requires that contract instructions be prepared for each contract. These contract instructions contain certain required items such as Customer Specifications, Welding & NDE Procedures, and also include instructions which invoke supplemental requirements not addressed in, or more stringent than, required by ASME Section VIII, Division I. The contract instructions for the LIGO Design (D) and Qualification Test (QT) Project will provide instructions and additional Quality Assurance Procedures that address specific contractual requirements. Quality Assurance Procedures (QAP's) used by other CBI Department Quality Management systems will be included and used in conjunction with the CBI ASME QCS when necessary. The CBI ASME QCS is modified by an addendum to tailor responsibilities and controls specifically for the LIGO Beam Tube Module Design and Qualification Test. The addendum is issued with the contract instructions and is shown for information in this QA Plan.

The CBI's corporate organization and the LIGO D & QT Project Team Organization Charts are issued with the contract instructions. Figures 2.1.1, 2.1.2, and 2.1.3 are the current organization charts and are shown for information.

FIGURE 2.1.1

CHICAGO BRIDGE & IRON COMPANY ORGANIZATION



* Chicago Bridge & Iron Technical Services Company known as CBI Technical Services (CBITSC)

Figure 2.1.1

FIGURE 2.1.2

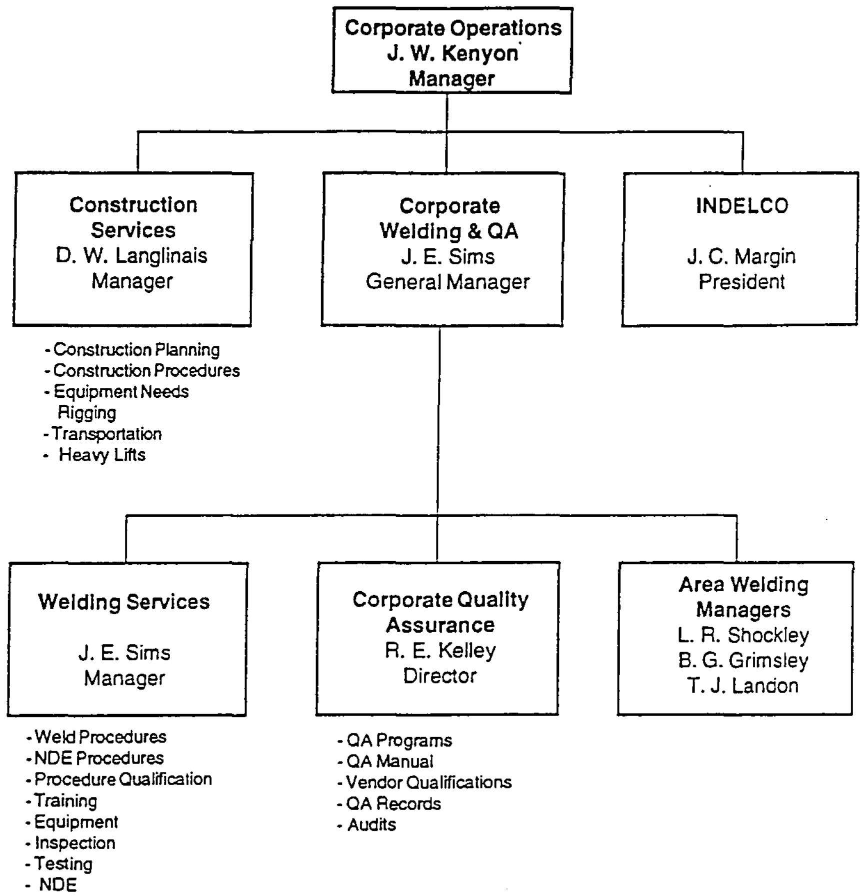


Figure 2.1.2

FIGURE 2.1.3

LIGO BEAM TUBE MODULES PROJECT ORGANIZATION
DESIGN & QUALIFICATION TESTING LIGO TEAM

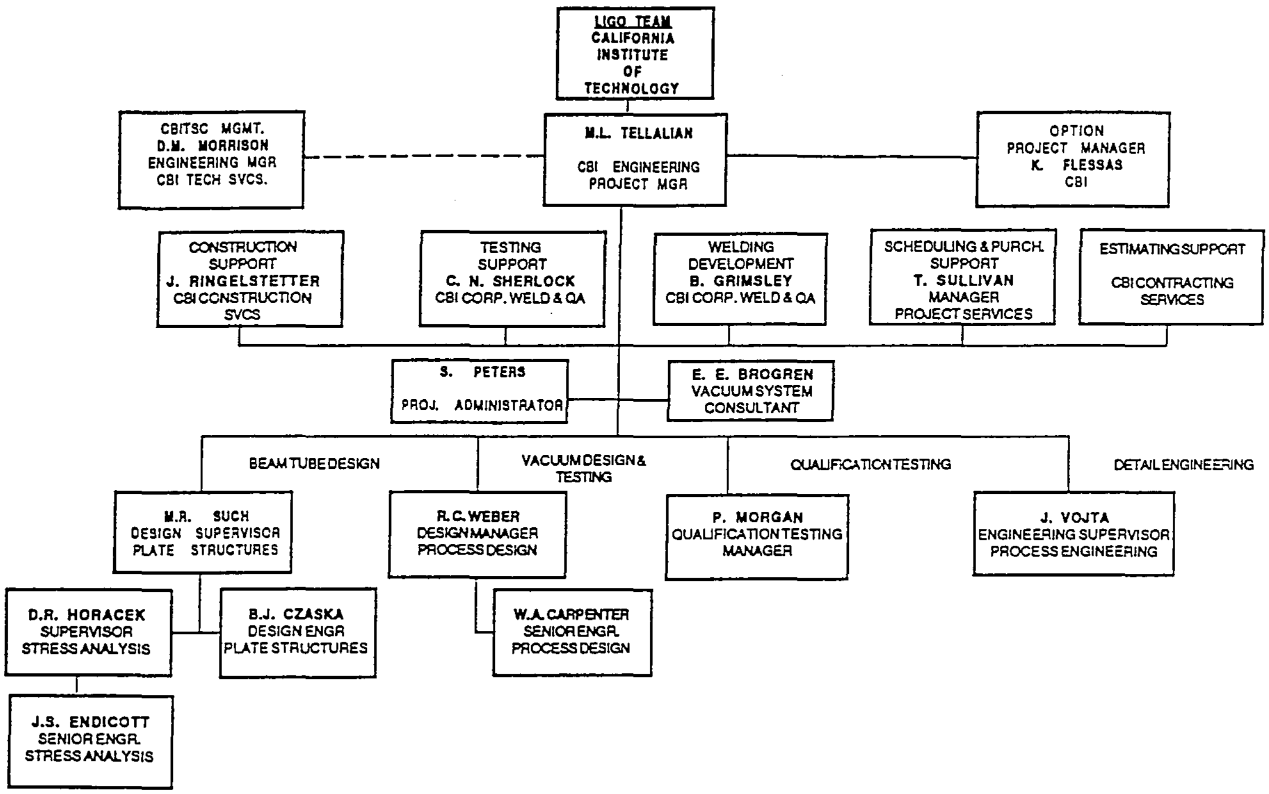


Figure 2.1.3

2.0 SCOPE OF QA PLAN (CONTINUED)

2.2 Responsibility and Authority

2.2.1 The President of Chicago Bridge & Iron has overall responsibility and authority for all work. The authority for execution of individual projects is delegated to the presidents of CBI subsidiaries. The President of Chicago Bridge & Iron Technical Services Company (for Engineering and Development activities) works with the Managers of Corporate Operations in order to execute all aspects of the LIGO D & QT Project.

2.2.2 The Engineering Project Manager is delegated the authority and will assume the functions and responsibilities of Project Manager and the Welding and Quality Control Manager. The Engineering Project Manager and other responsible management are responsible for evaluating Caltech's quality assurance requirements and for coordinating the preparation of the Quality Assurance Plan. The Engineering Project Manager is responsible for issuing and updating this plan. The Engineering Project Manager is responsible for coordinating all engineering and development activities. The Engineering Project Manager identifies the need for interaction with other groups.

2.2.3 The Manager of Engineering assigns design responsibilities to a "Design Group" and detail engineering to "Engineering-Assigned". Design activities are assigned to qualified personnel equipped with adequate resources.

2.2.4 The Qualification Test Manager is delegated the functions and responsibilities of Shop Manufacturing Superintendent/production foreman, and jobsite foreman as described in the ASME QCS for the Qualification Test.

2.2.5 The Director of Corporate Quality Assurance (CQA) is responsible for the interpretation and implementation of this Plan. Implementation shall be verified by internal CBI audit. Conditions adverse to quality shall be reported to the Director of Corporate QA who shall provide the final authority for corrective action, if necessary.

2.3 Contract Instructions

Contract instructions are prepared and issued by the Engineering Project Manager. The Quality Assurance Procedures (QAP's) and Instructions which are development design and engineering oriented shall be prepared, authorized and issued to the contract instructions by the Engineering Project Manager. The QAP's and instructions will identify the interaction with all groups and persons performing quality activities and functions. Personnel performing activities affecting quality shall be given sufficient training to enable them to understand and perform their work or function.

2.4 Log Notebook of Record

An instruction will be prepared and issued to the Contract Instructions by the Engineering Project Manager. The Instruction shall include instructions on who is to keep notes and how the notes are to be recorded. The instruction shall provide requirements for the transfer of personal notes and the editing or copying of other department notebook data into the Log Notebook of Record. Personal notebooks should be retained until the activity being worked is accepted or the notes have been transferred into the Log Notebook of Record. The Log Notebook of Record shall be made available to Caltech for monitoring daily activities for contract requirements and shall be handled as a Quality Assurance Record.

2.0 SCOPE OF QA PLAN (CONTINUED)

2.5 Other Project Controls

The following plan documents also provide quality assurance for the LIGO Beam Tube Module Design and Qualification Test. These plans are executed in coordination with the QA Plan.

2.5.1 Configuration Management Plan
2.5.2 Documentation Control Plan
2.5.3 Procurement Plan

3.0 DESIGN AND QUALIFICATION TEST PROJECT TEAM

3.1 Project Team

The "Project Team Concept" is utilized in the execution of this project to coordinate all activities of the functional organization in such a manner as to assure all project requirements are met. These requirements include, but are not limited to, completion on schedule, procurement control, material control, engineering, manufacturing and construction control.

3.2 Organization

The LIGO D & QT Project Team consists of the Engineering Project Manager, Project Administrator, Beam Tube Design Supervisor, Vacuum System Design Manager, and Qualification Test Manager. For continuity in the event of the option, the operating company input will be coordinated by a designated Project Manager for the option. The project team will coordinate work performed by functional departments throughout the CBI organization. The LIGO Beam Tube Module D & QT will be executed primarily by CBI Technical Services with assistance from Chicago Bridge and Iron Company and from the operating companies, CBI Services and CBI Na Con. Chicago Bridge and Iron Company will assist in the development of construction plans and procedures, weld procedures and equipment, and a project quality assurance system. The operating companies will assist in construction plans, procedures and estimating.

3.3 Project Team Assignments and General Responsibilities

3.3.1 Engineering Project Manager - M.L. Tellalian

3.3.2 Project Administrator - S.W. Peters

3.3.3 Beam Tube Design Engineer - B.J. Czaska

3.3.4 Vacuum System Design Manager - R.C. Weber

3.3.5 Qualification Test Manager - P. Morgan

3.3.6 Option Project Manager - Ken Flessas

3.0 DESIGN AND QUALIFICATION TEST PROJECT TEAM (Continued)

3.4 LIGO D & QT Execution

The LIGO Beam Tube Module Design and Qualification Test project consists of the design and development of the beam tube configuration and the qualification test of representative designed beam tube sections. This project will be executed in accordance with the herein addendum to CBI's Manual for ASME QCS including Contract Instructions and any additional controls specified in the Configuration Management Plan, Document Control Plan, Material Acceptance Plan, and Procurement Plan. The beam tube configuration design may require some equipment procurement and testing which will be controlled by the functional department with review and approval of the LIGO Engineering Project Manager and Caltech, as required. The unique nature of the qualification test requires some specific control responsibility assignments which are outlined in paragraphs 4.1 through 4.3 and reflected in the attached Addendum to CBI's Manual for ASME Quality Control System.

4.0 DESIGN AND QUALIFICATION TEST

4.1 Engineering

4.1.1 The Beam Tube structural design will be performed by the Plate Structures Design Group. The vacuum system design and special testing design will be performed by the Process Design Group. Drawings and detailing will be performed by the Process Engineering Department which is the "Engineering Assigned" department referred to in CBI's ASME QCS Manual.

4.1.2 Due to the unique nature of the beam tube qualification test structure, the Design Groups will perform many of the responsibilities executed by "Engineering Assigned". Design controls shall be established for all activities directly affecting the quality of the design and qualification test. The contract instructions shall contain or reference Design Quality Assurance Procedures (QAP), Design Quality Assurance Instructions and other Design documents that are not specifically controlled by the ASME QCS, to the extent necessary to meet the contract requirements.

4.2 Purchasing

Purchasing functions for the qualification test have three primary material management control classifications. 1. Demonstration Components, 2. Qualification Test Construction Equipment, and 3. Beam Tube Module Components, which are described in the Project Procurement Plan.

4.2.1 Demonstration Components and Qualification Test Construction Equipment will be procured by NPS, Houston Corporate Welding (MWG), and the Plainfield Research and Development Purchasing Department (PFE). Procurement of these items will be as described in the LIGO Procurement Plan. The procurement plan describes each department's (NPS, MWG, or PFE) procurement method.

4.0 **DESIGN AND QUALIFICATION TEST (Continued)**

4.3 **Manufacturing and Construction (Continued)**

4.3.2 Process controls shall be established for all activities directly affecting the quality of the qualification test. The contract instructions shall contain or reference Quality Assurance Procedures (QAP), Quality Assurance Instructions, Contract Procedures for special processes (e.g. concrete, building structural, welding, NDE, bake out, cleaning, handling, testing, etc.) and other documents that are not specifically controlled by the ASME QCS to the extent necessary to meet the contract requirements. The contract instructions shall contain or reference Vendor procedures and instructions for special processes which are subject to contract requirements. The contract instructions index shall be made available to Caltech for monitoring the Project Quality System.

ATTACHMENT 1

1.0 SCOPE

1.1 This document outlines the changes to the CBI Manual for ASME Quality Control System to meet Caltech and CBI requirements in the engineering, manufacturing and construction of the LIGO Beam Tube Module Design and Qualification Test at CBITS Plainfield Research and Development Center.

1.2 Sections of the manual requiring changes or deletions are listed under Section 2.0.

2.0 MODIFICATION TO THE MANUAL FOR ASME QUALITY CONTROL SYSTEM

2.1 Modifications to all Divisions:

2.1.1 Delete references and requirements regarding Authorized Inspector/Inspection

2.1.2 References to "Project Manager" and "Welding and QC Manager" shall be changed to "Engineering Project Manager"

2.2 Modifications to Division 1: None

2.3 Modifications to Division 2: CORPRATE

2.3.1 Replace the organization charts shown in Sections 2 and 4, with the Chicago Bridge & Iron Company Organization Charts contained in the contract instructions showing current organization assignments.

2.3.2 Add the following Paragraph 3.2 to Section 3, Sales

"3.2 The Manager of Engineering and the LIGO Engineering Project Manager will perform the responsibilities of the Manager of Sales for the D & QT only."

ATTACHMENT 1 (Continued)

ADDENDUM TO MANUAL FOR ASME
QUALITY CONTROL SYSTEM
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID QAM ADD
REV. 0(DRAFT)
PAGE 2 OF 3

2.3 Modifications to Division 2: CORPORATE (Continued)

2.3.3 Add the following Paragraph 4.4 to Section 4, Engineering

"4.4 Engineering Project Manager Responsibilities

4.4.1 The Engineering Project Manager will be responsible for the distribution of all customer furnished engineering documents.

4.4.2 The Engineering Project Manager shall transmit all engineering documents to the customer as required by the specifications and shall ensure timely customer review and comment as required.

4.4.3 No drawing or purchase order is to be released for fabrication without approval of the Engineering Project Manager. The P.O.T. form shall be used to indicate approval."

2.4 Modifications to Division 3: Manufacturing: Same as Division 4

2.5 Modifications to Division 4: Construction

2.5.1 Change all Sections of Division 4 to:

2.5.1a References to "Construction Manager" shall be changed to "Engineering Manager".

2.5.1b References to "foreman" shall be changed to "Qualification Test Manager".

2.5.1c References to "jobsite" shall be changed to "Plainfield Research and Development Center".

2.5.2 Add the following Paragraph 0.0 to Division 4:

"0.0 The qualification test fabrication, construction and testing will be executed by the Plainfield Research and Development Center of CBI Technical Services. The Qualification Test Manager is delegated the authority and will assume the functions and responsibilities of Shop Manufacturing Superintendent/production foreman, and jobsite foreman. The Welding and QC Supervisor works for the Qualification Test Manager. The Welding and QC Supervisor has direct access to the Engineering Project Manager to identify Quality Control problems."

ATTACHMENT 1 (Continued)

ADDENDUM TO MANUAL FOR ASME
QUALITY CONTROL SYSTEM
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID QAM ADD
REV. 0(DRAFT)
PAGE 3 OF 3

2.5 **Modifications to Division 4: Construction (Continued)**

2.5.3 Change Paragraph 1.1 to:

"**1.1** A Project Organization Chart shall be contained in the contract instructions showing current specific assignments."

2.5.4 Change Paragraph 1.2 to:

"**1.2** The Engineering Manager reports to the President of CBITSC.. The President of CBITSC is in charge of LIGO project operations and is responsible for the implementation of this division of the Quality Control Manual."

2.5.5 Add the following paragraph 14.2 to Division 4:

"**14.2** Qualification Test

14.2.1 The Qualification Test Manager is responsible for the Qualification Test.

14.2.2 The Qualification Test Manager is responsible for assuring that:

1. The construction and execution of the qualification test are performed in accordance with contract procedures.
2. Testing equipment is calibrated for tests when necessary.
3. The Engineering Project Manager receives adequate notice of qualification testing to satisfy customer witness requirements.
4. Adequate construction and testing documentation is recorded to prepare and complete the Design Qualification Test Report."

2.6 **Modifications to Division 5**: National Board

Repairs and Alterations: Deleted.

CBI	IDENTIFICATION MI			
TITLE MATERIAL TRACEABILITY	REFERENCE NO. 930212		SHT 1 OF 2	
	OFFICE		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES DESIGN & QUALIFICATION TEST	MADE BY PM	CHKD BY	MADE BY	CHKD BY
	DATE 04/04/94	DATE	DATE	DATE

1.0 SCOPE

This procedure describes the system followed to maintain traceability of the beam tube can sections, expansion joints, baffles, and pump ports.

2.0 REFERENCES

2.1 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

2.2 LIGO Specification 1100007, "Process Specification", dated May 11, 1993.

2.3 LIGO Quality Assurance Manual (QAM) to ANSI/ASQC Standard Q91.

2.4 Receipt Inspection Procedure, IR8

2.5 Coup-1, "Coupon Outgassing Test Procedure for Option Phase".

2.6 LIGO Material Specifications and Purchasing Specifications.

3.0 QAM REQUIREMENTS

The basic requirements for material identification and traceability are stated in the LIGO QAM (Reference 2.3). Additional requirements and clarifications are specified in the following sections.

4.0 MATERIAL

4.1 Material shall be identified and tracked as required by the applicable material specification.

4.2 Information pertaining to material baking shall be considered part of, and be attached to, the CMTR.

4.3 Material coupon outgas test results shall be considered part of, and be attached to, the CMTR.

5.0 FABRICATED COMPONENTS

5.1 Fabricated Components shall be documented and identified to maintain material traceability during fabrication.

5.2 Fabricated Components identification shall be transferred as necessary to maintain visible traceability during and after beam tube section subassembly fabrication.

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MI</td></tr>
<tr></tr>
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0</td></tr>
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DESIGN & QUALIFICATION TEST</td><td>MADE BY
PM</td><td>CHKD BY</td><td>MADE BY</td><td>CHKD BY</td></tr>
<tr><td>DATE
04/04/94</td><td>DATE</td><td>DATE</td><td>DATE</td></tr>
</table>

6.0 SUB-ASSEMBLIES (BEAM TUBE CAN SECTIONS)

6.1 Traceability is maintained by producing assembly checklists. Fabrication including dimensional control, leak testing and cleaning of each subassembly (beam tube can section) is documented. This documentation includes the material/fabricated component identification which is unique to each subassembly.

6.2 Subassembly documentation shall be maintained as a unique package throughout fabrication, installation and testing. This documentation shall also include any repairs unique to the subassembly.

7.0 INSTALLATION

7.1 Traceability is maintained during installation through the use of checklists. Checklists provide material identification as well as welder and joint ID.

7.2 Unique documentation shall be maintained for each sub-module which includes checklists, cleaning, leak testing, and repair records as they apply to specific subassemblies and installation joints.

7.3 Baffle identification shall be documented by location during installation.

7.4 Unique documentation shall be maintained for each beam tube module which includes checklists, cleaning, leak testing, and repair records as they apply to specific sub-modules and installation joints.

L.I.G.O. CONSTRUCTION ENVIRONMENTAL PLAN

GENERAL CONDITIONS

Environmental

The contractor shall keep and maintain the project site clean and free of any environmental hazards in accordance with federal, state, and local regulations. During all phases of construction, including supervision of work and until final acceptance of the project, the contractor shall keep the site of work and other areas by it in neat and clean condition and free from any accumulation of rubbish and debris. The contractor shall dispose of all rubbish and waste materials of any nature occurring at the work site and shall establish regular intervals of collection and disposal of such materials and waste. The contractor shall also keep its access roads free from dirt, rubbish and unnecessary obstructions resulting from its operations. Care shall be taken to prevent spillage along roads during transport. Any such spillage shall be removed immediately and the area cleaned.

Disposal of rubbish and surplus materials shall be off the site of construction, at the contractor's expense, all in accordance with local codes and ordinances governing locations and methods of disposal, and in conformance with all applicable safety laws. The contractor will be required to have a waste minimization program outlining the procedures being implemented to reuse and recycle materials so that reduction of waste generated can be achieved.

Portable chemical toilets shall be provided by the contractor whenever needed for the use of the contractor's employees. These accommodations shall be maintained in neat and sanitary condition and shall conform with 29 CFR 1926.51.

The contractor shall establish a regular schedule for collection of all sanitary and organic waste. All wastes and refuse from sanitary facilities provided by the contractor or organic waste materials from any other source related to the contractor's operations shall be disposed of from the site in accordance with all laws and regulations.

When disposing of hazardous waste the contractor is to reference the owner of the project as the generator and use the owner's EPA I.D. number assigned to the facility.

The contractor shall mitigate the adverse environmental impacts associated with the work of the contract. The contractor shall indemnify and hold harmless the owner from all fines and penalties or damages for violation of any environmental mitigation measures or permit caused by the contractor's failure to comply with environmental mitigation measures. The measures that the contractor shall take to mitigate environmental impacts include, but are not limited to, the following:

- Implement a fugitive dust and erosion control plan.
- Apply for a general construction stormwater permit and prepare a stormwater pollution prevention plan.
- Protect sensitive habitats and species through the use of fencing to prohibit construction personnel adjacent habitat areas and other such measures that may be called for by the environmental assessment report for this project. At the completion of construction activities, the contractor will be required to re-vegetate the disturbed areas to its original condition with native plants.
- Comply with the following emission control measure to minimize construction activity emissions:
  - Reduce construction equipment emissions by shutting off all equipment not in use
  - Tune and maintain construction equipment properly
  - Use low sulfur fuel for construction equipment
- The contractor, a minimum of 30 days prior to beginning work on each new major activity, shall submit a written plan for approval to the engineer detailing how the environmental impacts for the area will be mitigated. This plan shall include, at a minimum:
  - Anticipated site conditions
  - Equipment to be utilized
  - Means and methods of construction
  - Impacts likely to occur
  - Mitigation methods to be employed

Cleaning solutions brought on-site by contractors for construction/fabrication purposes are to be disposed of in a proper manner by the contractor. The contractors maintain a record of all manifests evidencing proper disposal techniques.

The use of any chlorinated solvent at this job site is banned. ?

Where appropriate, electrical power to the site is to be provided so that the contractor can avoid any unnecessary fuel handling

Environmental friendly paint systems without the constituents of toluene, xylene, methyl ethyl keytone and methyl isobuetyl keytone are to be selected to reduce toxic emissions during coating operations.

During abrasive blasting operations, all expended blast grit is to be contained and removed from the site by the contractor. Any costs for monitoring for Total Suspended Particulate (TSP) or Particulate Matter under 10 microns (PM10), if required by the state, will be the responsibility of the contractor.

Since this construction site will involve more than five acres of ground surface being disturbed, the EPA requires that the owner or an authorized representative develop a stormwater pollution prevention plan and secure a stormwater permit.

Prior to the discharge of any test water, a sample must be taken and analyzed by an analytical laboratory to confirm the absence of any additives or contaminants: The contractor will be responsible to secure the necessary permission prior to any discharge.

Where possible, the dry film process for developing x-rays is to be utilized so that generation of hazardous wastes resulting from photographic fixer can be avoided.

In accordance with oil pollution prevention regulation, a Spill Prevention Control and Counter measure plan must be established for the job site in the event that the above ground fuel storage capacity exceeds 1,320 gallons total or exceeds 660 gallons in any single tank. One of the primary provisions of the SPCC is the requirement for the development of a written plan in accordance with 40 CFR 112.3. The plan must detail the equipment, manpower, procedures, and provide adequate countermeasures to an oil spill.

All portable equipment is to be operated and serviced on an impervious surface. All fueling of equipment is to be done on impervious surfaces and all fuels and lubricants are to be stored with secondary containment for 110% of the designed vessel storage capacity. All fuel areas are to be locked when not in use.

All spills of hazardous substances at this jobsite in amounts greater than normal work quantities shall be handled in accordance with 29 CFR 1910.120. The contractor is expected to have a spill response plan, the necessary equipment and trained personnel.

In the event that any hazardous chemical or mixture present at the facility exceeds 10,000 pounds or the threshold planning quantity, as indicated in 40 CFR 355 appendix A, the contractor is to notify the owner of the facility so that this information can be submitted to the Local Emergency Planning Committee, State Emergency Response Planning Commission, and Local Fire Department.

The National Primary Drinking Water Standard for Lead is 15ug/L. A sample of water from each on-site drinking water fountain is to be collected and analyzed for total lead. Any drinking fountain containing greater that 15ug/L of lead should be disconnected or replaced.

No open burning will be permitted on-site.

At the completion of the job the owner will perform an environmental audit to document the site condition at the date of completion. The contractor will be responsible for correcting deficiencies that may have resulted from construction activities.

CBI NA-CON, INC.

HOUSTON, TEXAS

AFFIRMATIVE ACTION PROGRAM

JANUARY 1, 1993 TO DECEMBER 31, 1993

CBI NA-CON, INC.

HOUSTON, TEXAS

AFFIRMATIVE ACTION PROGRAM

1/1/93 **12/31/93**

R. J. O'Neill Construction Manager	Louis D. Carvelli Personnel Manager

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INTRODUCTION

CBI Na-Con, Inc. is fully committed to the policy of equal opportunity in all aspects of employment.

The purpose of this written Affirmative Action Program ("AAP" or "Program") is to specify in a formalized manner the continuing program of CBI Na-Con, Inc. (the "Company") for promoting and insuring equal employment opportunity to all people in all aspects of employment without discrimination because of race, color, religion, sex, national origin, handicap, or covered veteran status.

In preparing this Affirmative Action Program, the terminology and methodology used in Executive Order 11246, Section 503 of the Rehabilitative Act of 1973, and Section 402 of the Vietnam Era Veterans Readjustment Assistance Act of 1974, and their implementing regulations have been used, but only as a guide. Therefore, nothing contained in the Program or its supporting data should be construed as an admission that the Company is obligated to comply with these laws or their implementing regulations, or that the Company has violated any federal, state or local employment practice law.

The terms "utilization analysis", "underutilization", "problem areas", and "availability" appearing in this Affirmative Action Program are terms specified by government regulations. These terms have no legal or factual significance independent of this Affirmative Action Program. The Company will use the terms in good faith in connection with its Affirmative Action Program, but such usage does not necessarily signify that it agrees that these terms are properly applied to any particular factual situation.

Additionally, the use of certain statistics and statistical comparisons herein is in compliance with government regulations as interpreted by government officials. The use of such statistics in no way indicates the Company's agreement that they are appropriate or relevant. The use of such statistics has no legal or factual significance independent of this Affirmative Action Program, although they are used in good faith with regard to this program.

In developing and implementing this Affirmative Action Program, the Company has been guided by its established policy of providing equal employment opportunity. Whenever the term "goal" is used, it is expressly intended not as a rigid, inflexible quota that must be met, but rather is intended as a target reasonably attainable by applying a good faith effort in implementing this program. The use of goals and timetables in this Program is not intended, nor is the effect of such goals and timetables intended, to discriminate against an individual or group of individuals with respect to any employment opportunity for which he, she, or they are qualified on the grounds that he, she or they are not the beneficiaries of affirmative action themselves. Indeed, nothing contained in this AAP is intended to sanction the discriminatory treatment of any person. Rather, this Program has been developed in strict reliance upon the Guidelines on Affirmative Action issued by the Equal Employment Opportunity Commission ("EEOC") (29 C.F.R. Part 1608).

The material set forth in this Program is deemed to constitute trade secrets, operations information, confidential statistical data, and other confidential commercial and financial data within the meaning of the Freedom of Information Act, 5 U.S.C. 552, Title VII of the Civil Rights Act of 1964 (as amended), 42 U.S.C. 2000e et seq., the Trade Secrets Act, 18 U.S.C. 1905, and 44 U.S.C. 3508, the disclosure of which is prohibited by law and would subject the individual making the disclosure to criminal and civil sanctions.

Copies of this AAP and all related appendices, documents and support data are made available on loan to the U. S. Government upon the request of said Government on the condition that the Government hold them totally confidential and not release copies to any persons whatsoever. This AAP and its appendices and other supporting documents contain much confidential information which may reveal, directly or indirectly, the Company's plans for business or geographical expansion or contraction. Disclosure of this information is likely to cause substantial competitive harm to the competitive position of the Company. The Company considers this Program to be exempt from disclosure, reproduction and distribution under the Freedom of Information Act upon the grounds, among others, that such material constitutes (1) personnel files, the disclosure of which would constitute a clearly unwarranted invasion of personal privacy, which are exempt from disclosure under 5 U.S.C. 522(b)(6); (2) confidential, commercial or financial information, which is exempt from disclosure under 5 U.S.C. 522(b)(4); (3) investigatory records compiled for law enforcement purposes, the production of which would constitute an unwarranted invasion of personal privacy, which are exempt from disclosure under 5 U.S.C. 522(b)(7)(C); and (4) matters specifically exempted from disclosure by statute, which are exempt from disclosure under 5 U.S.A. 522(b)(3). Notice is hereby given of a request pursuant to 41 C.F.R. 60-60.4(d) that these portions of this Program be kept confidential.

Thus, the Company wishes to make it clear that it does not consent to the release of any information whatsoever contained in this Program under the Freedom of Information Act or otherwise. If this U. S. Government, or any agency or subdivision thereof, is considering breaching the conditions under which this AAP is loaned to it, or is considering a request for a release of this Program under the Freedom of Information Act, request is hereby made that the Government immediately notify the EEP/AAP Officer of this Company of any and all Freedom of Information Act requests received by the Government or any other contemplated release of this Program by the Government which relates to information obtained by the Government from this Company.

The Company further requests that everyone who has any contact with this AAP, or its supporting appendices, documents, and other data, treat such information as totally confidential and that such information not be released to any person whatsoever. Retention or disclosure of information relating to identifiable individuals may also violate the Privacy Act of 1974.

Finally, nothing in this AAP is intended to create any contractual rights in favor of any employee or applicant, or to impose any contractual obligations on the Company with respect to employees or applicants. The Company reserves the right to change the terms of this AAP at any time.

I Company Policy

It has been and is the policy of CBI Na-Con, Inc. to afford equal employment opportunity to all persons, without regard to race, color, religion, sex, national origin, age handicap or status as a qualified disabled veteran or veteran of the Vietnam Era in employment; upgrading, demotion, or transfer, recruitment or recruitment advertising, layoff or termination, rates of pay or other forms of compensation and selection for training, including apprenticeship. This policy must be made known to and followed by all of our management and supervisory employees and applied equally at every office, warehouse, plant and field construction site in the United States. This policy is set forth by the President of CBI Na-Con, Inc.

This policy shall be administered by the following officials:

A. C. W. Bauer, President - CBI Na-Con, Inc.

B. M. M. Houseal, Corporate Equal Employment Opportunity Officer

C. L. D. Carvelli, Equal Employment Opportunity Coordinator - Houston

A letter of commitment signed by the Corporate President, C. W. Bauer, follows.

R. J. O'Neill
Construction Manager

CBI

CBI Na-Con, Inc.

a national construction services organization

800 Jorie Boulevard
Oak Brook, Illinois 60522-7001

708 572 7000
Telex: 82684
82688
FAX: 708 572 7405

January 1, 1993

EQUAL EMPLOYMENT OPPORTUNITY

ALL OFFICES:

It has been and is the policy of CBI Na-Con, Inc., to afford equal employment opportunity to all persons, without regard to race, color, religion, sex, national origin, age, handicap or status as a qualified disabled veteran or veteran of the Vietnam Era with respect to all personnel actions, including but not limited to employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. This policy must be made known to and followed by all of our management and supervisory employees and applies equally at every office, warehouse, plant, and field construction site in the United States. The CBI Na-Con's Affirmative Action Program is available for inspection to any employee or applicant for employment upon request at the CBI Na-Con operating offices during normal business hours.

We expect our employees to respect the employment rights of others so that there shall be no discrimination in the conduct of our business.

If you are an individual with a disability, qualified disabled veteran or veteran of the Vietnam Era and would like to be considered under the Affirmative Action Program, please tell us. Submission of this information is voluntary and refusal to provide it will not subject you to adverse treatment. It will also be kept confidential and will only be used in accordance with the law. CBI Na-Con will make reasonable accommodation where necessary for employees or applicants with disabilities, provided the individual otherwise qualified and the accommodation does not impose an undue hardship on the business.

Our policy was formally stated on January 3, 1983, and since that time, we have been reviewed for compliance with Executive Order 11246, as amended, as well as other applicable federal, state and local equal employment opportunity laws and regulations.

CBI Na-Con, Inc., will continue to comply with all applicable equal employment opportunity laws and regulations.

C. W. Bauer

C. W. BAUER
President

Marian Houseal

M. M. HOUSEAL
Corporate EEO Officer

R. J. O'Neill

R. J. O'NEILL
Houston Construction Manager

bp

II Dissemination of Policy

A. Internal:

1. Annually, the company policy will be updated, reaffirmed and distributed as follows:

   a. A copy will be displayed in the Personnel Department for exposure to job applicants.

   b. A copy will be displayed on the company bulletin boards along the other required federal, state and local equal employment opportunity posters.

   c. A copy will be included in the pay envelope of each employee.

   d. A copy will be included in the Administrative Manual, which sets forth overall company policy.

2. The words "An Equal Opportunity Employer" will appear on the company recruiting and advertising brochures and bulletins.

3. Periodic meetings with first line supervisors and managers will be conducted to discuss company policy, problems and individual responsibility for effective implementation.

4. The division managers, working through their managers and supervisors, will convey the policy to the employees explaining the individual employee's responsibility.

5. The company policy will be conveyed to each employee during the initial interview, and subsequent orientation program, and reiterated to those individuals entering one of the company's training programs.

B. External:

1. Annually the Company will reaffirm its equal employment opportunity policy with all recruiting sources by written notice, including the policy statement as set forth by the President of CBI Na-Con, Inc.

Each recruiting source will be instructed to actively refer qualified individuals, including minorities and women, for all available positions.

2. The Equal Opportunity clause, covered by Executive Order 11246, as amended, will be incorporated in all purchase orders, contracts, etc. Annually, the Company shall reaffirm its Equal Employment Opportunity policy with all subcontractors, vendors, and suppliers requesting appropriate action on their part.

3. Annually, minority and womens organizations, community agencies and leaders, colleges, junior colleges and high schools will be advised in writing of the company policy.

4. The company policy and the existence of an Affirmative Action Program will be communicated to employees and prospective employees, enabling them to know of and avail themselves of its benefits.

5. Include the phrase "an Equal Opportunity - Affirmative Action Employer" in all employment advertisement.

III Responsibilities for Policy Implementation

A. An individual has been appointed Equal Employment Opportunity Coordinator for the Facility. As the Equal Employment Opportunity Coordinator, his or her responsibilities for implementing the Affirmative Action Program shall include, but not be limited to:

1. Developing policy statements.

2. Assisting in the identification of problem areas and arriving at solutions.

3. Designing and implementing audit and reporting systems that will:

   a. Measure the effectiveness of the programs.
   b. Indicate the need for remedial action.
   c. Determine the degree to which the established goals and objectives have been attained.

4. Serving as liaison between CBI Na-Con, Inc. and enforcement agencies, minority organizations, womens organizations and community action groups.

B. Line managers responsibilities for implementing the Affirmative Action Program shall include, but not be limited to:

1. Assisting in the identification of program areas and the establishment of goals and objectives.

2. Active involvement with local minority and womens organizations, community action groups and service programs.

3. Periodic auditing of training programs, hiring and promotion patterns to insure the attainment of goals and objectives.

4. Discussions by managers and supervisors with employees to be certain the established policy is being followed.

5. Reviewing the qualifications of all employees to insure that minorities and women are given full opportunity for transfer and promotion.

6. Career counseling for employees.

7. Periodic auditing to insure that the facility is in compliance regarding:

   a. The proper display of federal, state and local equal employment opportunity posters.

   b. The maintenance of desegregated facilities in policy and use.

   c. The participation of all employees, including minorities and women, in all company sponsored educational, training and recreational and social activities.

8. Reviewing first line supervisors efforts and results with respect to equal employment opportunity, making certain that they understand that this aspect is to be included in the supervisors periodic work performance evaluation.

9. Action by the first line supervisor to prevent harassment of the employees placed through affirmative action efforts.

IV Utilization and Work Force Analysis

A. Utilization Analysis

The purpose of the utilization analysis to identify job groups within the company's work force in which there are fewer minorities and women than would reasonably be expected by their availability. In determining if minorities and women are underutilized in any job group, the company will consider at least all of the following:

1. The minority population of the labor area surrounding the facility.

2. The size of the minority unemployment force in the labor area surrounding the facility.

3. The percentage of the minority work force as compared with the total work force in the immediate labor area.

4. The general availability of minorities having requisite skills in the immediate labor area.

5. The availability of minorities having requisite skills in an area in which the contractor can reasonably recruit.

6. The availability of promotable and transferable minorities within the organization.

7. The existence of training institutions capable of training persons in the requisite skills.

8. The degree of training which the contractor is reasonably able to undertake as a means of making all job classes available to minorities.

9. The size of the female unemployment force in the labor area surrounding the facility.

10. The percentage of the female work force as compared with the total work force in the immediate labor area.

11. The general availability of women having requisite skills in the immediate labor area.

12. The availability of women having requisite skills in an area in which the contractor can reasonably recruit.

13. The availability of women seeking employment in the labor or recruitment area of the contractor.

14. The availability of promotable and transferable female employees within the contractor's organization.

15. The existence of training institutions capable of training persons in the requisite skills.

16. The degree of training which the contractor is reasonable able to undertake as a means of making all job classes available to women.

B. Work Force Analysis:

A work force analysis will be prepared listing each job title as it appears in payroll records ranked from the lowest paid to the highest paid within each department or similar organizational unit including departmental or unit supervision. For each job title, the total number incumbents, and the total number of male and female minority incumbents will be identified.

C. Identification of Problem Areas: An in-depth analysis of the following will be made:

1. Composition of the work force by minority group status and sex.

2. The recruitment and selection process.

3. Transfer and promotion practices.

4. All company training programs, formal and informal.

5. As a result of its in depth analysis, the company has identified under Utilization in various Job Groups.

6. The company will continue to recruit minorities and females for these Job Groups. However, the economic outlook could limit our recruiting and hiring.

V Goals and Timetables

If, after considering each of the eight factors for determining underutilization of minorities or the eight factors for determining the underutilization of females, underutilization is determined to exist, goals and timetables will be established. These goals will be significant, measurable and attainable with timetables for completion.

VI Recruiting Practices

An extensive recruiting program has been established to provide personnel for immediate and future needs of the company. Recruiters are continually instructed to seek qualified individuals including minority and female candidates.

A. Professional Recruiting - The recruiting of engineers and other professional employees is conducted through an established college recruiting program.

B. Non-Professional Recruiting - Many different sources are available and used in the recruiting of non-professional employees. Advertisements are placed in newspapers having a general circulation for jobs which the company does not expect to fill by either transfer or promotion from within. These are also placed with the State Employment Services and privately owned employment services. Through personal contact, rapport has been established with local schools, including those having predominately minority enrollments, for the referral of co-op, temporary and full-time employees.

VII Selection and Placement Procedures

Every individual entering the reception area seeking employment, is given an opportunity to complete an application form and is screened by Personnel if an opening exists. Those individuals who meet the minimum requirements to fill an existing job opening are referred to the department supervisor or manager to be interviewed. If no job opening exists, or if the applicant lacks the minimum requirements for the job he or she is seeking, the individual is so told, and the application or resume is retained in a pending file for 60 days after which it is no longer considered.

VIII Transfers and Promotions

The qualifications of employees are continually being reviewed by Personnel and department managers and supervisors to provide employees with additional training and experience enabling the company, when the need arises, to fill vacancies from within the organization through transfer or promotion. Openings for professional employees are communicated through the manager to Personnel or to recruiters. Openings for non-professional employees are communicated to Personnel for review and recommendation.

IX Educational Assistance Program

Educational assistance through a company provided tuition reimbursement program is open to employees to continue their education at the college level. The prerequisites for receiving such assistance are that the employee has completed two years of service with the company and that the course work is applicable to employee's current work activity. The company also offers job related educational and training assistance for course work other than that on the college level. This assistance is provided by approved expense reimbursement.

X Development and Execution

1. The Company shall evaluate the total selection process to insure freedom from stereotyping persons in a manner which limits their access to all jobs for which they are qualified.

2. All personnel involved in the recruitment, screening, selection promotion, disciplinary, and related processes shall be carefully selected and trained to insure that the Affirmative Action commitments are implemented.

3. Minority and female employees will be actively encouraged to refer qualified applicants.

4. All recruiting efforts will incorporate special efforts to reach minorities and females.

5. The Company has and will continue to review seniority practices to ensure that such practices are non-dis-criminatory and do not have a discriminatory effect.

6. The Company has and will continue to make certain that its facilities and all Company sponsored activities are desegregated.

XI Internal Audit and Reporting System

On a daily basis the names of all applicants will be entered on a log. Annually, an audit will be conducted to review the goals and accomplishments of the previous year and to establish goals for the coming year. Transfers, promotions and terminations are also monitored.

XII Compliance with Sex Discrimination Guidelines

It has been and continues to be the policy of CBI Na-Con, Inc. not to discriminate on the basis of sex and to this end we shall continue to require the following:

A. Recruitment - This facility recruits both men and women for available jobs. No sex discrimination exists within the company's recruitment. Referral sources are informed that CBI Na-Con, Inc. has no specific sex preference and seeks only qualified applicants without regard to race, sex, religion, national origin, color, age, handicap or veterans status.

B. Job Policies and Practices - All written personnel policies clearly stipulate that all policies and practices apply to every employee on an equal basis, regardless of the sex of the employee. All employees have equal opportunity to any job for which they are qualified. Sex is not considered a bona fide occupational qualification for any job within the facility.

No distinction is made between the sexes in regard to equal opportunity, wages, hours or other conditions of employment.

There is no distinction between the treatment of a female versus a male relative to marital status.

CBI Na-Con, Inc. provides appropriate and equal physical facilities to both female and male employees.

Females are not penalized in their employment because of time spent away from work on account of childbearing. Our leave policy includes provision for maternity leave. Seniority, position and other benefits are retained when the employee returns to work.

No difference is made between females and males as to retirement age for any particular reason.

C. Discriminatory Wages - Our wage scales are based on actual job skills required regardless of sex of the employee.

No employee is restricted from seeking employment in any job group.

D. CBI Na-Con, Inc. will not tolerate sexual harassment of employees. This means that all unwelcome sexual conduct is completely unacceptable. Examples of such behavior include, but are not limited to: Unwelcome sexual advances, requests for sexual acts or favors, use of insulting or degrading sexual remarks, or suggestions that an employee's work status is contingent upon acquiescence to sexual advances.

If you encounter such behavior from anyone, including supervisors, fellow employees, or customers, you <u>must</u> bring the problem to the attention of responsible Company officials. This is the proper and <u>required</u> course. If the problem is with your direct superior, you should bring your complaint to the attention of his or her superior. The Company will then investigate the matter and take appropriate action to end any sexual harassment found, including disciplining the offending individual, if necessary and appropriate.

All complaints will be handled promptly, and special privacy safeguards applied. The privacy of all persons involved will be respected, and all complaints kept confidential.

XIII <u>Compliance with Guidelines on Discrimination Because of Religion or National Origin</u>

CBI Na-Con, Inc. has had and will continue to have a policy of prompting and insuring equal employment opportunities for all persons employed or seeking employment without regard to religion or national origin. As a direct result of this policy, persons of various religious and ethnic backgrounds are employed at CBI Na-Con, Inc. in various job capacities.

CBI Na-Con, Inc. does not analyze the religious persuasions of its employees. The ethnic background of its employees is analyzed only to the extent to determine recognized minority groups such as Blacks, Spanish sur-named American, American Indians or Orientals.

As a result of informal discussions and interchanges among employees, we have become aware that our work force contains persons who are of numerous and diverse faiths as well as persons of diverse ancestries, including European, African and Latin American ancestries.

The Company will make reasonable accommodations to employees or prospective employees' religious observances or practices as long as it does not create an undue hardship on the conduct of the Company's business. In determining whether or not such accommodations create an undue hardship, the Company will consider the following factors: (a) business necessity; (b) financial costs and expenses; and (c) resulting personnel problems.

XIV Support of Community Action Programs

Through the CBI Foundation and our parent company, contributions are made to both local and national health and charitable organizations. Contributions made during 1991 include:

Junior Achievement
DuPage Easter Seal Treatment Center
Friend of St. Thomas Hospice
Recording for the Blind
NACME, Inc.
Native American Educational Services, Inc.
Society of Women Engineers - Chicago Regional Section
United Negro College Fund
Donka, Inc.
Illinois Special Olympics
Park Lawn Association
Ray Graham Association for People with Disabilities
Recording for the Blind, Inc.
The Lambs, Inc.
The Urban Foundation (USA), Inc.
United Way of Texas Gulf Coast

XV Consideration of Women and Minorities not Currently in Work Force

The Company actively recruits minorities and females through the Texas Employment Commission and Colleges and Universities.

Through various company offices, the Company participates in job fairs sponsored by the National Action Council of Minorities in engineering and at local colleges and universities.

The Company will continue to use female and minority recruitment sources as identified elsewhere in our Affirmative Action Program and further, to augment the present number of sources in order to utilize other sources which can help toward the identification of women or minorities currently not in the workforce.

XVI Report of Previous Years AAP Progress

The Company recognized underutilization of females and minorities in certain Job Groups. Economic conditions restricted our recruiting and hiring.

CERTIFICATE OF NON-SEGREGATED FACILITIES

CBI Na-Con, Inc. does not and will not maintain any facilities that it provides for its employees in a segregated manner. Nor will CBI Na-Con, Inc. permit its employees to work at any location under its control where segregated facilities for employees are maintained.

____

R. J. O'Neill
Construction Manager

CBI NA-CON, INC.
HOUSTON, TEXAS

AFFIRMATIVE ACTION PROGRAM

FOR THE HANDICAPPED

AND

DISABLED VETERANS AND

VETERANS OF THE VIETNAM ERA

JANUARY 1, 1993 TO DECEMBER 31, 1993

CBI NA-CON, INC.

AFFIRMATIVE ACTION PROGRAM

FOR THE HANDICAPPED

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1/1/93 12/31/93

R. J. O'Neill
Construction Manager

Louis D. Carvelli
Personnel Manager

COMPANY POLICY

It has been and is the policy of CBI Na-Con, Inc. to afford Equal Employment Opportunity to all persons without regard to handicap or status as a qualified disabled veteran or veteran of the Vietnam Era with respect to all personnel actions, including, but not limited to, recruiting, hiring, promotion, demotion, transfer, recruitment advertising, layoff, return from layoff, termination, rates of pay or other forms of compensation or benefits. This policy must be made known to, and followed by, all of our management and supervisory employees. A letter of commitment from C. W. Bauer, President of CBI Na-Con, Inc., follows.

CBI

CBI Na-Con, Inc.

a national construction services organization

800 Jorie Boulevard
Oak Brook, Illinois 60522-7001

708 572 7000
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January 1, 1993

EQUAL EMPLOYMENT OPPORTUNITY

ALL OFFICES:

It has been and is the policy of CBI Na-Con, Inc., to afford equal employment opportunity to all persons, without regard to race, color, religion, sex, national origin, age, handicap or status as a qualified disabled veteran or veteran of the Vietnam Era with respect to all personnel actions, including but not limited to employment, upgrading, demotion, or transfer; recruitment or recruitment advertising; layoff or termination; rates of pay or other forms of compensation; and selection for training, including apprenticeship. This policy must be made known to and followed by all of our management and supervisory employees and applies equally at every office, warehouse, plant, and field construction site in the United States. The CBI Na-Con's Affirmative Action Program is available for inspection to any employee or applicant for employment upon request at the CBI Na-Con operating offices during normal business hours.

We expect our employees to respect the employment rights of others so that there shall be no discrimination in the conduct of our business.

If you are an individual with a disability, qualified disabled veteran or veteran of the Vietnam Era and would like to be considered under the Affirmative Action Program, please tell us. Submission of this information is voluntary and refusal to provide it will not subject you to adverse treatment. It will also be kept confidential and will only be used in accordance with the law. CBI Na-Con will make reasonable accommodation where necessary for employees or applicants with disabilities, provided the individual otherwise qualified and the accommodation does not impose an undue hardship on the business.

Our policy was formally stated on January 3, 1983, and since that time, we have been reviewed for compliance with Executive Order 11246, as amended, as well as other applicable federal, state and local equal employment opportunity laws and regulations.

CBI Na-Con, Inc., will continue to comply with all applicable equal employment opportunity laws and regulations.

C. W. Bauer — Marian Houseal — R. J. O'Neill

C. W. BAUER
President

M. M. HOUSEAL
Corporate EEO Officer

R. J. O'NEILL
Houston Construction Manager

bp

I. Dissemination of Policy

A. Internal

1. Annually, the Company policy shall be updated, reaffirmed and distributed as follows:
   a. A copy shall be displayed on the Company's bulletin boards along with other required Federal, State and Local Equal Employment Opportunity posters.
   b. A copy shall be included in the pay envelope of each employee.
   c. A copy shall be included in the CBI Standards, which sets for the company's overall policy.
2. The Company's policy shall be conveyed to each employee during the initial interview and subsequent orientation program.

B. Outreach, Positive Recruitment, and External Dissemination of Policy

1. Annually, the Company shall reaffirm its Equal Employment Opportunity policy with all recruiting sources by written notices including the policy statement as set forth by the President of CBI Na-Con, Inc. Each recruiting source shall be instructed to actively recruit and refer qualified individuals, including qualified individuals with handicaps, disabled veterans or veterans of the Vietnam Era, for all positions.
2. The Affirmative Action clauses set forth in Section 402 of the Vietnam Era Veterans Readjustment Assistance Act of 1974 and Section 503 of the Rehabilitation Act of 1973, as amended, shall be incorporated in all contracts and subcontracts.
3. Annually, the Company shall reaffirm its Equal Employment Opportunity policy with suppliers, vendors and subcontractors requesting appropriate action on their part.
4. The Company's policy and the existence of this Affirmative Action Program shall be communicated to existing and prospective employees.
5. The words "An Equal Opportunity Employer" shall appear on the Company advertising and recruiting brochures and bulletins, and in all written recruiting advertisements.

6. The Company shall continue to consider all qualified individuals with handicaps and qualified disabled veterans and veterans of the Vietnam Era not currently in the work force, having requisite skills, who can be recruited through Affirmative Action measures.
7. When employees are pictured in product, consumer or recruiting advertisements, handicapped employees shall be included when possible.

II. <u>Responsibility for Implementation</u>

A. M. Houseal has been designated the Company's Equal Employment Opportunity Officer ("EEO Officer"). L. D. Carvelli is the local EEO Coordinator. Their responsibilities for implementing the Affirmative Action Program shall include but not be limited to:

1. Developing policy statements, Affirmative Action Programs and internal and external communication techniques.
2. Assisting in the identification of problem areas.
3. Designing and implementing an auditing and reporting system that will:
    a. Measure the effectiveness of the Company's programs.
    b. Determine the degree to which the Company's objectives have been attained.
    c. Determine whether known individuals with handicaps, disabled veterans and veterans of the Vietnam Era have had the opportunity to participate in all Company sponsored educational, recreational and social activities.
4. Serving as liaison between the Company and enforcement agencies.
5. Serving as liaison between the Company and organizations serving individuals with handicaps and disabled veterans and veterans of the Vietnam Era.
6. Supervisors are made to understand that their work performance is, in part, being evaluated on the basis of their equal employment opportunity efforts. Supervisors are also informed that the Company must take actions to prevent harassment of employees placed through affirmative action efforts.

III. Review of Personnel Policies

The Company shall review all personnel processes to determine whether present procedures assure careful, thorough and systematic consideration of the job qualifications of known individuals with handicaps and disabled veterans and veterans of the Vietnam Era for job vacancies and for all training opportunities offered or available.

IV. Physical and Mental Qualifications

The Company will review periodically all physical and/or mental job qualification requirements to insure that, to the extent they tend to screen out otherwise qualified individuals with handicaps or disabled veterans, they are job related and are consistent with business necessity and safe performance of the job. Whenever the Company inquires into an applicant's or employee's physical or mental condition, any information supplied will be kept confidential.

V. Accommodation

The Company, in carrying out its Affirmative Action Program, shall make reasonable accommodations to the physical and mental limitations of applicants and employees, provided, however, that such accommodation would not impose an undue hardship on the conduct of the Company's business. In determining whether an accommodation would cause an undue hardship, the following factors, among others, will be considered: (1) business necessity; and (2) financial costs and expenses.

VI. Compensation

In offering employment or promotion to qualified individuals with handicaps or qualified disabled veterans and veterans of the Vietnam Era, the Company shall not reduce the amount of compensation offered because of any disability income, pension or other benefit the applicant or employee receives from another source.

VII. Development and Execution

A. The Company shall evaluate the total selection process to insure freedom from stereotyping individuals with handicaps, disabled veterans and veterans of the Vietnam Era in a manner which limits their access to all jobs for which they are qualified.

B. All personnel involved in the recruitment, screening, selection, promotion, disciplining, and related processes shall be carefully selected and trained to insure that the Affirmative Action commitments are implemented.

C. Special efforts will be made to include qualified individuals with handicaps, disabled veterans and veterans of the Vietnam Era in the personnel department.

D. Recruiting efforts at all schools shall incorporate special efforts to reach qualified individuals with handicaps, disabled veterans and veterans of the Vietnam Era.

VIII. Listing of Suitable Employment Openings

Listing of suitable employment openings with the state employment service system pursuant to the affirmative action clause for disabled veterans and veterans of the Vietnam Era will be made at least concurrently with the use of any other recruitment source and efforts will involve the normal obligations that attach to the placing of a bona fide job offer, including the acceptance of referral of veterans and non-veterans. The Company will also request state employment services to refer qualified individuals with handicaps for consideration.

IX. Internal Procedure to Review Complaints

The Company has an internal procedure to review complaints filed by employees alleging that they have been discriminated against on account of their status as an individual with a handicap, qualified disabled veteran or veteran of the Vietnam Era. Any complaint and all actions taken thereunder will be kept confidential by the Company. The procedure is as follows:

A. Complaining individual will meet with his or her immediate supervisor and attempt to resolve the dispute. (This step may be bypassed at the complaining employee's request if the complaint involves the employee's immediate supervisor.)

B. If no resolution occurs at the first step, the complaining individual will present a written complaint to L. D. Carvelli and attempt to resolve the dispute.

C. If no resolution occurs in the first two steps, then the complaining individual will meet with R. J. O'Neill, Operations Manager, and attempt to resolve the dispute.

X. Invitation to Self-Identify

The Company maintains an Affirmative Action Program supplement for individuals with handicaps, disabled veterans and veterans of the Vietnam Era. All individuals with handicaps, disabled veterans, and/or veterans of the Vietnam Era who wish to benefit under the Company's Affirmative Action Program are invited to identify themselves. The information shall be voluntarily provided, it will be kept confidential, refusal to provide it will not subject the applicant or employee to any adverse treatment, and the information will be used only in accordance with Section 402 of the Vietnam Era Veterans Readjustment Assistance Act of 1974, Section 503 of the Vocational Rehabilitation Act of 1973, and the accompanying regulations to these federal laws.

The full AAP supplement is available for inspection to any employee or applicant for employment upon request at the office during normal business hours.

CBI	IDENTIFICATION C-240-0186			
TITLE COIL MATERIAL SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE NOE-C		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY SWP	CHKD BY WJC	MADE BY	CHKD BY
	DATE 03/03/94	DATE 03/03/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for material intended for use in a ASME VIII, Division 1 pressure vessel in vacuum service with low hydrogen outgassing.

1.0 MATERIALS

1.1 This material shall conform to the requirements of ASME Specification SA-240 Type 304L with the additional supplementary requirements described in this specification.

1.2.0 Applicable Codes

1.2.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

1.2.2 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

1.2.3 LIGO Specification 1100007, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

1.2.4 ASME SA-240, "Specification for Heat-Resisting and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels".

1.2.5 ASME SA-480, "Standard Specification for General Requirements for Flat-Roll Stainless and Heat-Resisting Steel Plate, Sheet, and Strip".

1.2.6 ASTM A-700, "Standard Packages for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment".

1.2.7 The latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

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

2.0 MANUFACTURE

2.1 The nominal material thicknesses shall be 0.127"

The material thickness shall not exceed 0.130".
The material thickness shall not be less than 0.120".

2.2 Camber and Width Tolerance

The coil material shall be slit to the width specified in the purchase order. The camber and width tolerance of the finished material shall not exceed 1/2 the tolerances specified in ASME SA-480 specification.

2.3 Flatness and Camber Tolerance

The material shall be stretcher leveled to improve the dimensional properties. The flatness tolerance shall meet specified tolerances for hot rolled stretcher leveled material in ASME SA-480 specification.

2.4 The surface finish of the material shall be no smoother than 2.5 microns RMS. Hot rolled, Annealed, and Pickled (HRAP) surface finish is acceptable.

2.5 The sulfur content of the material shall not be less than 0.010% or greater than 0.020% by heat and product analysis.

2.6 The carbon content of the material shall not be greater than .020% as measured by heat and product analysis.

3.0 PREPARATION FOR BAKING (by others)

3.1 Each coil of material that is produced will be baked by others as specified in the latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

4.0 MECHANICAL TESTING

4.1 Mechanical tests shall be performed on each coil of material as described in ASME 480 with the additional supplementary requirements as described herein.

4.2 One tension test shall be performed on specimens taken from both ends of all coils.

5.0 INSPECTION/WITNESS

5.1 The purchaser shall have the right to witness all manufacturing processes.

5.2 The purchaser shall be informed 10 working days before the coil material is hot rolled.

CBI	IDENTIFICATION C-240-0186			
TITLE COIL MATERIAL SPECIFICATION	REFERENCE NO. 930212		SHT 3 OF 3	
	OFFICE NOE-C		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY SWP	CHKD BY WJC	MADE BY	CHKD BY
	DATE 03/03/94	DATE 03/03/94	DATE	DATE

6.0 REJECTIONS AND REPAIR OF DEFECTS

6.1 No weld splices or repair welding is permitted to the material.

7.0 IDENTIFICATION

7.1 Identification of the material shall be maintained through all manufacturing processes.

7.2 If material identity is lost, the plate shall be re qualified by making all tests that were required for the material or as indicated in this specification

8.0 DOCUMENTATION

8.1 The Certified Material Test Report (MTR) shall be mailed to the purchaser within 48 hours after shipment of the material.

8.2 A record of the material thickness for each coil of material is required. Thickness shall be measured and recorded at both edges and the center of the coil material at 100 feet intervals along the length of the coils.

9.0 PACKAGING, STORING AND SHIPPING

9.1 The material shall be packaged for shipment as described in ASTM A700-90, Section 12.4.5.6 or 7 with the additional supplementary requirements as described herein.

9.2 The coils shall be shipped as specified in the purchase order.

CBI	IDENTIFICATION C-CMBS1			
TITLE COIL MATERIAL BAKE SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 4	
	OFFICE NOE-C		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY SWP	CHKD BY WJC	MADE BY	CHKD BY
	DATE 03/03/94	DATE 03/03/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for the air bake of the SA-240 Type 304L material to reduce the materials hydrogen outgassing rate. It covers the bake of the materials used to manufacture the spiral welded tubing, the expansion joints, and the internal baffles for the LIGO Beam Tube Modules.

1.0 APPLICABLE CODES AND SPECIFICATIONS

1.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

1.2 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

1.3 LIGO Specification 1100007, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

1.4 The latest revision of Specification C-240-0186, "Coil Material Specification for LIGO Beam Tube Modules".

1.5 ASME SA-240, "Specification for Heat-Resisting and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels".

2.0 GENERAL REQUIREMENTS

2.1 The material shall be positioned on a raised grating with it's surface vertical to promote convection flow over the surface.

2.2 If the furnace is fuel fired the combustion products shall not come into contact with the baked material.

2.3 The material shall be air baked to 440°C ±8°C for a minimum soak time of 36 hours.

2.4 Sufficient time shall be given during the heat up to ensure that the material is heated to a uniform (440°C±8°C) temperature.

2.5 The first coil of a given geometry and size shall have one or more thermocouples attached to the coil material at the location(s) of anticipated lowest temperature (center of the coil) to establish the minimum heat up and cooldown times for the baking process. The thirty six hour bake shall not begin until all thermocouples attached to the coil material read 432°C or greater. A 5/32" thick by 1"wide shim will be installed across the width of the coil at the center of the coil to provide a gap between the coil layers for installing a 1/8" diameter thermocouple.

2.6 If the furnace air temperatures will exceed 448°C, thermocouples shall also be attached to the coil material at location(s) of anticipated maximum temperatures to assure that the material temperatures do not exceed the 448°C maximum allowable temperature.

2.7 The baked material shall cool to 100°C before it is remove from the furnace.

2.8 A bake procedure shall be written and submitted for approval prior to use. No bake shall be performed without a written and approved procedure. As a minimum the procedure shall include the following:

- A description of the heating process and equipment. It shall include the furnace configuration, the number of furnaces available, the size of the furnaces, the type and capacity of the heating system, and other equipment that will be used.
- A description of the temperature monitoring and control system that will be used to perform the bake.
- The location and type of thermocouples that will be used.
- An example of the bake out temperature data that will be provided as documentation for the bake.
- The time required for the baking process.

3.0 INSPECTION/WITNESS

3.1 The purchaser shall be informed 10 working days before the bake will begin.

3.2 The purchaser has the right to witness any or all of the material bakes.

4.0 RECORDS AND DOCUMENTATION

4.1 A Certificate of Performance certifying that the bake was performed to this specification is required for each bake.

4.2 A thermal chart or graph is required for all bakes. The chart shall record all temperatures monitored during the bake from the start of heating through cooling to 100°C.

4.3 A Record of bake the process is required that includes the following:

- Material heat and slab
- Material coil ID
- Furnace ID
- Operator name and/or ID
- Temperature recorder ID and calibration date
- Non-conforming items and/or unusual events that occurred during the bake out.

5.0 COUPONS FOR HYDROGEN OUTGAS TESTING

5.1 Two sets of coupons (110 coupons in one set and 50 coupons in the other set) for hydrogen outgas testing shall be taken from the end of all coils after the bake. Both sets of coupons can be taken from the same end of the coil. Each coupon shall be 1" wide by 18" long. A total 160 coupons shall be obtained from the end of each coil.

5.2 The coupon material shall not be contaminated after the bake. The coupon material shall be removed from the coil and coupons cut to size without using lubricants or heat. Grinding and shearing processes can be used to remove the coupon material and size the coupons. The set of 110 coupons shall be packaged and shipped overnight to CBI Technical Services in Plainfield, IL for testing. The set of 50 coupons shall be shipped by the most cost effective means to Caltech in Pasadena, California.

5.3 Traceability of the coupon material shall be maintained throughout all processes. One coupon in each set of coupons shall be vibro etched to identifying the coil from which the coupons were removed. No other marking is permitted on the coupons. Each set of coupons shall be kept separated and package separately. The package shall be clearly labeled to identify the coil from which the coupons were removed.

5.4 The baked coils shall be packaged immediately after the bake is completed and the material for the coupons has been removed. The coils shall be stored until approval is obtained from the purchaser to ship.

5.5 If the material does not meet the hydrogen outgas requirements, re-bake of the coil material may be performed per written approval.

CBI	IDENTIFICATION C-240-0187			
TITLE BAFFLE MATERIAL SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE NOE-C		REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY RJW	MADE BY	CHKD BY
	DATE 03/23/94	DATE 03/23/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for material for internal baffles intended for use in a ASME VIII, Division 1 pressure vessel in vacuum service with low hydrogen outgassing.

1.0 APPLICABLE DOCUMENTS

1.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

1.2 ASME SA-240, "Specification for Heat-Resisting and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels".

1.3 ASME SA-480, "Standard Specification for General Requirements for Flat-Roll Stainless and Heat-Resisting Steel Plate, Sheet, and Strip".

1.4 ASTM A-700, "Standard Packages for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment".

1.5 The latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

1.6 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

1.7 LIGO Specification 1100007, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

2.0 MATERIALS

2.1 This material shall conform to the requirements of ASME Specification SA-240 Type 304L with the additional supplementary requirements described in this Specification.

3.0 MANUFACTURE

3.1 The nominal material thicknesses shall be 0.105"

The material thickness shall not exceed 0.110".
The material thickness shall not be less than 0.100".

3.2 The surface finish of the baffle material is critical. The surface finish of the material shall be no smoother than 2.5 microns RMS. Hot-Rolled, Annealed, and Pickled (HRAP) surface finish is acceptable.

4.0 PREPARATION FOR BAKING

4.1 Each coil of material that is produced will be baked by others as specified in the latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

5.0 MECHANICAL TESTING

5.1 Mechanical tests shall be performed on each coil of material as described in ASME 480 with the additional supplementary requirements as described herein.

5.2 One tension test shall be performed on specimens taken from both ends of all coils.

6.0 INSPECTION/WITNESS

5.1 The Purchaser shall have the right to witness all manufacturing processes.

5.2 The Purchaser shall be informed 10 working days before the coil material is hot rolled.

7.0 REJECTIONS AND REPAIR OF DEFECTS

7.1 No weld splices or repair welding is permitted to the material.

8.0 IDENTIFICATION

8.1 Identification of the material shall be maintained through all manufacturing processes.

8.2 If material identity is lost, the plate shall be requalified by making all tests that were required for the material or as indicated in this specification

CBI

TITLE BAFFLE MATERIAL SPECIFICATION PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	IDENTIFICATION C-240-0187			
	REFERENCE NO. 930212		SHT 3 OF 3	
	OFFICE NOE-C		REVISION 1	
	MADE BY WJC	CHKD BY RJW	MADE BY	CHKD BY
	DATE 03/23/94	DATE 03/23/94	DATE	DATE

9.0 DOCUMENTATION

9.1 The Certified Material Test Report (MTR) shall be mailed to the Purchaser within 48 hours after shipment of the material.

9.2 A record of the material thickness for each coil of material is required. Thickness shall be measured and recorded at both edges and the center of the coil material at 100 foot intervals along the length of the coils.

10.0 PACKAGING AND SHIPPING

10.1 Package the material for shipment as described in ASTM A700-90, Section 12.4.5.6 or Section 12.4.5.7.

10.2 Ship the coils as specified in the Purchase Order.

CBI

IDENTIFICATION			
C-BMBS1			
REFERENCE NO. 930212		SHT 1 OF 4	
OFFICE NOE-C		REVISION 0	
MADE BY WJC	CHKD BY	MADE BY	CHKD BY
DATE 2/23/94	DATE	DATE	DATE

TITLE BAFFLE MATERIAL BAKE SPECIFICATION

PRODUCT LIGO BEAM TUBE MODULES
CALIFORNIA INSTITUTE OF TECHNOLOGY

0.1 SCOPE

This specification gives the technical requirements for the air bake of the SA-240 Type 304L material to reduce the material's hydrogen outgassing rate. It covers the bake of the materials used to manufacture the internal baffles (and spacer bars) for the LIGO Beam Tube Modules.

1.0 APPLICABLE CODES AND SPECIFICATIONS

1.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

1.2 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

1.3 LIGO Specification 1100007, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

1.4 The latest revision of Specification C-240-0187. "Baffle Material Specification for LIGO Beam Tube Modules".

1.5 ASME SA-240, "Specification for Heat-Resisting and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels".

2.0 GENERAL REQUIREMENTS

2.1 The material shall be positioned on a raised grating with it's surface vertical to promote convection flow over the surface.

2.2 If the furnace is fuel fired the combustion products shall not come into contact with the baked material.

2.3 The material shall be air baked to 440°C ±8°C for a minimum soak time of 36 hours.

PRELIMINARY

2.4 Sufficient time shall be given during the heat up to ensure that material is heated to a uniform (440°C ±8°C) temperature.

2.5 The first bake of baffle material shall have one or more thermocouples attached to the material at the location(s) of anticipated lowest temperature to establish the minimum heat-up and cool-down times for the baking process. The 36 hour bake shall not begin until all thermocouples attached to the baffle material read 432°C or greater.

2.6 If the furnace air temperatures will exceed 448°C, thermocouples shall also be attached to the baffle segments at location(s) of anticipated maximum temperatures to assure that the material temperatures do not exceed the 448°C maximum allowable temperature.

2.7 The baked material shall cool to 100°C before it is removed from the furnace.

2.8 A bake procedure shall be written and submitted for approval prior to use. No bake shall be performed without a written and approved procedure. As a minimum the procedure shall include the following:

1. A description of the heating process and equipment. It shall include the furnace configuration, the number of furnaces available, the size of the furnaces, the type and capacity of the heating system, and other equipment that will be used.

2. A description of the temperature monitoring and control system that will be used to perform the bake.

3. The location and type of thermocouples that will be used.

4. An example of the bake out temperature data that will be provided as documentation for the bake.

5. The time required for the baking process.

CBI

TITLE	BAFFLE MATERIAL BAKE SPECIFICATION	IDENTIFICATION C-BMBS1			
		REFERENCE NO. 930212		SHT 3 OF 4	
		OFFICE NOE-C		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY	MADE BY	CHKD BY
		DATE 2/23/94	DATE	DATE	DATE

3.0 INSPECTION / WITNESS

3.1 The Purchaser shall be informed 10 working days before the bake will begin.

3.2 The Purchaser has right to witness any or all of the material bakes.

4.0 RECORDS AND DOCUMENTATION

4.1 A Certificate of Performance certifying that the bake was performed to this specification is required for each bake.

4.2 A thermal chart or graph is required for all bakes. The chart shall record all temperatures monitored during the bake from the start of heating through cooling to 100°C.

4.3 A log of the bake process is required that includes the following:

- Material identification from which baffle segments are fabricated
- Furnace ID
- Operator name and/or ID
- Temperature recorder ID and calibration date
- Non-conforming items and/or unusual events that occurred during the bake out.

5.0 COUPONS FOR HYDROGEN OUTGAS TESTING

5.1 Two sets of coupons (110 coupons in one set and 50 coupons in the other set) for hydrogen outgas testing shall be prepared after the bake. Both sets of coupons can be taken from a separate, baked sheet of steel from the same heat of material as the baffle material. Each coupon shall be 1" wide by 18" long. A total of 160 coupons shall be prepared.

CBI

IDENTIFICATION			
C-BMBS1			
REFERENCE NO. 930212		SHT 4 OF 4	
OFFICE NOE-C		REVISION 0	
MADE BY WJC	CHKD BY	MADE BY	CHKD BY
DATE 2/23/94	DATE	DATE	DATE

TITLE BAFFLE MATERIAL BAKE SPECIFICATION

PRODUCT LIGO BEAM TUBE MODULES
CALIFORNIA INSTITUTE OF TECHNOLOGY

5.2 The coupon material shall not be contaminated after the bake. The coupon material shall be removed from the furnace and coupons cut to size without using lubricants or heat. Grinding and shearing processes can be used to remove the coupon material and size the coupons. The set of 110 coupons shall be packaged and shipped overnight to CBI Technical Services in Plainfield, Illinois for testing. The set of 50 coupons shall be shipped by the most cost effective means to Caltech in Pasadena, California.

5.3 Traceability of the coupon material shall be maintained throughout all processes. One coupon in each set of coupons shall be vibro etched to identify the material from which the coupons were removed. No other marking is permitted on the coupons. Each set of coupons shall be kept separated and packaged separately. The package shall be clearly labeled to identify the material from which the coupons were removed.

5.4 The baked baffle material shall be stored until approval is obtained from the Purchaser to proceed with fabrication. Fabrication of the baffles shall not proceed until the results of the outgas testing results have been received by the Purchaser.

5.5 If the material does not meet the hydrogen outgas requirements, re-bake of the coil material may be performed per written approval.

	IDENTIFICATION C-240-0194			
TITLE EXPANSION JOINT MATERIAL SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE NOE-C		REVISION 0	
PRODUCT LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY RJW	CHKD BY	MADE BY	CHKD BY
	DATE 03/07/94	DATE	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for material intended for use in a ASME VIII, Division 1 pressure vessel in vacuum service with low hydrogen outgassing.

1.0 MATERIALS

1.1 This material shall conform to the requirements of ASME Specification SA-240 Type 304L with the additional supplementary requirements described in this specification.

1.2.0 Applicable Codes

1.2.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

1.2.2 ASME SA-240, "Specification for Heat-Resisting and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels".

1.2.3 ASME SA-480, "Standard Specification for General Requirements for Flat-Roll Stainless and Heat-Resisting Steel Plate, Sheet, and Strip".

1.2.4 ASTM A-700, "Standard Packages for Packaging, Marking, and Loading Methods for Steel Products for Domestic Shipment".

1.2.5 The latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

1.2.6 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

1.2.7 LIGO Specification 1100007, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

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

2.0 MANUFACTURE

2.1 The nominal material thicknesses shall be 0.105"

The material thickness shall not exceed 0.110".
The material thickness shall not be less than 0.100".

2.2 The preferred surface finish of the material shall be no smoother than 2.5 microns RMS. Hot rolled, Annealed, and Pickled (HRAP) surface finish is acceptable.

2.3 The sulfur content of the material shall not be less than 0.010% or greater than 0.020% by heat and product analysis.

2.4 The carbon content of the material shall not be greater than .020% as measured by heat and product analysis.

3.0 PREPARATION FOR BAKING

3.1 Each coil of material that is produced will be baked by others as specified in the latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

4.0 MECHANICAL TESTING

4.1 Mechanical tests shall be performed on each coil of material as described in ASME 480 with the additional supplementary requirements as described herein.

4.2 One tension test shall be performed on specimens taken from both ends of all coils.

5.0 INSPECTION/WITNESS

5.1 The purchaser shall have the right to witness all manufacturing processes.

5.2 The purchaser shall be informed 10 working days before the coil material is hot rolled.

6.0 REJECTIONS AND REPAIR OF DEFECTS

6.1 No weld splices or repair welding is permitted to the material.

CBI	IDENTIFICATION C-BT-CO			
TITLE LIGO BEAM TUBE SECTIONS CONSTRUCTION OPTION	REFERENCE NO. 930212		SHT 1 OF 6	
	OFFICE NOE-C		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MLT	CHKD BY KHF	MADE BY	CHKD BY
	DATE 03/22/94	DATE 03/23/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for spiral welded tube sections to be used in the LIGO Beam Tube Modules for the construction option. The scope of work consists of the fabrication of spiral welded tube sections and the associated documentation and inspection as defined by this specification. The beam tube sections will be incorporated into the LIGO facilities at Hanford, Washington and Livingston, Louisiana by CBI(Purchaser). Although not subjected to internal pressure, the beam tube modules will be built to the requirements of ASME Section VIII Code, Division 1 as applicable to ultra high vacuum facilities.

1.0 MATERIALS

1.1 The material will conform to the requirements of ASME Specification SA-240 Type 304L with the additional supplementary requirements described in the attached material specifications C-240-0186 and C-CMBS1. These supplemental specifications contain special chemical and heat treatment requirements for the material. After material bake, as described in specification C-CMB1, coupons taken from each coil will be tested by the purchaser to determine the hydrogen outgassing characteristics of the material. Fabrication of the beam tube sections will not be allowed until the hydrogen outgassing rate has been determined and the material has been approved for fabrication by the Purchaser.

1.2 No external attachment welds to the tube sections are allowed without the prior approval of the Purchaser.

1.3 The beam tube fabricator shall execute and coordinate the material procurement and bake at Purchaser's direction. Approximately 28 square feet of beam tube material shall be taken from the coil after bake and delivered to Purchaser. This material will be used by the Purchaser to determine the hydrogen outgassing characteristics of each coil. After successful completion of the outgas test, material will be released by the Purchaser for use. Two weeks are required to complete an outgas test after receipt of coupon material. Coil material shall not be slit until after material acceptance has been confirmed.

1.4 For purposes of the initial budget pricing, the Purchaser will determine the material, bake, and outgas testing costs. Beam tube fabricators shall state the material dimensional requirements and percentage scrap anticipated in the budget price and shall provide procurement costs or mark ups if applicable as a separate price.

2.0 CODES & SPECIFICATIONS

The following codes and specifications shall apply unless revised by this specification. Any conflicts between the requirements given herein and the applicable ASME Specification shall be brought to the attention of the purchaser for resolution.

2.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", 1992 Edition, 1993 Addenda.

2.2 ASME Unfired Pressure Vessel Code, Section VIII, Division 1, 1992 Edition, 1993 Addenda as applicable. (Code stamping is not required.)
2.3 ASME Section IX Code, Welding and Brazing Qualifications 1992 Edition, 1993 Addenda.
2.4 CBI Specification WMS-ER308L
2.5 CBI Coil Material Specification C-240-0186
2.6 CBI Material Bake Specification C-CMBS1
2.7 LIGO Specification 110004, Rev. C, "Beam Tube Module Specification dated May 11, 1993
2.9 LIGO Specification 1100007, Rev. 0. "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993.

3.0 PHYSICAL DESCRIPTION

The beam tube modules are composed of a repeating 130' long configuration which consists of two beam tube sections and an expansion joint with fixed and flexible supports. The modules will be composed of equal numbers of 65'-0 and 62'-4 beam tube sections plus shorter make up sections at the ends of each module. Details are shown on the attached drawings which are listed below:

Drawing Title	Dwg #	Rev #
General Module Configuration	1	0
Sub Module Details	2	0
Sub Modules E, F, G, & H	3	0
Sub Modules A, B, & C	4	0
Sub Modules D, E, F, & G	5	0

Only the unstiffened tube sections are covered by this specification. All tube sections shall have a nominal inside diameter of 48.75".

4.0 TOLERANCES

Tube tolerances are generally not critical. Close circumferential tolerance at the tube section ends are required to enable tube sections to be butt welded to either adjacent tube sections or expansion joints. Tube ends may be expanded to produce the required circumferential tolerance but all tube ends must have the same nominal diameter and lie within the circumferential tolerance specified. Tube ends must be perpendicular to the tube axis and flat to produce a straight butt welded tube section and to provide close fit up for welding. Tube ends must therefore be machined. In general, tube sections shall have the following tolerances:

Perpendicularity of the end of the tube to the axis of the tube:	.010"
Flatness of the tube end:	.010"
Circumference of the tube ends:(See note below)	+/-3/64"
Circumference of the tubes other than at ends	+/- 1/2"
Longitudinal straightness of tube:	+/- .25"
Diameter when supported to prevent sag or stiffened:	+.25, -0
Concentricity of expanded end to tube axis (if ends are expanded)	.010"

Longitudinal straightness is critical for approximately 10% of the tube sections. The longitudinal straightness of each tube will be checked before and after stiffener attachment by the Purchaser.. The best tube sections will be used in areas where straight tube sections are required. The longitudinal straightness of 10% of the tubes must be within +/- 1/16" measured at the third points of the tube only.

5.0 SUBMITTALS, DOCUMENTATION, AND RECORDS

5.1 Information Required With Quotation

5.1.1 The vendor shall state in the quotation that the quotation complies with this technical specification with any exceptions or alternatives noted and explained. Purchaser will assume complete conformance unless deviations are noted.

5.1.2 A description of the vendor's Quality Assurance Manual in accordance with ANSI/ASQC Standard Q91(Certification not required) or ASME Section VIII Quality Control System Manual.

5.1.3 Procedures for making and documenting measurements of dimensions with specified tolerances.

5.1.4 A description of the vendor's manufacturing facilities and equipment required to perform the work covered by this specification.

5.1.5 A description of the vendors procurement approach, including source of materials, traceablilty of materials, and management of subcontracts if applicable.

5.1.6 A description of the vendor's management plan, including the process by which the work covered by this specification will be monitored and controlled, and the identification and function of key personnel to be assigned.

5.1.7 Coil material dimensional requirements, tolerances required, and processing requirements.

5.1.8 Equipment and procedures to be used for beam tube end preparation including diameter of sized ends if applicable.

5.2 Information Required After Receipt of Order and 4 Weeks Prior to Fabrication For Approval

5.2.1 Welding procedures with supporting procedure qualification records in accordance with ASME Section IX.

5.2.2 Welder Performance Qualification Test Records in accordance with ASME Section IX. (Available for review)

5.2.3 Repair Procedures.

5.2.4 NDE procedures and NDE personnel qualifications (Qualifications available for review).

5.2.5 Cleaning Procedures.

5.2.6 Packaging and Handling procedures.

5.3 Information Required for Record and Documentation at the Completion of the Work

5.3.1 Record of measured tolerance dimensions of each spiral welded tube section provided with the tube section.

5.3.2 Record drawings and check lists indicating welder identification to each weld joint and traceability of Certified Material Test Reports (CMTR) to the location in each tube section.

5.3.3 Signed off checklist and reports indicating that all required NDE was completed.

6.0 FABRICATION

6.1 Welding

6.1.1 ER308L weld material shall be cleaned and baked per CBI Specification WMS-ER308L. (Note: This requirement is not included at this time. Outgas tests are being conducted to confirm the acceptability of as received weld material. For the purposes of budget pricing, use standard as received weld material.)

6.1.2 All welding exposed to the vacuum shall be done by the gas tungsten arc welding (GTAW) process. Welding shall be autogenous with the exception that weld passes on the outside of the tube section spiral weld joints may use filler metal meeting the requirements of paragraph 6.1.1.

6.1.3 For all welding, an inert gas purge on the vacuum side is required.

6.1.4 Unless directed otherwise by the purchaser, temporary attachments and weld tacks for fit up, lifting, or handling shall not be used.

6.1.5 Welding procedures shall be submitted prior to production welding. Welder and welding operator performance qualification test records shall be submitted prior to any individual performing welding. Welding procedures, welders and welding operators shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The purchaser shall have the option to require re-qualification of any welder at any time, if in the purchaser's opinion, the welder's qualifications are suspect or welds appear not to be of proper quality.

6.1.6 Edge registry for spiral welds must be within 1/4 of the thickness which is 1/32". Edge registry for coil splices must be within .010". All edges including strip edges must be power brushed with stainless steel brushes just prior to tube fabrication.

6.1.7 The minimum depth of penetration for the inside and outside weld is 70% which will provide an overlap of approximately .050".

6.18 Coil splices shall be made with end tabs if coil edges are not removed by slitting prior to tube fabrication. Tabs are to be made from SA240 typpe 304L material, baking is not required. Tabs shall be removed by mechanical means such that a full edge at the coil splice is provided.

6.2 Cleaning and Cleanliness Maintenance

6.2.1 All contact made with the stainless steel material during fabrication shall be such that carbon steel contamination is prevented.

6.2.2 After fabrication of the spiral welded tube sections is complete, the inside surface shall have all visible traces of oil, grease, or other foreign material removed with a solvent wipe. Detergent / water solutions are not allowed. Vendor shall submit a cleaning procedure stating solvents to be used for approval by the Purchaser.

6.3 Spiral Mill

6.3.1. Spiral mills shall have variable speed DC drives to enable smooth material flow at speeds ranging from 5" per minute to 24" per minute.

6.3.2 Cleanliness of the stainless steel shall be preserved. Cleaning of the spiral mill may be required to accomplish the cleanliness requirements of the stainless steel tube sections. The manufacturer is to evaluate the contamination potential and advise the necessary course of action. Spiral mills may have to be steam cleaned of all hydrocarbons prior to the tube fabrication and located or placed such that cleanliness is preserved during tube manufacturing.

6.3.3 Only the necessary guides and rollers of the mill shall contact the coil material and tube sections before, during, and after fabrication. All items of the mill which contact the strip material or inside surface of the fabricated tube should be cleaned by wiping with alcohol prior to fabrication.

6.3.4 Coil strip edges shall be power brushed just before welding to remove the oxide layer developed during coil bake.

6.3.5 All bearings and lubrication fittings which could allow hydrocarbons to leak or drip onto the coil or fabricated tube shall be wiped free of excessive lubrication with a solvent wipe.

6.4 Material Identification

6.4.1 Material traceability shall be maintained throughout fabrication and shipping.

6.4.2 Each beam tube section shall be uniquely identified. The identification shall enable the complete history of each tube to be maintained. A record for each beam tube section shall indicate all weld repairs, stops and starts, and fabrication abnormalities including locations of coil butt splices.

7.0 INSPECTION / REPAIRS

7.1 The Purchaser shall have the right to witness all manufacturing processes.

7.2 Each tube section shall be inspected to determine the tubes dimensional tolerances and weld abnormalities.

7.3 Dimensional information, weld abnormalities, and any relevant information concerning the tube fabrication shall be recorded on a unique drawing(s) for each tube section.

8.0 REJECTIONS AND REPAIR OF DEFECTS

8.1 No weld splices or repair welding is permitted to the material without approval by the Purchaser using approved repair procedures and qualified welders.

8.2 Circumferential weld joints in the beam tube sections are not permitted.

8.3 Coil splice weld joints are not permitted within 6" of the tube ends.

9. PROCESS QUALIFICATION

9.1 Beam tube sections shall not be incorporated into the LIGO facilities until the vendor's process has been tested qualificed by the Purchaser.

9.2 The Qualification Test shall consist of leak testing and outgas testing of two sections of beam tube. Vendor shall provide two unstiffened beam tube sections from material supplied by the purchaser for stiffening and testing by the Purchaser.

10.0 PACKAGING, STORING AND SHIPPING

10.1 Vendor is to provide procedures for approval by the Purchaser for packaging, storing, and shipping of the beam tube sections These procedures shall include details for end sealing and protection of the tube ends and interior, any internal bracing for shipment and storage, and external shipping saddles.

10.2 Tubes shall be shipped four to a truck and be supported within 5 feet of the tube ends and at the mid points. Tube shall be supported or braced at the support points to prevent ovalling of the tube cross section. The supports shall prevent relative motion between the tubes and supports or adjacent tubes. Tubes shall be packaged to permit standard width unescorted trucks which have a maximum width of 8'-6 and a maximum length of 65'.

IDENTIFICATION C-EJ-CO			
TITLE LIGO BEAM TUBE EXPANSION JOINTS CONSTRUCTION OPTION	REFERENCE NO. 930212	SHT 1 OF 11	
	OFFICE NOE-C	REVISION 1	
PRODUCT LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
	DATE 03/07/94	DATE 03/10/94	DATE 03/23/94	DATE 03/23/94

1.0 GENERAL

1.1 Description

This specification defines the technical requirements for the materials, fabrication, and supply of the LIGO Beam Tube Expansion Joints for the construction option. The construction option consists of two Laser Interferometer Gravitational-Wave Observatories. One will be located near Hanford, Washington and the second will be located near Livingston, Louisiana. Each observatory is comprised of 48.75" inside diameter beam tubes with a total length of 25600 feet. Expansion joints will be required over the entire length and will be used to connect the beam tube segments. The expansion joints will have an approximate spacing of 130 feet. The beam tubes and the expansion joints are the key elements of the vacuum system for sensitive interferometer components and optical beams used by the observatories.

1.2 Scope

The scope of work includes calculations, design and detail engineering, material purchase, fabrication, welding, dimensional control, inspection, nondestructive examination, cleaning and preparation for shipping. Field installation will be by others. The LIGO Expansion Joint design requirements are shown in Section 3.0.

1.2.1 Drawings/Figures

The following drawing(s) and figure(s) form an integral part of this specification:

Figure 1 - Beam tube bellows configuration

Figure 2 - Dimensional limitations

1.2.2 Specifications

Standards of the Expansion Joint Manufactures Association, Inc. Sixth Edition

ASME Boiler & Pressure Vessel Code, Section II, "Materials", the 1992 Edition with the 1993 Addenda.

ASME Unfired Pressure Vessels, Section VIII, Division 1 as applicable, the 1992 Edition with the 1993 Addenda. Code stamping is not required.

ASME Section IX Welding and Brazing Qualification, 1992 Edition with the 1993 Addenda.

CBI Expansion Joint Material Specification C-240-0194.

CBI Material Bake Specification C-CMBS1.

LIGO Specification 1100004, Rev C, "Beam Tube Module Specification", dated May 11, 1993. (Reference only)

LIGO Specification 1100007, Rev 0, "Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products", dated April 5, 1993. (Reference only)

1.3 Submittals

Information Required with Quotation:

1.3.1 The vendor must state in his quotation that the quotation complies with this technical specification with any exceptions or alternates noted and explained. The purchaser will assume complete conformance unless deviations are noted.

1.3.2 Shop practices, including forming method, lubricants used, cleaning procedures, etc. See paragraph 4.3.3 concerning the use of lubricants.

1.3.3 A sketch or drawing showing the following information:

1.3.3.1 Expansion joint dimensions including thickness and bellows configuration.

1.3.3.2 Expansion joint spring rates for axial, lateral and rotational movements, and the estimated deviation as a percentage of the spring rate.

1.3.3.3 Degree of axial pretension or compression based on a 70 degree temperature.

1.3.3.4 Design movements

1.3.4 Procedures for making and documenting measurements of dimensions with specified tolerances.

1.3.5 A description of the vendor's manufacturing facilities and the equipment required to perform the work covered by this specification.

1.3.6 A description of the vendor's procurement approach, including source of materials, traceability of materials, and management of subcontracts.

1.3.7 A description of the vendor's quality assurance manual in accordance with ASME Section VIII, Division 1 or ANSI/ASQC Standard Q91. (Certification is not mandatory).

1.3.8 A description of the vendor's management plan, including the process by which the work covered by this specification will be monitored and controlled, and identification and function of key personnel to be assigned.

Information Required After Receipt of Order and 4 Weeks Prior to Fabrication:

1.3.9 Design calculations and drawings.

1.3.10 Weld procedures with supporting procedure qualification records and welder personnel qualification records per ASME Section IX.

1.3.11 Shop practices, including forming method, lubricants used, etc.

1.3.12 NDE procedures.

1.3.13 Qualification for NDE personnel.

Information Required 2 Weeks Prior to Shipment:

1.3.14 Certified material test reports for material and welding material.

1.3.15 Documentation of measured helium leakage rates for each Expansion Joint.

1.3.16 Record of measured toleranced dimensions of each Expansion Joint.

2.0 MATERIALS

2.1 Strip or sheet

Stainless steel conforming to ASTM SA240-type 304L and LIGO Specification 1100007. Material shall be supplied by the fabricator per specification C-240-00194 and C-CMBS1.

2.2 External attachments

Stainless steel conforming to ASTM SA240-type 304

2.3 Weld material for external attachments

If required, contact the purchaser for approved weld material and weld procedure.

3.0 DESIGN

The configuration of the beam tube and expansion joint is illustrated in Figure 1. The following requirements are based on this configuration.

3.1 Nominal size: 48 3/4" Match inside diameter. Expansion joints will be field welded by the purchaser to 65' long tubes with a 48.75" ID and 49.004" OD. The expansion joint thickness will be 0.105.

3.2 Expansion joint type: Single, unreinforced

3.3 Flow medium:
During installation: dry air, 15 feet per second
Operating & Transient: Vacuum < 1 x 10E-9 torr

3.4 Design Pressure:
External: 14.7 psi Continuous after start up
Internal: 0.20 psi During construction only

3.5 Temperatures
Transient: 302^{o} F
Minimum: -16^{o} F
Maximum operating: 100^{o} F
Installation temperature: 20^{o} to 100^{o} F

3.6 Maximum installation movements:
These movements will be one time movements. The shipping restraints will not be removed until the expansion joint is welded to tubes on both sides. The shipping restraints, having adjustment

capability (see section 4.4.3), will impose the movements listed below. The adjustments will be made to assist the fit up of the second joint between the expansion joint and the tube sections.

Axial:	± 0.25"	in addition to other specified axial movements
Lateral:	0.0"	
Rotational:	± 0.13	degrees in addition to other specified rotations

3.7 Maximum movements:

3.7.1 Operating

Axial: 0.43" Contraction, 70^{o} to 100^{o} F
1.21" Extension, 70^{o} to -16^{o} F
7300 total cycles
Lateral: 0.125"(5 cycles) The 5 cycles of lateral movement may be caused by differential settlement between supports.
Rotational: 0.10 degrees (1 cycle) due to dead load of tube
0.20 additional degrees (5 cycles)

3.7.2 Transient

Axial: 3.26" Contraction (20 cycles) 70^{o} to 302^{o} F.
Lateral: 0.00"
Rotational: 0.10 to 0.20 degrees (20 cycles)

3.8 Rods (Tie/Limit/Control): None

3.9 Dimensional limitations: See Figure 2

Nominal Overall length:	None
Tangents (straight portion of ends)	6" plus the length required for shiping restraints
Second end	4" plus the length required for shiping restraints (6" preferred)
Maximum Outside diameter:	55"
Minimum Inside diameter:	48.75"
Minimum thickness at ends:	0.100"
Maximum thickness at ends:	0.130"

3.10 Spring Rates: (Based on a 70^{o} F material temperature.)

Axial:	Supplied by Vendor, Less than 8000 lbs/in, based on a full stroke per 3.7.2, at 70^{o} F.)
Lateral:	Supplied by Vendor
Rotational:	Supplied by Vendor
Torsion:	Supplied by Vendor

3.11 Torsional Rotation:
Vender shall specify the maximum torsional rotation the expansion joint can have during the operating condition. There would be a maximum of 30 cycles for this torsional rotation. Also specify the torque required to cause this rotation.

3.12 Installation Position: Horizontal

3.13 Vibration frequency: by Vendor

4.0 FABRICATION

4.1 Material Bake (LIGO Specification 1100007, Section 2.2 & 2.5)

The material will be provided by the purchaser. The expansion joint manufacturer will receive the material in the air baked condition per CBI specification C-CMBS1. The vacuum baking per Section 2.5 of the LIGO Specifications will be performed by others.

4.2 Welding (LIGO Specification 1100007, Section 2.3)

4.2.1 All welding exposed to vacuum shall be done by the gas tungsten arc welding (GTAW) process. Welding shall be autogenous with the exception that weld passes on the outside of the expansion joint may use filler wire meeting the requirements of paragraph 2.3.

4.2.2 All welding of external attachments to the expansion joints shall be made by the GTAW or gas metal arc welding (GMAW) processes. The use of flux cored arc welding (FCAW) is not permitted.

4.2.3 For all welding, use an inert gas purge on the vacuum side of the weld. An inert gas purge shall also be used on the vacuum side when welding attachments including shipping lugs if required.

4.2.4 The bellows element shall not be constructed from lap-welded pipe or lap-welded tubing.

4.2.5 Unless directed otherwise by the purchaser, temporary attachments and weld tacks for shop fit-up, lifting or handling shall not be used.

4.2.6 Welding procedures shall be submitted prior to production welding. Welder and weld operator qualification records shall be submitted prior to any individual performing welding. Welders and weld operator qualifications shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The purchaser shall have the option to require the requalification of any welder at any time if, in the purchaser's opinion, the welder's qualifications are suspect or welds appear not to be of the proper quality.

4.3 Cleanliness and Cleaning

4.3.1 All contact made with the stainless steel material during fabrication shall be such as to prevent carbon steel contamination.

4.3.2 After fabrication of the Expansion Joints is complete, the inside surfaces shall have all visible traces of oil grease or other foreign material removed with a solvent wipe. Detergents/water are not allowed. The expansion joint fabricator shall submit a cleaning procedure stating solvents used. Cleaning with Oakite 33 per LIGO Specification 1100007 paragraph 2.4 will be conducted by others.

4.3.3 Lubricants that affect the ability to obtain high vacuum levels such as silicon lubricants shall not be used during fabrication. It is also preferred that a hydrocarbon based lubricant is not used. If a lubricant must be used, the type of lubricant and the cleaning process shall be provided in a cleaning procedure.

4.4 Preparation for Shipping

4.4.1 Wrap the Expansion Joints securely in plastic and seal at both ends to maintain a clean state until installation by others. Cover the ends of the Expansion Joints with a cap to protect the edges and prevent punctures of the plastic wrap. Type of desiccant used to minimize condensation shall be specified.

4.4.2 Ship the expansion joints in crates to protect the expansion joint and plastic wrap during shipping. The crates can be sized to hold multiple expansion joints to minimize shipping costs. The crates can be reusable. Provide a procedure specifying how paragraph 4.4.1 will be met, and state what type of crate and quantity will be used.

4.4.3 The vendor shall attach shipping devices to maintain the installed length and to provide adjustment per Paragraph 3.6. The shipping device shall include lifting lugs to lift and turn the expansion joint. The length must also be maintained by the shipping devices while the expansion joint is attached and supported at only one end. If justified by cost savings, the shipping devices can be reusable The dimensional limitations of paragraph 3.9 and Figure 2 shall be met. If lugs welded to the expansion joint are required, the lugs will remain in place after the removal of the restraint arms. Shipping devices shall be painted yellow or otherwise distinctively marked.

4.4.4 The shipping device shall be designed to resist the longitudinal load for a vacuum leak test (approximately 28000 pounds). During this vacuum test, one tube section will be welded to the expansion joint. Instead of designing the shipping devices for vacuum load, two reusable pressure resisting devices can be provided. The pressure resisting device can be mounted inside or outside of the expansion joint. If mounted inside, A240 Type 304 material shall be used. If mounted outside, the dimensional limitations of paragraph 3.9 and Figure 2 apply.

4.5 Dimensional Control

The fabricator shall measure and record all dimensions for which tolerances are specified.

4.6 Fabrication Tolerances

4.6.1 Records of measured toleranced dimensions shall include the temperature of the expansion joint during the measurements. Temperatures shall be between 60^{o} and 80^{o} Fahrenheit.

4.6.2 The outside circumference of the ends of the expansion joints shall be within $\pm$3/64", of the theoretical circumference corresponding to the specified inside diameter.

4.6.3 The ends of the Expansion Joints shall be perpendicular to the cylindrical axis within 0.010".

4.6.4 The ends of the expansion joint shall be flat within 0.005".

4.6.5 The overall length shall be within ±1/8".

4.6.6 The ends of the expansion joint shall be concentric within 3/16".

4.6.7 The axial spring rate of all expansion joints shall be within ± 10% of the average of all spring rates. The expansion joint supplier shall also estimate the difference between the average spring rate and the calculated spring rate. The maximum axial spring rate of any expansion joint shall not be more than 20% of the specified maximum spring rate specified in paragraph 3.10. Measured spring rates shall be based on a full stroke per paragraph 3.7.2.

4.7 Surface Finish

An inside surface finish rougher than a 2.5 micron rms finish is preferred.

5.0 INSPECTION

5.1 The Expansion Joints shall be tested with a helium mass spectrometer. The Expansion Joints shall be sealed at both ends, bagged with plastic, and the envelope evacuated and injected to provide a 100% helium environment at 1 atm surrounding the Expansion Joint. The mass spectrometer sensitivity shall be sufficient to measure a helium leakage rate of 1×10^{-10} atm cc/sec. The mass spectrometer shall show no leak equal to or greater than the specified sensitivity after evacuating the Expansion Joints below 1×10^{-6} torr.

5.2 The purchaser shall have the option of inspecting at the vendor's facility and witnessing tests or procedures required in this specification.

5.3 Each expansion joint shall be tested to determine the axial spring rate based on the axial movement specified in paragraph 3.7.2. The temperature of the expansion joint shall be between 60^{o} and 80^{o} F during the test. The spring rate determined by the test shall be provided on the expansion joint tag.

CBI

TITLE LIGO BEAM TUBE EXPANSION JOINTS CONSTRUCTION OPTION	IDENTIFICATION C-EJ-CO			
	REFERENCE NO. 930212		SHT 10 OF 11	
	OFFICE NOE-C		REVISION 1	
PRODUCT LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
	DATE 03/07/94	DATE 03/10/94	DATE 03/23/94	DATE 03/23/94

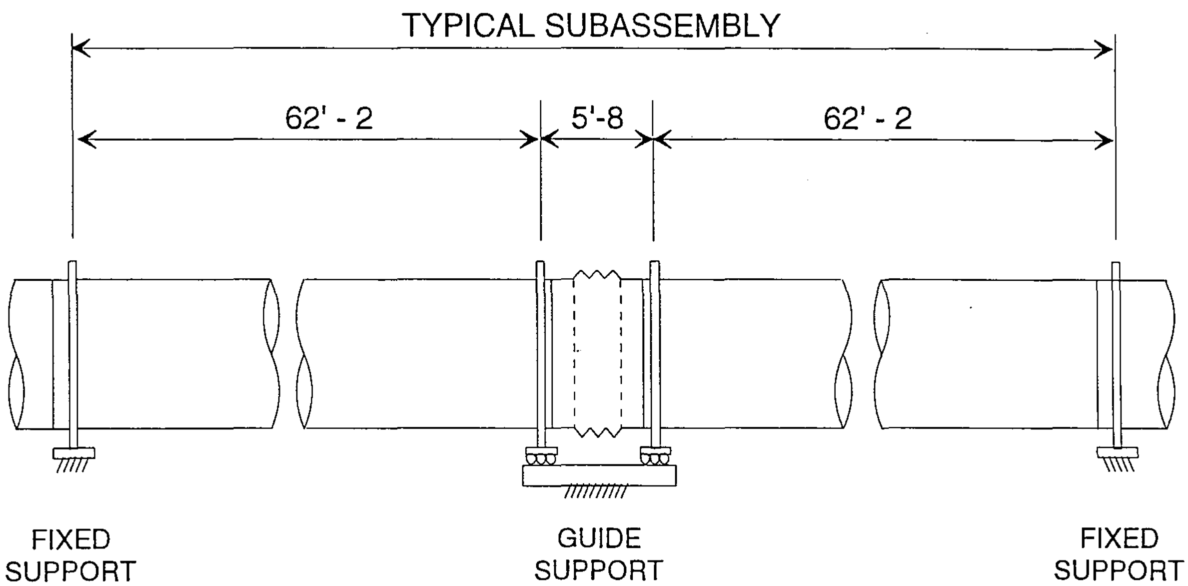


FIGURE 1

	IDENTIFICATION C-EJ-CO			
TITLE LIGO BEAM TUBE EXPANSION JOINTS CONSTRUCTION OPTION	REFERENCE NO. 930212		SHT 11 OF 11	
	OFFICE NOE-C		REVISION 1	
PRODUCT LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
	DATE 03/07/94	DATE 03/10/94	DATE 03/23/94	DATE 03/23/94

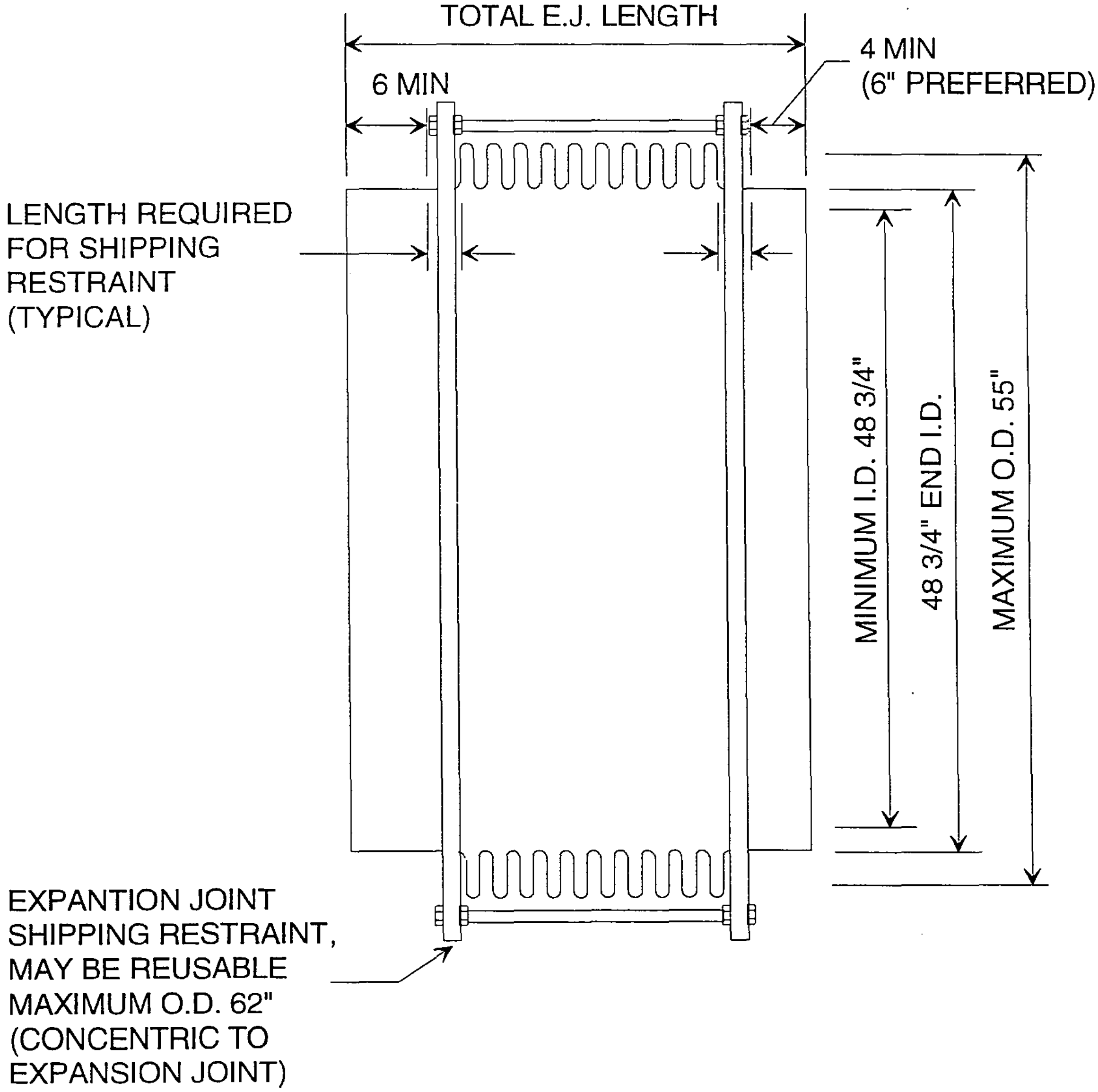


FIGURE 2

TITLE BAFFLE FABRICATION SPECIFICATION PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	IDENTIFICATION C-BAF-1			
	REFERENCE NO. 930212		SHT 1 OF 6	
	OFFICE NOE-C		REVISION 1	
	MADE BY WJC	CHKD BY	MADE BY	CHKD BY
	DATE 03/23/94	DATE	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for the supply, fabrication, inspection, cleaning, packaging and shipping of baffles for use within a vacuum chamber with low hydrogen outgassing. The baffles are part of a vacuum system for sensitive interferometer components and optical beams for the Laser Interferometer Gravitational-Wave Observatory (LIGO). The baffles will be installed inside a $48^3/_4$" I.D. vacuum tube by CBI (Purchaser). The purpose of the baffles is to reflect scattered light.

1.0 APPLICABLE DOCUMENTS

1.1 The latest revision of Specification C-240-0187, "Baffle Material Specification".

1.2 The latest revision of Specification C-CMBS1, "Coil Material Bake Specification".

1.3 Specification CLCOUPA0, "Cleaning of Plain Coupons, Alternate Method #0, For Surface Analysis and Outgassing Test", Revision 2.

1.4 ASME Code, Section IX, "Welding and Brazing Qualifications", 1992 Edition with the 1993 Addenda.

1.5 Sketch 1 -- Baffle (As-Installed Dimensions and Tolerances) and Spacer Bar
Sketch 2 -- Baffle Segment Dimensions

2.0 MATERIALS

2.1 All material for the baffles and spacer bars shall be stainless steel conforming to ASME Specification SA-240 Type 304L. All material for the baffles and spacer bars will be in accordance with Specification C-240-0187. The nominal material thickness for the baffles and spacer bars shall be 0.105".

2.2 All material for the baffles and spacer bars will be supplied by the Purchaser in sheet form. **The vendor is <u>not</u> responsible for the supply of the material for the baffles.**

2.3 The material supplied to the vendor will have been subjected to an air bake in accordance with Specification C-CMBS1 prior to receipt by the vendor. **The vendor is <u>not</u> responsible for performing an air bake of the baffle material.**

3.0 SUBMITTALS -- INFORMATION REQUIRED WITH QUOTATION

3.1 The vendor shall state in his quotation that the quotation complies with this specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

3.2 A description of the vendor's manufacturing facility and the equipment required to perform the work covered by this specification.

3.3 A description of the vendor's quality assurance plan.

3.4 A description of the procedures for making and documenting measurements of baffle dimensions with the tolerances specified.

3.5 A description of the vendor's management plan, including the process by which the work covered by this specification will be monitored and controlled, and the identification and function of key personnel to be assigned.

4.0 INFORMATION REQUIRED AFTER RECEIPT OF ORDER AND 4 WEEKS PRIOR TO FABRICATION FOR REVIEW AND APPROVAL

4.1 Fabrication methods for the baffles and spacer bars.

4.2 Welding procedures with supporting procedure qualification records and welder performance qualification records in accordance with ASME Code Section IX.

4.3 Packaging and handling procedures.

5.0 FABRICATION, GENERAL

5.1 **All contact made with all stainless steel material during all phases of the manufacturing process shall be such as to prevent carbon steel contamination.**

5.2 The method of baffle fabrication shall be such that the installed baffles require no fastening to the inside of the tube wall -- design parameters such as the baffle thickness and the unconstrained helix diameter shall provide sufficient radial "clamping" force to the tube wall for secure positioning.

5.3 The material for the baffle will be supplied to the vendor in a "baked" condition. As such, the method by which the baffles and spacer bars are fabricated **cannot** re-introduce hydrogen into the material. Methods such as plasma cutting or laser cutting are therefore not acceptable. Waterjet cutting of the baffle material is acceptable.

6.0 WELDING, GENERAL

6.1 All welding shall be done by the gas tungsten arc welding (GTAW) process. Filler wire shall **not** be used for any weld.

6.2 Use an inert gas purge for all welding.

6.3 All welds shall be full fusion butt welds.

6.4 Welding procedures shall be submitted to the Purchaser prior to production welding. Welder and weld operator qualification records shall be submitted prior to any individual performing welding. Welders and weld operators shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The Purchaser shall have the option to require the requalification of any welder at any time if, in the Purchaser's opinion, the welder's qualifications are suspect or welds appear not to be of the proper quality.

7.0 BAFFLE FABRICATION PROCEDURE

7.1 Waterjet cut the baffle segments and spacer bars from the Purchaser-supplied sheet material. Each baffle will be fabricated from a total of four (4) segments with the dimensions as shown on Sketch 2 of this Specification.

7.2 Weld two (2) baffle segments together end-to-end, using the welding procedures of Section 6.0 of this Specification. The welded assembly shall have the dimensions as shown on Sketch 2 of this Specification.

7.3 Repeat 7.2 for the two (2) remaining initial baffle segments.

7.4 Roll each baffle assembly to a conical shape 60" O.D.

7.5 Weld the two (2) assemblies together, using the welding procedures of Section 6.0 of this Specification, to form a baffle.

7.6 Coil the baffle to $48^3/_4$" O.D. on major diameter, with a pitch of 11.81" (30 cm). On the inside edge of the baffle, locate the position of the two (2) notches in the baffle for the insertion of the spacer bar. Refer to Sketch 1 of this Specification.

7.7 Cut the two (2) notches for the spacer bar on the inside edge of the baffle. The notches in the baffle shall be deep enough so that the top edge of the spacer bar, when inserted in the installed baffle, shall **not** project above the inside edge of the baffle. The notches, in both the baffle and the spacer bar, shall **not** be formed by burning or any other method that melts the air-baked stainless steel material.

8.0 DIMENSIONAL CONTROL

8.1 The vendor shall procure a tube with an inside diameter of $48^3/_4$" which is to be used to verify that the dimensions of the fabricated baffle are within the specified tolerances. This tube shall not impart any carbon steel contamination on the baffle. All baffles for the Qualification Test shall be fitted within this tube.

8.2 The vendor's proposed method for making and documenting measurements of baffle dimensions with the specified tolerances shall be submitted to the Purchaser for review and approval.

9.0 CLEANLINESS AND CLEANING

9.1 **All contact made with all stainless steel material during all phases of the manufacturing process shall be such as to prevent carbon steel contamination.**

9.2 After fabrication of the baffles and spacer bars is completed, the baffles and spacer bars shall be inspected for hydrocarbon contamination and cleaned in accordance with the following sections of Specification CLCOUPA0, with the following modifications:

9.2.1 The equipment and materials required shall be as per Section 4.0 of Specification CLCOUPA0, except that Items 4.9, 4.10, 4.11 and 4.12 of that Specification shall not be required for the cleaning of the baffles and spacer bars.

9.2.2 The cleaning procedure shall be as per Section 5.0 of Specification CLCOUPA0, except that Sections 5.1, 5.2, 5.3, 5.4, 5.9, 5.15, and 5.17 of that Specification shall not apply to the cleaning of the baffles and spacer bars.

9.2.3 In all applicable procedures of Section 5.0 of Specification CLCOUPA0, the word "coupons" may be understood to mean "baffles" and "spacer bars".

9.3 At all times after cleaning, the baffles and spacer bars shall only be handled by personnel wearing polyethylene (or equal) gloves to avoid contamination of the baffles.

10.0 PACKAGING FOR SHIPPING

10.1 After cleaning and prior to sealing for shipment, the vendor shall attach to the baffle ends stainless steel banding that restrain the baffle to an outside diameter of 40 inches.

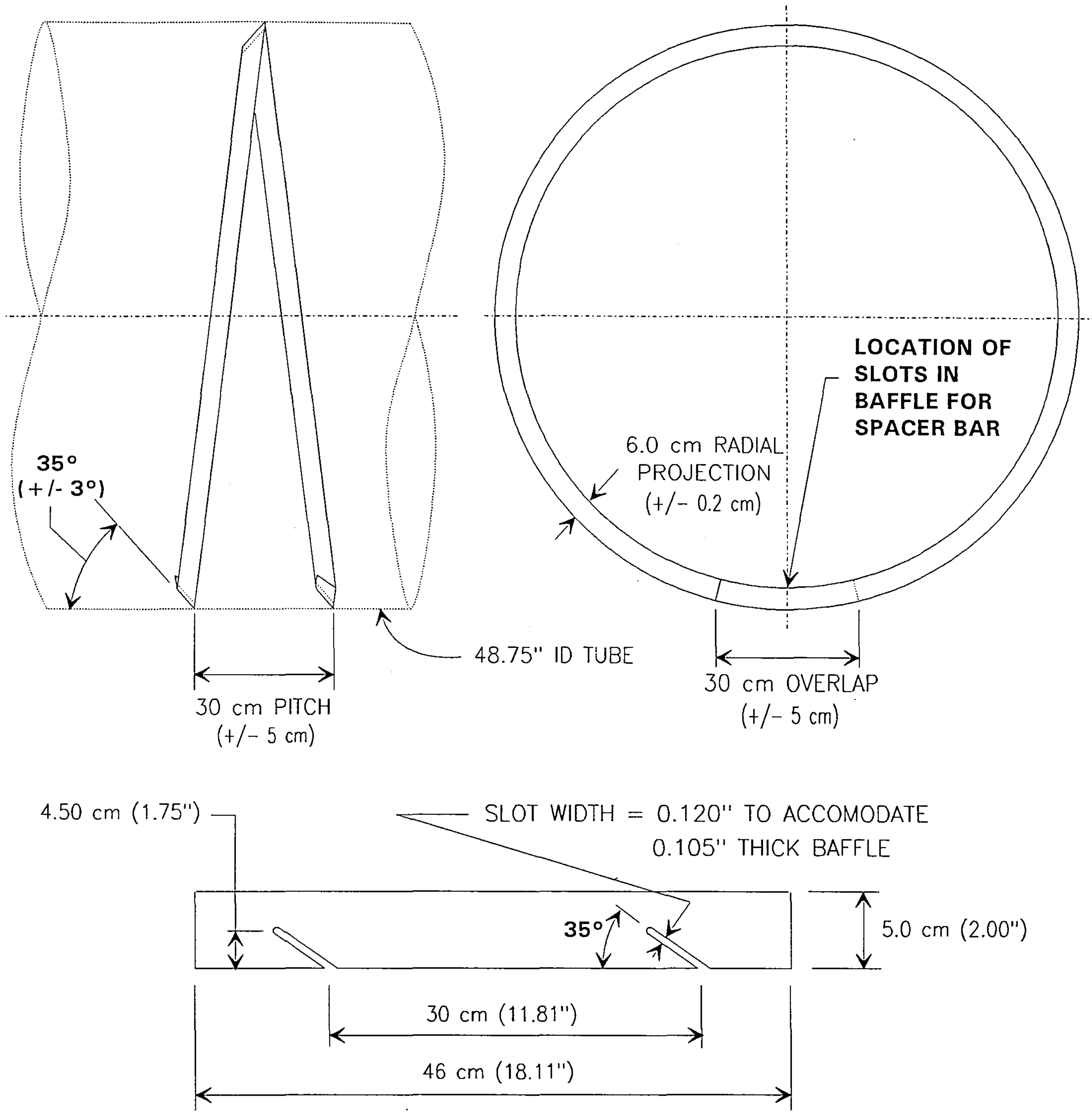
10.2 The stainless steel banding, prior to being attached to the baffles, shall be cleaned in accordance with the procedures outlined in Sections 9.2 and 9.3 of this Specification.

10.3 The vendor shall seal and protect the baffles from contamination during shipment by sealing the baffles and spacer bars within polyethylene shrink wrap. One baffle and one spacer bar shall be sealed together -- sealing of multiple baffles and/or multiple spacer bars within the same package shall not be permitted. The vendor's proposed procedure of sealing the baffles and spacer bars prior to shipment shall be submitted to the Purchaser for review and approval.

10.4 The vendor shall protect the baffles from damage during shipment. The vendor's proposed method and procedures of protecting the baffles from damage during shipment shall be submitted to the Purchaser for review and approval.

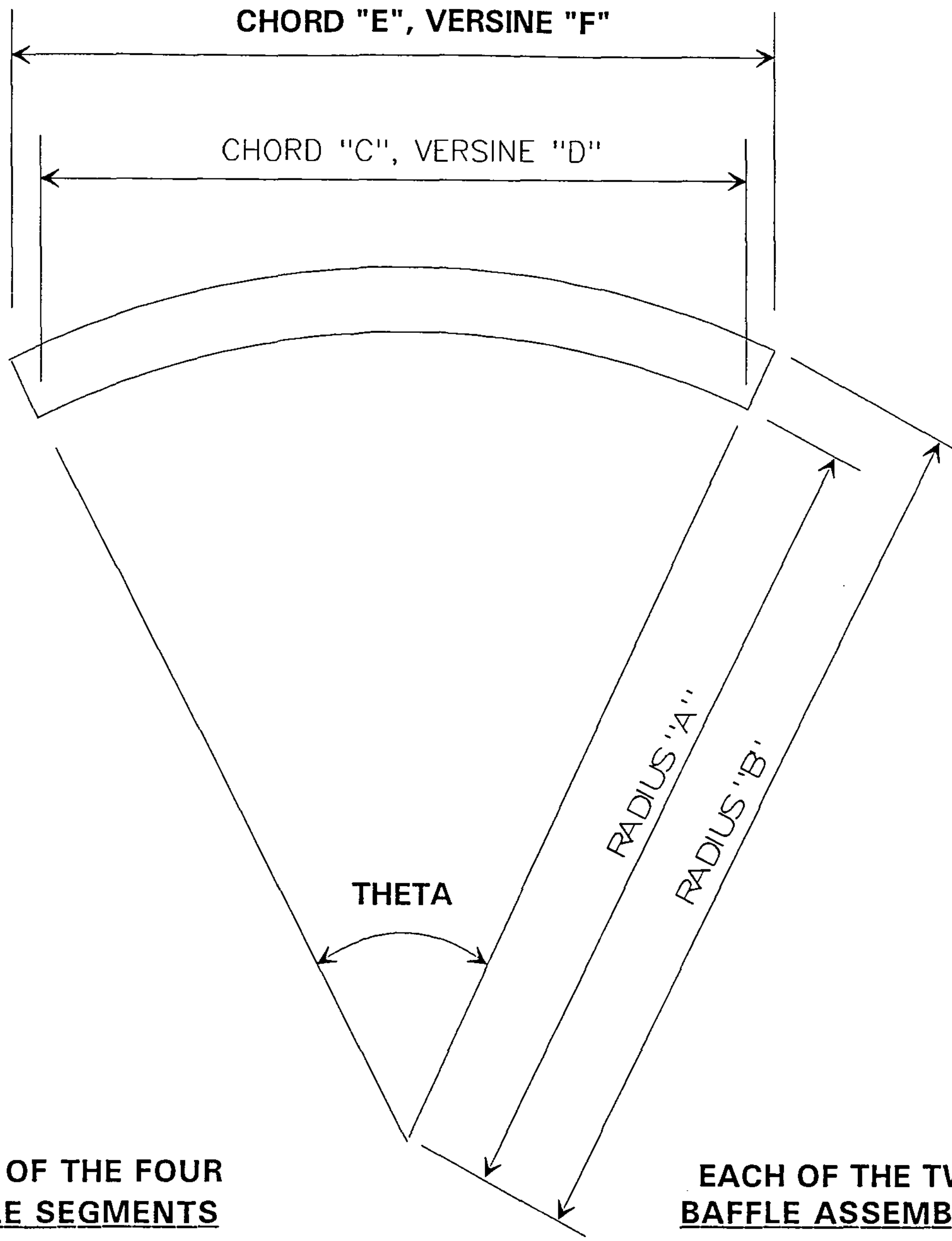
11.0 INSPECTION

The Purchaser shall have the right of inspecting the vendor's facility and witnessing the fabrication of the baffles.



SKETCH 1

BAFFLE (AS-INSTALLED DIMENSIONS AND TOLERANCES) AND SPACER BAR



EACH OF THE FOUR
<u>BAFFLE SEGMENTS</u>

RADIUS "A" = 41.782"
RADIUS "B" = 45.900"
THETA = 51.62 degrees
CHORD "C" = 36.384"
VERSINE "D" = 4.168"
CHORD "E" = 39.970"
VERSINE "F" = 4.579"

EACH OF THE TWO
<u>BAFFLE ASSEMBLIES</u>

RADIUS "A" = 41.782"
RADIUS "B" = 45.900"
THETA = 103.24 degrees
CHORD "C" = 65.508"
VERSINE "D" = 15.842"
CHORD "E" = 71.964"
VERSINE "F" = 17.403"

<u>SKETCH 2</u>

<u>DIMENSIONS OF BAFFLE ANNULAR SEGMENTS</u>

CBI	IDENTIFICATION C-VAC-1			
TITLE VACUMM STIFFENER FABRICATION SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE NOE-C		REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY SWP	MADE BY	CHKD BY
	DATE 03/07/94	DATE 03/07/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for the supply, fabrication, inspection, cleaning, packaging and shipping of shop fabricated beam tube vacuum stiffeners. The stiffeners shall be attached to a 49.00 inch O.D. vacuum tube by CBI (the "Purchaser").

1.0 APPLICABLE DOCUMENTS

1.1 ASME SA-240, "Specification for Heat-Resisting and Chromium Nickel Stainless Steel Plate, Sheet, and Strip".

1.2 ASME Boiler and Pressure Vessel Code, Section II, "Materials", 1992 Edition with the 1993 Addenda.

1.3 Sketch 1 -- "Beam Tube Vacuum Stiffener".

2.0 MATERIALS

2.1 All material for the vacuum stiffeners shall conform to ASME Specification SA-240 Type 304L. The stiffeners shall be fabricated from $1^{3}/_{4}$" x $^{3}/_{16}$" bars.

2.2 All material for the stiffeners shall be supplied by the vendor.

3.0 SUBMITTALS -- INFORMATION REQUIRED WITH QUOTATION

3.1 The vendor shall state in his quotation that the quotation complies with this specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

3.2 A description of the vendor's manufacturing facility and the equipment required to perform the work covered by this specification.

3.3 A description of the procedures for making and documenting measurements of stiffener dimensions with the tolerances specified.

4.0 INFORMATION REQUIRED AFTER RECEIPT OF ORDER AND 4 WEEKS PRIOR TO FABRICATION FOR REVIEW AND APPROVAL

4.1 Cleaning procedures stating the solvents used.

4.2 Packaging and shipping procedures.

5.0 FABRICATION

5.1 A stiffener shall be fabricated by rolling a continuous $1^3/_4$" x $^3/_{16}$" bar of A240 Type 304L stainless steel about its strong axis to the radius and tolerances shown on Sketch 1 of this Specification.

5.2 Welded splices of bar material is not permitted.

5.3 The ends of a fabricated stiffener shall overlap to the dimension and tolerances shown on Sketch 1 of this Specification. The ends of the fabricated stiffener may be cut in order to obtain the required overlap.

6.0 WELDING

6.1 There shall be no welding of any kind on the stiffeners.

7.0 CLEANLINESS AND CLEANING

7.1 All contact made with the stainless steel material during fabrication shall be such as to prevent carbon steel contamination.

7.2 After fabrication and prior to packaging, the stiffeners shall be cleaned with a solvent wipe to remove all visible traces of oil and grease. A detergent and water cleaning mix shall not be used. The vendor shall submit a cleaning procedure stating the solvents used to the Purchaser for review and approval.

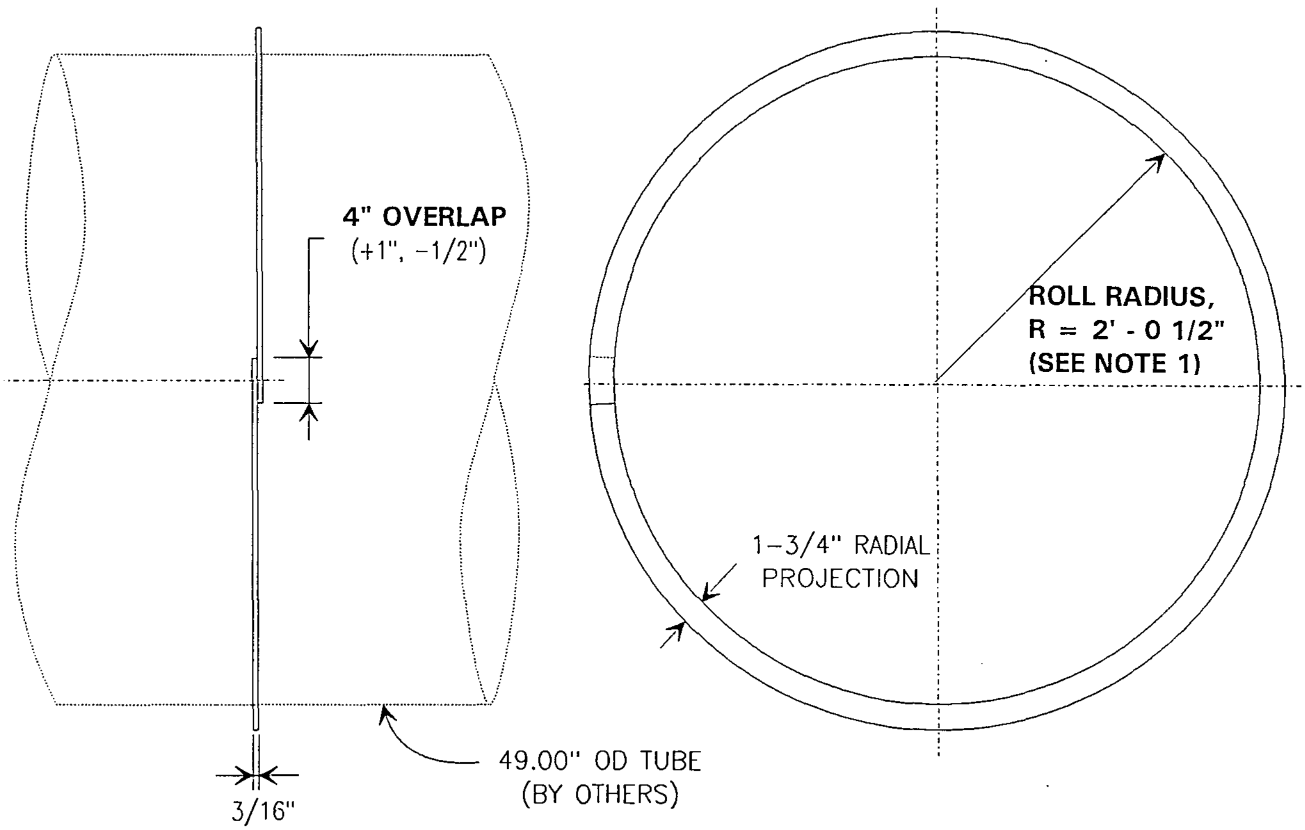
8.0 PACKAGING FOR SHIPPING

8.1 After cleaning, the stiffeners shall be placed on pallets for shipping. The stiffeners shall be sealed from contamination by wrapping securely in plastic. The vendor shall submit a packaging and shipping procedure to the Purchaser for review and approval.

8.2 The stiffeners shall be shipped as specified in the Purchase Order.

9.0 INSPECTION

9.1 The Purchaser shall have the right of inspecting the vendor's facility and witnessing the fabrication of the stiffeners.



STIFFENER MATERIAL: A240 TYPE 304L STAINLESS STEEL
ROLL RADIUS, R = 2' - 0 1/2" (+1/4", -0")

NOTES:

1. STIFFENERS TO BE A SINGLE CONTINUOUS PIECE FORMED BY ROLLING 3/16" x 1-3/4" FLATS; ONLY THE ENDS OF THE STIFFENER TO BE CUT EDGES.

SKETCH 1
BEAM TUBE VACUUM STIFFENERS

CBI	IDENTIFICATION C-SUPT-1			
TITLE BEAM TUBE SUPPORT SPECIFICATION	REFERENCE NO. 930212		SHT 1 OF 8	
	OFFICE NOE-C		REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY	MADE BY	CHKD BY
	DATE 03/09/94	DATE	DATE	DATE

0.1 SCOPE

This specification provides the technical requirements for the supply, fabrication, welding and galvanizing of structural steel and miscellaneous steel for the beam tube supports. The supports shall be installed by CBI (the "Purchaser").

1.0 APPLICABLE DOCUMENTS

1.1 ASME SA-240, "Specification for Heat-Resisting and Chromium Nickel Stainless Steel Plate, Sheet, and Strip".

1.2 ASTM A36, "Specification for Structural Steels".

1.3 AISC "Manual of Steel Construction", 9th Edition.

1.4 AISC "Code of Standard Practice for Steel Buildings and Bridges".

1.5 AWS D1.1, "Structural Welding Code".

1.6 AWS D19.0, "Welding Zinc Coated Steel".

1.7 Design Sketches -- See Appendix A, "Design Drawing List".

2.0 FABRICATOR SUPPLY

2.1 The Fabricator shall supply all fabricated structural and miscellaneous steel details as described on the design sketches listed in Appendix A. All bolts, washers and nuts required for erection shall be supplied, including 5 percent more than the computed quantity. All shims, wedges and leveling plates required for proper fit-up shall also be furnished by the Fabricator.

2.2 Any exceptions or exclusions to Fabricator-supplied items will be noted by the Purchaser in the Purchase Order.

3.0 MATERIALS

3.1 Only new material meeting the specified ASTM or ASME designation shall be used unless approved, in advance, by the Purchaser.

3.2 All structural steel shall conform to the requirements of ASTM A36 unless noted otherwise. All miscellaneous steel plates and bars shall conform to the requirements of ASTM A36 unless noted otherwise.

3.3 All stainless steel shall conform to the requirements of ASME Specification SA-240 Type 304L.

3.4 Welding electrodes shall meet requirements of AWS D1.1, E70XX, unless noted otherwise.

4.0 INFORMATION REQUIRED WITH QUOTATION

4.1 The Fabricator shall state in his quotation that the quotation complies with this technical specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

4.2 A description of the Fabricator's facility and the equipment required to perform the work covered by this Specification.

4.3 Country of Origin of all materials. This project contains a "Buy American" clause.

5.0 INFORMATION REQUIRED AFTER RECEIPT OF ORDER AND 4 WEEKS PRIOR TO FABRICATION FOR REVIEW AND APPROVAL

5.1 The Fabricator shall supply shop drawings to the Purchaser for review and approval prior to the start of fabrication. Refer to Section 7.2 of this Specification for additional information.

5.2 Welder personnel qualification records. Refer to Section 9.2. of this Specification for additional information.

5.3 Galvanizing procedures, including cleaning methods used prior to galvanizing.

5.4 Packaging and shipping procedures.

6.0 DOCUMENTATION REQUIRED AFTER COMPLETION OF FABRICATION

6.1 Certificates of Compliance (COC) for all material including weld material.

7.0 DRAWINGS

7.1 The Purchaser will furnish design drawings to the Fabricator. These drawings will show the following:

- The principal views of the structures.
- The controlling dimensions.
- The member sizes.
- Special details.

7.2 The Fabricator shall supply shop drawings to the Purchaser for review and approval prior to the start of fabrication. These shop drawings shall include fabrication details, bills of material, weight lists, field bolt lists, and product data information as required. Review by the Purchaser is to assure the correct interpretation of the work and compatibility with the erection plan, and does not relieve the Fabricator of the responsibility for the accuracy of the detailing. The Fabricator shall assume full responsibility for the correctness of details and dimensions. The cost of rectifying fabricating or detailing errors in the field will be charged to the Fabricator. The Fabricator shall show the weights of all shipping pieces either on the erection drawings or bill of material. Changes in details, splices in members, or substitution of member sizes shall not be made without the authorization of the Purchaser.

8.0 FABRICATION

8.1 All workmanship shall follow standard structural shop practice and shall be in accordance with the AISC "Specification for the Design, Fabrication and Erection of Structural Steel for Buildings" and the AISC "Code of Standard Practice of Steel Buildings and Bridges".

9.0 WELDING

9.1 Shop welding, where required, shall conform to the American Welding Society D.1.1, "Structural Welding Code".

9.2 Welder certification and weld procedures shall be as follows:

9.2.1 All welders shall have certification showing their qualification according to AWS Standard D1.1. Welders qualified in accordance with ASME Code Section IX are acceptable. These documents must be submitted to the Purchaser prior to the commencement of any welding.

9.2.2 A copy of certified welding procedures not prequalified by AWS shall be submitted to the Purchaser for review prior to the commencement of any welding. Welding procedures qualified in accordance with ASME Code Section IX are acceptable.

9.2.3 Groove welds, where used, shall be terminated at the ends of a joint in a manner that will ensure their soundness. Where possible, this should be done by use of extension bars or run-off plates. Extension bars or run-off plates, if used, shall be removed upon completion of the weld and the ends of the weld made smooth and flush with the abutting parts.

9.3 Welds shall be inspected by the Fabricator according to the provisions of AWS D1.1 with respect to technique, equipment and acceptance criteria.

10.0 GALVANIZING

10.1 All galvanizing shall be performed in accordance with the requirements of Appendix B of this Specification.

10.2 Unless noted otherwise on the design drawings, all carbon steel, bolts, washers and nuts shall be galvanized. Stainless steel shall <u>not</u> be galvanized.

11.0 PACKAGING FOR SHIPPING

11.1 After galvanizing, the support material shall be packaged for shipping. The Fabricator shall submit a packaging and shipping procedure to the Purchaser for review and approval.

12.0 SCHEDULE

12.1 Material shall be shipped as specified in the Purchase Order.

13.0 INSPECTION

13.1 The Purchaser shall have the right of inspecting the Fabricator's facility and witnessing the fabrication of the supports.

APPENDIX A
DESIGN DRAWING LIST

APPENDIX B
SPECIFICATION FOR GALVANIZING STRUCTURAL STEEL

1.0 SCOPE

1.1 This specification provides the technical requirements for hot dipped galvanizing of fabricated structural steel. The requirements in this specification are designed to minimize the risk of cracking in structural steel, sometimes caused by the galvanizing process, and to insure that an examination is performed to detect any cracking.

1.2 The Fabricator shall be responsible for the visual inspection of all material both before and after the galvanizing process.

1.3 The Fabricator shall furnish fabricated material free of defects in material and workmanship. Costs incurred by others to correct defects shall be at the Fabricator's expense.

2.0 PURCHASING OF MATERIALS

2.1 The structural steel material supplied shall be suitable for hot-dip galvanizing without undue risk of cracking.

3.0 INSTRUCTIONS TO THE FABRICATOR

3.1 When the Fabricator's scope of supply includes materials, the material shall be furnished in accordance with the requirements of Section 2.0 above.

3.2 All cuts, copes and blocks shall be fabricated following American Institute of Steel Construction (AISC) recommended practices as set forth in the AISC Manual of Steel Construction, Ninth Edition. Unless noted otherwise on the design drawings, all re-entrant corners shall be shaped, and ground notch-free to a radius of at least 1/2 inch.

3.3 All attachment welds, flame cut edges, and re-entrant corners of cutouts, copes and blocks shall be visually inspected for cracks before galvanizing, and prior to shipment after galvanizing.

3.4 If any cracks are found after galvanizing, all members with similar details shall be inspected. Defective members and welds shall be rejected or repaired at the Purchaser's discretion. Repair procedures must be submitted to the Purchaser for review and approval before any repairs are permitted.

4.0 INSTRUCTIONS TO THE GALVANIZER

4.1 Galvanizing shall be performed after completion of all cutting, drilling, forming, punching and welding operations.

4.2 Galvanizing shall be performed in accordance with the latest editions of ASTM A123, A143, A384 and A385.

4.3 The Galvanizer shall have a written procedure for hot dip galvanizing. This procedure shall be submitted to the Purchaser for review and approval prior to galvanizing.

5.0 SURFACE PREPARATION OF STEEL TO BE GALVANIZED

5.1 All material to be galvanized shall be chemically cleaned to ensure a proper galvanizing bond. Abrasive blasting shall be employed in the following situations:

- Mill or heat scale deeply embedded in the surface of the steel.
- Welding slag is present.
- Severe cold working of the steel has occurred.

Cleaning procedures shall be submitted to the Purchaser for review and approval prior to galvanizing.

6.0 QUALITY CONTROL & INSPECTION

6.1 It shall be the responsibility of the Galvanizer to supply a finished product, ready for shipment, that is free of bare spots, stalactites, and inclusions of flux or ash. Inspection shall be completed at the Galvanizer's facility. The Purchaser reserves the right to reject any or all galvanized items for imperfections, distortion, or warpage.

6.2 Touch-up of minor coating defects shall be allowed in the Galvanizer's facility according to the methods covered in ASTM A780, "Standard Practice for Repair of Damaged Hot-Dip Galvanized Coatings".

6.3 The Purchaser shall have the right of inspecting the Galvanizer's facility and witnessing all galvanizing procedures, inspections and repair procedures.

CBI

TITLE	IDENTIFICATION C-SUPSTF-1			
SUPPORT RING/BAFFLE RING FABRICATION SPECIFICATION	REFERENCE NO. 930212	SHT 1 OF 4		
	OFFICE NOE-C	REVISION 0		
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY	MADE BY	CHKD BY
	DATE 03/14/94	DATE	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for the supply, fabrication, inspection, cleaning, packaging and shipping of shop fabricated support/baffle rings (hereafter referred to solely as "support rings"). The support rings shall be attached to a 49.00 inch O.D. vacuum tube by CBI (the "Purchaser").

1.0 APPLICABLE DOCUMENTS

1.1 ASME SA-240, "Specification for Heat-Resisting and Chromium Nickel Stainless Steel Plate, Sheet, and Strip".

1.2 Sketch 1 -- "Beam Tube Support / Baffle Ring -- Type A".

1.3 Sketch 2 -- "Beam Tube Support / Baffle Ring -- Type B".

2.0 MATERIALS

2.1 All material for the support rings shall conform to ASME Specification SA-240 Type 304L. Each support ring shall be fabricated from 2 bars, each of which is $4^1/_2$" x $^3/_8$". Refer to Sketch 1 of this Specification.

2.2 All material for the support rings shall be supplied by the vendor.

3.0 SUBMITTALS -- INFORMATION REQUIRED WITH QUOTATION

3.1 The vendor shall state in his quotation that the quotation complies with this specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

3.2 A description of the vendor's manufacturing facility and the equipment required to perform the work covered by this specification.

3.3 A description of the procedures for making and documenting measurements of stiffener dimensions with the tolerances specified.

4.0 INFORMATION REQUIRED AFTER RECEIPT OF ORDER AND 4 WEEKS PRIOR TO FABRICATION FOR REVIEW AND APPROVAL

4.1 The vendor shall supply shop drawings to the Purchaser for review and approval prior to the start of fabrication. Refer to Section 6.2 of this Specification for additional information.

4.2 Cleaning procedures stating the solvents used.

4.3 Packaging and shipping procedures.

5.0 DOCUMENTATION REQUIRED AFTER COMPLETION OF FABRICATION

5.1 Certificates of Compliance (COC) for all material.

5.2 Record of measurement of the as-built machined outside diameter of each support ring.

6.0 DRAWINGS

6.1 The Purchaser will furnish design drawings to the vendor. These drawings will show the following:

- The principal views of the structures.
- The controlling dimensions.
- The member sizes.
- Special details.

6.2 The vendor shall supply shop drawings to the Purchaser for review and approval prior to the start of fabrication. These shop drawings shall include fabrication details, bills of material, weight lists, field bolt lists, and product data information as required. Review by the Purchaser is to assure the correct interpretation of the work and compatibility with the erection plan, and does not relieve the vendor of the responsibility for the accuracy of the detailing. The vendor shall assume full responsibility for the correctness of details and dimensions. The cost of rectifying fabricating or detailing errors in the field will be charged to the vendor. The vendor shall show the weights of all shipping pieces either on the erection drawings or bill of material. Changes in details, splices in members, or substitution of member sizes shall not be made without the authorization of the Purchaser.

7.0 FABRICATION

7.1 Each half of a support ring shall be fabricated from a continuous $4^{1}/_{2}$" x $^{3}/_{8}$" bar of A240 Type 304L stainless steel to the radius and tolerances shown on Sketch 1 of this Specification.

7.2 In each half of a support ring, the vendor shall drill and ream a total of four (4) Type "A" holes to 0.500" (+0.001", -0.000") as shown on Sketch 1..

7.3 In each half of a support ring, the vendor shall drill and taper ream a total of two (2) Type "B" holes for a No. 7 taper dowel as shown on Sketch 1.

7.4 The vendor shall securely bolt together each half of the support ring by installing $^1/_2$" socket head shoulder bolts in each of the the four Type "A" holes and torquing to 50 foot-pounds.

7.5 The vendor shall install $^3/_8$" - 16UNC bolts in each of the two Type "B" holes and torque to 40 foot-pounds.

7.6 The vendor shall then machine the **outside diameter** of the support ring to 57.000" (+0.010", -0.010"). The vendor shall <u>not</u> machine the inside diameter of the support ring.

7.7 **After machining the outside diameter of the support ring, the vendor shall not, at any time, unbolt the two halves of the support ring.**

7.8 The vendor shall scribe the cardinal centerlines of the support ring on each assembly.

7.9 If the support ring is a Type "A" support ring, drill the two (2) $^7/_8$" diameter holes as shown on Sketch 1 of this Specification. **Do not drill these holes in a Type "B" support ring.**

7.10 If the support ring is a Type "B" support ring, drill the eight (8) $^7/_8$" diameter holes as shown on Sketch 2 of this Specification. **Do not drill these holes in a Type "A" support ring.**

7.11 Prepare the support ring for cleaning and shipment.

8.0 WELDING

8.1 There shall be no welding of any kind on the support rings.

9.0 CLEANLINESS AND CLEANING

9.1 After fabrication and prior to packaging, the support rings shall be cleaned with a solvent wipe to remove all visible traces of oil and grease. A detergent and water cleaning mix shall not be used. The vendor shall submit a cleaning procedure stating the solvents used to the Purchaser for review and approval.

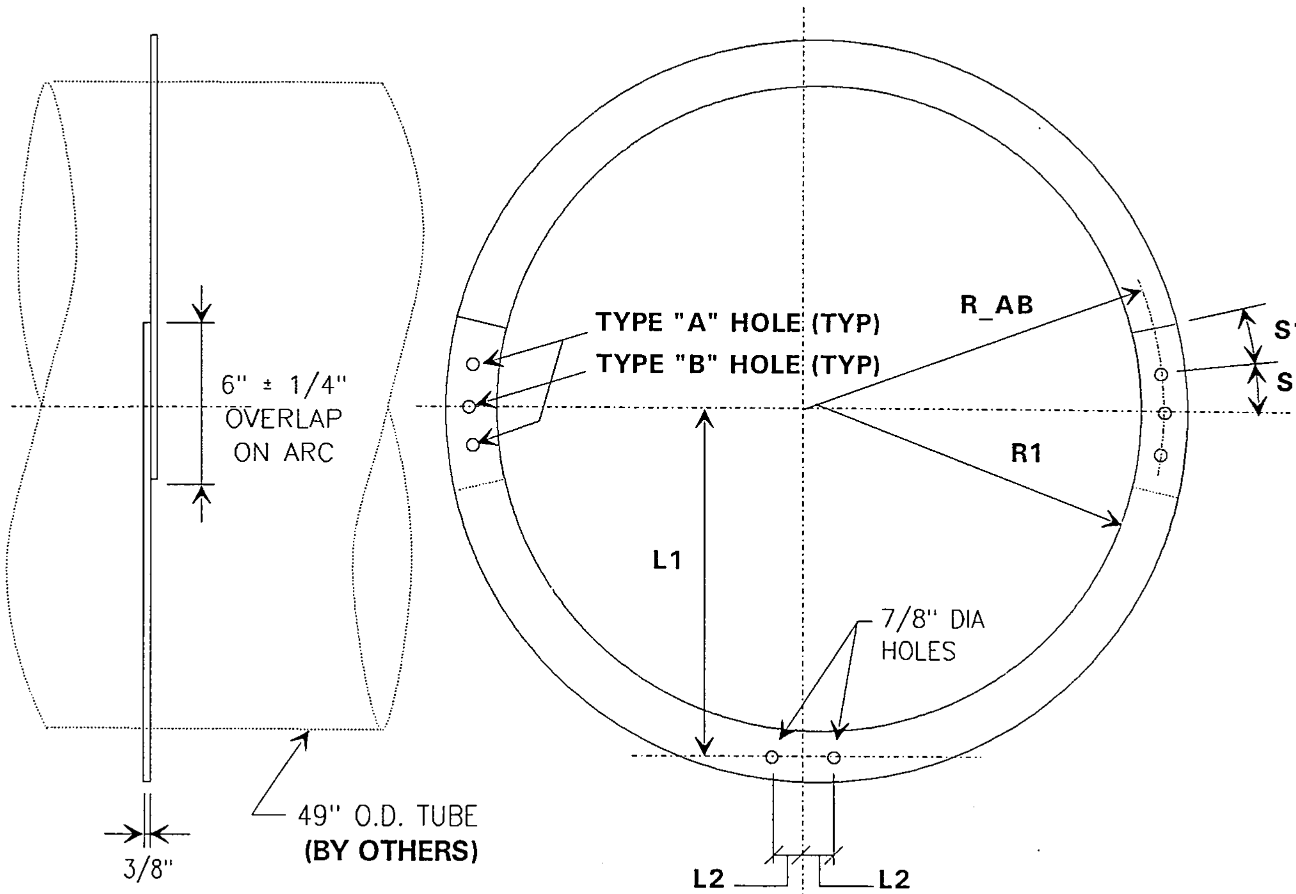
10.0 PACKAGING FOR SHIPPING

10.1 After cleaning, the support rings shall be placed on pallets for shipping. The support rings shall be sealed from contamination by wrapping securely in plastic. The vendor shall submit a packaging and shipping procedure to the Purchaser for review and approval.

10.2 The support rings shall be shipped as specified in the Purchase Order.

11.0 INSPECTION

11.1 The Purchaser shall have the right of inspecting the vendor's facility and witnessing the fabrication of the support rings.



SUPPORT RING MATERIAL: A240 TYPE 304L STAINLESS STEEL
R1 = INSIDE RADIUS = 24.375" (+0.00", -0.0625")
R_AB = RADIUS TO CENTERLINE OF HOLE TYPES "A" AND "B" = 26.75" (+0.00", -0.00")

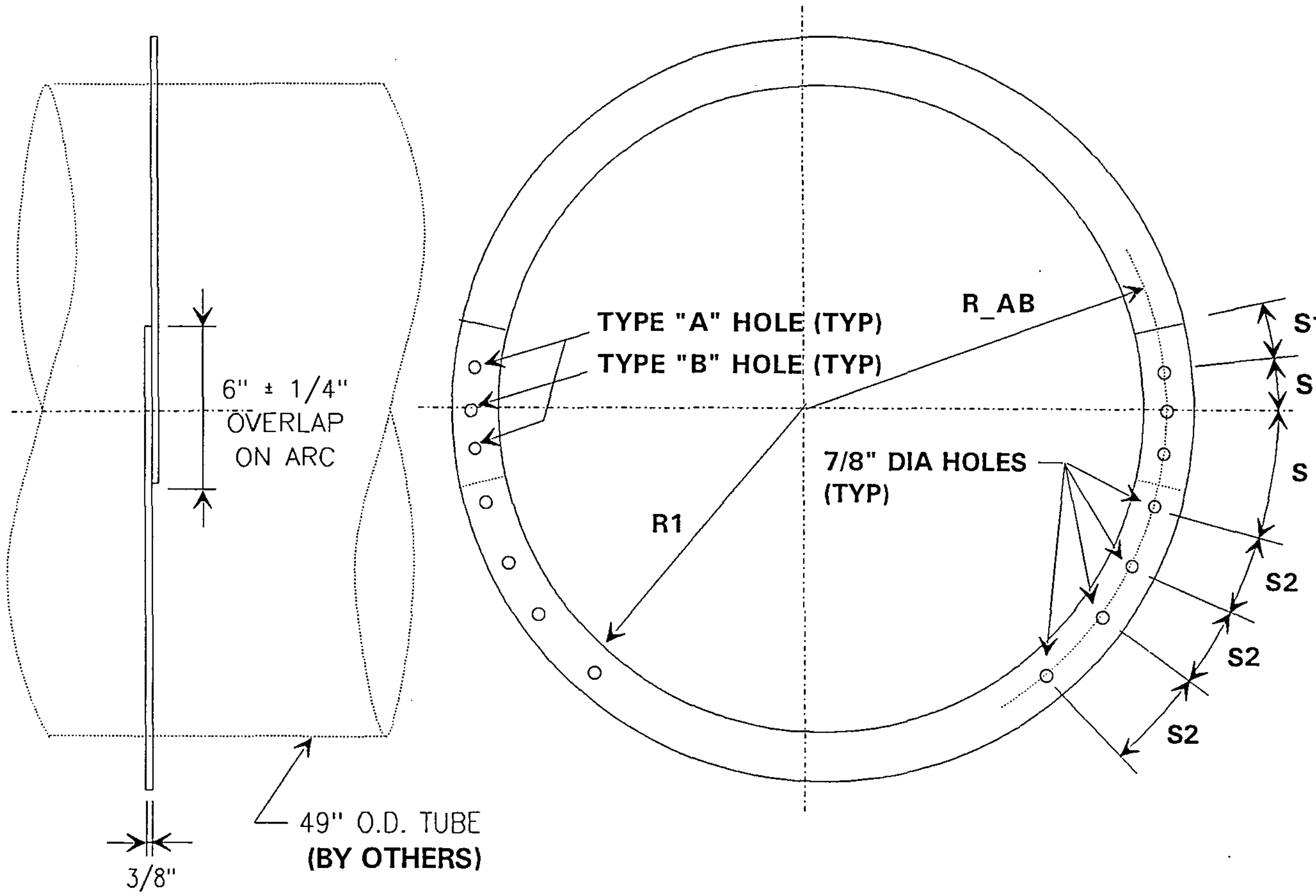
SPACING S1 = 1.50" ON RADIUS R_AB

DISTANCE L1 = 27.00"
DISTANCE L2 = 1.75", MEASURED FROM VERTICAL CENTERLINE

NOT TO SCALE

SKETCH 1

BEAM TUBE SUPPORT / BAFFLE RING -- TYPE "A"



SUPPORT RING MATERIAL: A240 TYPE 304L STAINLESS STEEL
R1 = INSIDE RADIUS = 24.375" (+0.00", -0.0625")
R_AB = RADIUS TO CENTERLINE OF HOLE TYPES "A" AND "B" = 26.75" (+0.00", -0.00")

SPACING S1 = 1.50" ON RADIUS R_AB
SPACING S2 = 5.00" ON RADIUS R_AB

NOT TO SCALE

SKETCH 2

BEAM TUBE SUPPORT / BAFFLE RING -- TYPE "B"

CBI

TITLE	IDENTIFICATION			
	C-PORT-OP			
PUMP PORT FABRICATION SPECIFICATION CONSTRUCTION OPTION	REFERENCE NO. 930212		SHT 1 OF 5	
	OFFICE NOE-C		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY JGS	CHKD BY WJC	MADE BY	CHKD BY
	DATE 03/01/94	DATE 03/04/94	DATE	DATE

0.1 SCOPE

This specification is for the supply, welding, fabrication, cleaning, testing, and packaging of shop fabricated pump ports for **ultra high vacuum service**. The pump ports are part of a vacuum system for sensitive interferometer components and optical beams for the Laser Interferometer Gravitational-Wave Observatory (LIGO). VAT Series 10 gate valves will bolt to the pump ports. Field installation will be by CBI (Purchaser).

1.0 APPLICABLE DOCUMENTS

1.1 Drawings / Figures

The following drawing(s) and figure(s) form an integral part of this specification:

Sketch 1 -- "Pump Port".

1.2 Specifications

1.2.1 The vendor shall comply with all applicable sections of the latest edition of the following documents and codes:

ASME Unfired Pressure Vessels, Section VIII, Div. 1 as applicable (Code stamping is **not** required).

ASME Welding Qualifications, Section IX.

LIGO Specification 1100007, Process Specification for Low Hydrogen, Type 304L Stainless Steel Vacuum Products, dated March 26, 1992.

1.2.2 In the event of a conflict between the text of this specification (including drawings and figures) and the references listed in Section 1.2.1, the vendor shall immediately notify the Purchaser for resolution.

2.0 MATERIAL SUPPLY

2.1 A minimum of fifty-six (56) pump ports with gaskets and test bolts per Figure 1 shall be supplied to the Purchaser for installation in the vacuum vessels. Up to fifty-six (56) additional pump ports may be required.

3.0 SUBMITTALS

Information Required with Quotation:

3.1 The vendor shall state in his quotation that the quotation complies with this technical specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

3.2 Pricing for fifty-six (56) pump port units plus the price for additional pump ports up to a total of one-hundred twelve (112). Units shall include gaskets and test bolts.

3.3 Pricing for the leak testing described in Section 6.1 of this specification.

3.4 Type of forging material used for flange to be supplied (full SA or ASTM designation) and type of pipe material to be supplied (full SA or ASTM designation).

3.5 A description of the vendor's quality assurance manual in accordance with ANSI/ASQC Standard Q91. (Certification is not mandatory).

3.6 If the pipe material is welded, the welding procedure(s) used to fabricate the pipe shall be provided.

3.7 Sketch or drawing detailing the pump port pipe-to-flange joint and proposed welding procedure(s).

3.8 Thickness of flange and pipe wall.

3.9 Country of origin of the manufacturer. This project contains a "Buy American" clause.

3.10 Delivery schedule.

3.11 Other submittals as described elsewhere in this specification.

Information Required After Receipt of Order and 4 Weeks Prior to Fabrication:

3.12 Welding procedures with supporting procedure qualification records and welder personnel qualification records per ASME Section IX.

3.13 NDE procedures and qualifications for NDE personnel.

Information Required 2 Weeks Prior to Shipment:

3.14 Certified material test reports (CMTR) or certificate of compliance (COC) for all material.

3.15 Documentation of measured helium leakage rates for each pump port.

4.0 MATERIALS

4.1 Stainless steel conforming to ASTM A240 type 304L and LIGO Specification 1100007.

4.2 Flanges shall be fabricated from forged material and cross rolled.

4.3 Pipe is preferred to be seamless.

4.4 Welding material shall be ER308L.

4.5 Lubricants that affect the ability to obtain high vacuum levels such as hydrocarbons or silicon shall not be used during fabrication. If a lubricant must be used, the type of lubricant shall be specified.

5.0 FABRICATION

5.1 Welding

5.1.1 All welding exposed to vacuum shall be done by the gas tungsten arc welding (GTAW) process.

5.1.2 For all welding, use an inert gas purge on the vacuum side of the weld.

5.1.3 All vacuum welds shall be, wherever possible, internal and continuous. All external welds added to these for structural purposes shall be intermittent to eliminate trapped volumes.

5.1.4 Welding procedures shall be submitted prior to production welding. Welder and weld operator qualification records shall be submitted prior to any individual performing welding. Welders and weld operator qualifications shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The Purchaser shall have the option to require the re-qualification of any welder at any time if, in the Purchaser's opinion, the welder's qualifications are suspect or welds appear not to be of the proper quality.

5.1.5 Weld edge preparation shall be made by machine cutting or grinding. Burning is not permitted.

5.2 Cleanliness and Cleaning

5.2.1 All contact made with the stainless steel material during fabrication shall be such as to prevent carbon steel contamination.

5.2.2 After fabrication of the pump port is complete, the inside surfaces shall have all visible traces of oil, grease or other foreign material removed with a solvent wipe. Detergents/water are not allowed. Pump port vendor shall submit a cleaning procedure stating solvents used.

5.3 Tolerances

5.3.1 Tolerances shall be per the vendor's standard. The vendor's fabrication tolerances shall be submitted to the Purchaser with the quotation.

6.0 TESTING AND INSPECTION

6.1 The leak testing of pump ports shall be done with a helium mass spectrometer (HMS) using the helium hood technique. The pump port HMS test system must be calibrated and the system calibration must indicate that in-leakage of 1×10^{-10} atm. cc/sec. is readily detectable within a reasonable amount of time. The pump port shall contain no leakage in excess of 1×10^{-10} atm. cc/sec. The HMS leak test procedure to be used shall be submitted to the Purchaser for approval.

6.2 The Purchaser shall have the option of inspecting at the vendor's facility and witnessing tests or procedures required in this specification.

7.0 PACKAGING

7.1 It shall be the responsibility of the vendor to protect the pump ports during shipment. In particular, the interior of the pump port shall be protected from contamination by sealing all openings. The vendor's method of protecting the pump ports shall be submitted to the Purchaser for review with the quotation.

8.0 SCHEDULE

8.1 The vendor shall satisfy the following tentative schedule requirements:

- Supply a minimum of twenty-eight (28) and a maximum of fifty-six (56) completed pump ports between October 1, 1994 and July 1, 1995 at a steady rate.
- Supply a minimum of twenty-eight (28) and a maximum of fifty-six (56) completed pump ports between July 1, 1995 and March 1, 1996 at a steady rate.

<table>
<tr><td colspan="1" rowspan="1"></td><td colspan="4">IDENTIFICATION
C-PORTPAD-1</td></tr>
<tr><td rowspan="4">TITLE
PUMP PORT REINFORCING PAD
FABRICATION SPECIFICATION

PRODUCT
LIGO BEAM TUBE MODULES
CALIFORNIA INSTITUTE OF TECHNOLOGY</td><td colspan="2">REFERENCE NO.
930212</td><td colspan="2">SHT 1 OF 4</td></tr>
<tr><td colspan="2">OFFICE
NOE-C</td><td colspan="2">REVISION
1</td></tr>
<tr><td>MADE BY
WJC</td><td>CHKD BY
SWP</td><td>MADE BY</td><td>CHKD BY</td></tr>
<tr><td>DATE
03/08/94</td><td>DATE
03/08/94</td><td>DATE</td><td>DATE</td></tr>
</table>

0.1 SCOPE

This specification gives the technical requirements for the supply, fabrication, welding, inspection, cleaning, packaging and shipping of pump port reinforcing pads (hereafter referred to solely as "reinforcing pads"). The reinforcing pads shall be attached to a 49.00 inch O.D. vacuum tube by CBI (the "Purchaser").

1.0 APPLICABLE DOCUMENTS

1.1 ASME SA-240, "Specification for Heat-Resisting and Chromium Nickel Stainless Steel Plate, Sheet, and Strip".

1.2 ASME Boiler and Pressure Vessel Code, Section II, "Materials", 1992 Edition with the 1993 Addenda.

1.3 ASME Unfired Pressure Vessel Code, Section VIII, Division 1, 1992 Edition with the 1993 Addenda as applicable (Code stamping is not required).

1.4 ASME Code, Section IX, "Welding and Brazing Qualifications", 1992 Edition with the 1993 Addenda.

1.5 ANSI/ASQC Standard Q91.

1.6 Sketch 1 -- "Pump Port Reinforcing Pad".

2.0 MATERIALS

2.1 Material for the reinforcing pads shall conform to ASME Specification SA-240 Type 304L. Reinforcing pad material shall be $^{1}/_{4}$" thick.

2.2 All material for the reinforcing pads shall be supplied by the vendor.

3.0 SUBMITTALS -- INFORMATION REQUIRED WITH QUOTATION

3.1 The vendor shall state in his quotation that the quotation complies with this specification with any exceptions or alternates noted and explained. The Purchaser will assume complete conformance unless exceptions are noted.

3.2 A description of the vendor's manufacturing facility and the equipment required to perform the work covered by this specification.

3.3 A description of the procedures for making and documenting measurements of reinforcing pad dimensions with the tolerances specified.

3.4 Country of origin of the manufacturer. This project contains a "Buy American" clause.

3.5 Shop practices, including forming methods, lubricants used, cleaning procedures, etc. Refer to Section 7.0 of this Specification, "Cleanliness and Cleaning".

3.6 A description of the vendor's procurement approach, including sources of materials, traceability of materials and management of subcontracts.

3.7 A description of the vendor's quality assurance manual in accordance with ANSI/ASQC Standard Q91 (Certification not required).

3.8 A description of the vendor's management plan, including the process by which the work covered by this Specification will be monitored and controlled, and the identification and function of key personnel to be assigned.

4.0 INFORMATION REQUIRED AFTER RECEIPT OF ORDER AND 4 WEEKS PRIOR TO FABRICATION FOR REVIEW AND APPROVAL

4.1 Weld procedures and supporting procedure qualification records and welder personnel qualification records per ASME Section IX.

4.2 NDE procedures.

4.3 Qualifications for NDE personnel.

4.4 Cleaning procedures stating the solvents used.

CBI	IDENTIFICATION C-PORTPAD-1			
TITLE PUMP PORT REINFORCING PAD FABRICATION SPECIFICATION	REFERENCE NO. 930212		SHT 3 OF 4	
	OFFICE NOE-C		REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WJC	CHKD BY SWP	MADE BY	CHKD BY
	DATE 03/08/94	DATE 03/08/94	DATE	DATE

4.5 Packaging and shipping procedures.

5.0 DOCUMENTATION REQUIRED AFTER COMPLETION OF FABRICATION

5.1 Certified Material Test Reports (CMTR) or Certificates of Compliance (COC) for all material including weld material.

5.2 Record drawings and/or checklists detailing welder identifications, NDE and material identifications for each reinforcing pad.

5.3 A record of dimensional control measurements for each reinforcing pad.

5.0 FABRICATION

5.1 Fabricate the reinforcing pad from $^1/_4$" thick ASME SA-240 Type 304L stainless steel as shown in Figure 1 of this Specification. Figure 1 shows the reinforcing pad dimensions in the flat prior to rolling.

5.2 Roll the reinforcing pad to an inside radius of $24^1/_2$" ($+^1/_8$", $-^1/_8$").

6.0 WELDING

6.1 Welding procedures shall be submitted to the Purchaser prior to production welding. Welder and weld operator qualification records shall be submitted prior to any individual performing welding. Welders and weld operator qualifications shall comply with Section IX of the ASME Boiler and Pressure Vessel Code. The Purchaser shall have the option to require the re-qualification of any welder at any time if, in the Purchaser's opinion, the welder's qualifications are suspect or welds appear not to be of the proper quality.

7.0 CLEANLINESS AND CLEANING

7.1 All contact made with the stainless steel material during fabrication shall be such as to prevent carbon steel contamination.

7.2 After fabrication and prior to packaging, the reinforcing pads shall be cleaned with a solvent wipe to remove all visible traces of oil and grease. A detergent and water cleaning mix shall not be used. The vendor shall submit a cleaning procedure stating the solvents used to the Purchaser for review and approval.

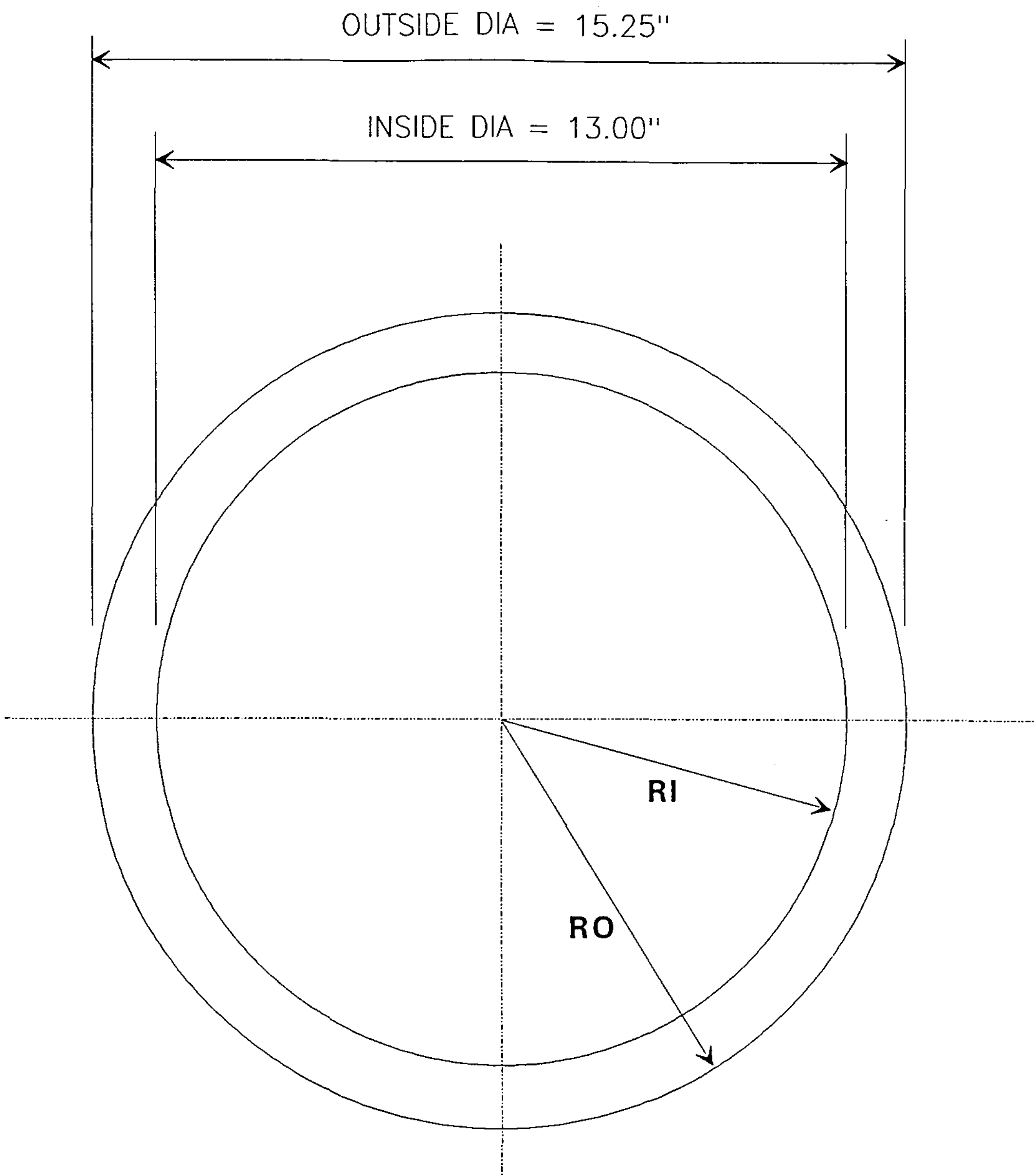
8.0 PACKAGING FOR SHIPPING

8.1 After cleaning, the reinforcing pads shall be placed on pallets for shipping. The reinforcing pads shall be sealed from contamination by wrapping securely in plastic. The vendor shall submit a packaging and shipping procedure to the Purchaser for review and approval.

8.2 The reinforcing pads shall be shipped as specified in the Purchase Order.

9.0 INSPECTION

9.1 The Purchaser shall have the right of inspecting the vendor's facility and witnessing the fabrication of the reinforcing pads.



INSIDE RADIUS, RI = 0' – 6 1/2"
OUTSIDE RADIUS, RO = 0' – 7 5/8"

PAD MATERIAL: A240 TYPE 304L STAINLESS STEEL
PAD THICKNESS: 1/4"

SKETCH 1

PUMP PORT REINFORCING PAD

DOC. ID	PROCEDURE/INDEX
REV. NO.	0
CONTRACT	930212

TITLE WELDING/QUALITY ASSURANCE/FITTING/PURGING/WMS PROCEDURE INDEX FOR LIGO BEAM TUBE MODULES

Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	RWP	3/1/94
REVISED		
AUTHORIZED	BGG	3/1/94
REFERENCED STANDARD	REV. NO.	

Document Identification	Prepared By	Revision Number
WPS INDEX	RWP	2
GWPS-SMAW	AEH	15
GWPS-GTAW	AEH	14
GWPS-GMAW&FCAW	AEH	15
WPS-ER308L/CIRC	RWP	2
WPS-ER308L/STIFFENER	RWP	2
WPS-ER308L/PORT	RWP	2
WPS-ER308L/GMA	RWP	0
WPS-ER308L/REPAIR	RWP	0
WPS-E7018/STRUCT	RWP	0
WPS-E308/STRUCT	RWP	0
WPS-E309/STRUCT	RWP	0
WMS-ER308L	RWP	1
WPS-WELDCOUP	RWP	1
FPCIRCUMFERENTIAL	RWP	1
FPSTIFFENER	RWP	1
FPPUMPPORT	RWP	1
GR-8X	RWP	1
CUP-8X	RWP	1
VI5	RWK	0
VI8	RWK	2
CLCOUP	CNS	3
CLCOUPA	CNS	0
CLCOUPA0	CNS	2
CLCOUPA1	CNS	1
LIGOTP	CNS	D3
HMST1N	CNS	D3
HMST2N	CNS	D3
HMST3N	CNS	D2
HMST4N	CNS	D2
HMST5N	CNS	D2

DOC. ID	PROCEDURE/INDEX
REV. NO.	0
CONTRACT	930212

TITLE WELDING/QUALITY ASSURANCE/FITTING/ PURGING/WMS PROCEDURE INDEX FOR LIGO BEAM TUBE MODULES

Document Identification	Prepared By	Revision Number
LIGO QUALITY ASSURANCE MANUAL (QAM)		0
QAP 1.0 MANAGEMENT RESPONSIBILITY	REK	0
QAP 2.0 QUALITY SYSTEM	REK	0
QAP 2.1 QUALITY PLAN	REK	0
QAP 2.2 CONTRACT QAPs	REK	0
QAP 3.1 PRE-CONTRACT REVIEW	ALD	0
QAP 3.2 POST-AWARD REVIEW	ALD	0
QAP 4.1 PREPARATION OF DETAIL DRAWINGS, WRITTEN REQUISITIONS AND PROCUREMENT SPECIFICATIONS	JGS	0
QAP 5.1 DOCUMENT CONTROL	JGS	0
QAP 5.2 DISTRIBUTION OF DETAIL DRAWINGS, WRITTEN REQUISITIONS AND PROCUREMENT SPECIFICATIONS	JGS	0
QAP 5.3 CBI STANDARDS	JGS	0
QAP 5.4 CONTRACT QA DOCUMENTS	ALD	0
QAP 5.5 CUSTOMER DRAWINGS	RGL	0
QAP 6.1 PURCHASE ORDERS	RGL	0
QAP 6.2 VENDOR SURVEY	RGL	0
QAP 6.3 VENDOR ASSESMENT & SURVEILLANCE	RGL	0
QAP 7.1 RECEIPT OF CUSTOMER SUPPLIED MATERIAL	RGL	0
QAP 8.1 MATERIAL CONTROL	RAJ	0
QAP 9.1 PROCESS CONTROL	ALD	0
QAP 9.2 WELDING CONTROL	ALD	0
QAP 9.3 HEAT TREATING	ALD	0
QAP 9.4 MISCELLANEOUS PROCESS CONTROL	ALD	0
QAP 10.1 RECEIVING INSPECTION	ALD	0
QAP 10.2 NDE, INSPECTION AND TESTING	ALD	0
QAP 10.3 FINAL INSPECTION	ALD	0
QAP 11.1 CALIBRATION	RAJ	0
QAP 12.1 INSPECTION AND TEST STATUS	RAJ	0
QAP 13.1 NONCONFORMITIES	REK	0
QAP 14.1 CORRECTIVE ACTION	REK	0
QAP 15.1 HANDLING, STORAGE, PACKAGING AND SHIPPING	REK	0
QAP 16.1 QUALITY RECORDS	REK	0
QAP 17.1 INTERNAL AUDITING	RGL	0
QAP 18.1 TRAINING	RGL	0

WELDING PROCEDURE SPECIFICATION	IDENTIFICATION WPS INDEX	CONTRACT 930212

PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. *1* OF *1*
CUSTOMER *CALTECH*	REV. NO. *3*
	BY *RWP* DATE *03/11/94*

GENERAL WELDING PROCEDURE SPECIFICATIONS

WELDING PROCEDURE SPECIFICATIONS

WELDING MATERIAL SPECIFICATIONS

TITLE: GENERAL WELDING PROCEDURE SPECIFICATION FOR THE SHIELDED METAL ARC PROCESS

1.0 SCOPE:

1.1 This is a general Welding Procedure Specification to be used with a specific Welding Procedure Specification (WPS) when referenced on the WPS. In cases of conflict between this document and the specific WPS, the specific WPS shall govern.

2.0 REFERENCE:

2.1 ASME Boiler and Pressure Vessel Code, Section IX , Welding Qualifications, Edition and Addenda as shown on the specific WPS.

3.0 PROCEDURE QUALIFICATIONS:

3.1 Procedure qualifications have been made in accordance with the requirements of the ASME Code, Section IX and will be available for review.

4.0 PREPARATION OF BASE METAL:

4.1 The edges or surfaces of the pieces to be joined by welding shall be prepared by flame cutting, plasma arc cutting, arc gouging, machining, shearing, grinding, or chipping and shall be cleaned of detrimental oil, grease, scale and rust. The edges of the pieces may have a protective coating applied to them which need not be removed before they are welded unless specifically prohibited by the specific WPS.

5.0 WEATHER CONDITIONS FOR WELDING:

5.1 Welding shall not be performed when the surfaces in the welding area (within 6" (15.2 cm) of the arc) are wet; nor in periods of high winds unless the welder and the pieces to be welded are properly protected.

6.0 JOINTS: (QW-402)

6.1 Root Opening:

Normal root opening shall be 0-1/4" (0 mm-6.4 mm). See contract drawings for the specific joint detail. Spacer bar joints are considered 0" gap.

6.2 Wide Gaps:

The following technique shall be used for welding joints with wide gaps which exceed twice that specified on the applicable contract drawing. When zero gap is specified on the contract drawings, gaps exceeding 3/16" (4.8 mm) shall be reduced as outlined below to a 3/16" (4.8 mm) or smaller gap. Maximum weld build-up shall be T (where "T" is the thickness of the plate) for each plate edge or 1/2" (12.7 mm) whichever is smaller.

Method:

Plate edge build-up shall be done with a welding procedure approved for contract use. Weld passes shall be deposited utilizing a stringer bead technique to restore the plate edges to the gap and approximate joint configuration as shown on the contract drawings.

On single or square butt joints, a temporary back-up bar of compatible material may be used. The edges should be built-up using stringer beads to restore the joint to the gap and approximate joint configuration as shown on contract drawings, before tying the edges together.

The temporary back-up bar shall be removed by gouging, chipping or grinding to clean, sound-metal before welding the second side.

6.3 Narrow Gaps:

The following technique shall be used for correcting joints with gaps less than specified on the applicable contract drawing which are not sufficiently wide to allow free manipulation of the electrode in the joint.

Method:

The plate edges of the joint shall be prepared by flame cutting, plasma arc cutting, grinding, arc gouging, or chipping to restore the joint to the gap and approximate joint configuration shown on the contract drawings. Gouging dross, burning dross, or residue shall be removed by brushing or grinding before welding commences.

6.4 Retainers:

Nonmetallic retainers or nonfusing metal retainers may only be used when they are specified on the specific WPS.

6.5 Backing:

Double welded groove welds are considered welding with backing.

For single welded groove welds, the backing shall be as specified in the specific WPS.

7.0 PREHEAT AND INTERPASS TEMPERATURE (When required by the specific WPS): (QW-406)

7.1 Method:

If required, preheat and/or interpass temperature shall be achieved by any suitable means which will keep the temperature of the joint within the specified limits shown on the specific WPS. The method of preheating and the heat source to be used may be changed or supplemented as deemed necessary or desirable.

7.2 Continuous Preheat:

When continuous preheat is required, it shall be a uniform preheat during the time of welding, obtained by pipe burners or strip heaters. On vertical joints or radial joints, the required preheat is necessary along the entire length. On circumferential joints of large diameter vessels, the required preheat is necessary along the area or areas being welded. When welders are spaced around the entire circumferential joint on small diameter vessels, the entire joint shall be preheated.

7.3 Monitoring:

Joints requiring preheat and/or interpass temperature control will be checked before and/or during welding of the joints to ensure that the minimum temperature is being maintained and that the maximum interpass temperature is not exceeded.

For temperatures greater than or equal to 150° F (66° C), temperature indicating crayons will normally be used to determine that the joint is at the required minimum temperature or above, but not exceeding the maximum interpass temperature.

8.0 CONTROL OF PARAMETERS: (QW-409)

8.1 Control of amperes and volts will be by the burn-off-rate (BOR) method. Control of heat input/volume of weld metal will be by bead size where applicable.

9.0 TECHNIQUE: (QW-410)

9.1 Tack Welds:

Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly made and prepared so that they may be satisfactorily incorporated into the final weld. Defective tack welds shall be removed.

TITLE: GENERAL WELDING PROCEDURE SPECIFICATION FOR THE SHIELDED METAL ARC PROCESS

9.2 Cleaning:

Pneumatic or other mechanical tools may be used as an aid to cleaning slag or flux from the weld. Such mechanical cleaning is not considered peening. Slag or flux remaining on any weld bead shall be removed before laying down the next successive weld bead to the extent required to assure complete fusion. Cleaning of stainless steel or Nickel-Chromium-Iron alloy weld metal or base metal shall be with uncontaminated stainless steel brushes, grinding discs or wheels or by other suitable means. All completed welds shall have the weld spatter removed and welds not ground shall be wire brushed.

9.3 Appearance of Welding:

Any defects that appear on the surface of any weld bead shall be removed by chipping, grinding, or arc gouging before depositing the next successive weld bead. The welding current and manner of depositing the weld metal shall be such that there shall be practically no undercutting of the finished joint except as permitted by the applicable Code. The surface of welds shall be free from coarse ripples or grooves, overlaps, and abrupt ridges or valleys. Reinforcement shall be according to the applicable Code.

9.4 Treatment of Backside of Welding Joint:

The backside of double butt welded groove welds shall be prepared by chipping, grinding, or arc gouging to clean sound metal. The root of the groove shall be sufficiently wide to permit fusion and allow free manipulation of the electrode. Gouging dross or residue shall be removed by brushing or grinding before welding commences.

9.5 Peening:

No peening shall be allowed unless specified on the specific WPS or unless specified in special instructions issued by the Welding and Q.C. Manager.

TITLE: GENERAL WELDING PROCEDURE SPECIFICATION FOR THE GAS TUNGSTEN ARC PROCESS

1.0 SCOPE:

1.1 This is a general Welding Procedure Specification to be used with a specific Welding Procedure Specification (WPS) when referenced on the WPS. In cases of conflict between this document and the specific WPS, the specific WPS shall govern.

2.0 REFERENCE:

2.1 ASME Boiler and Pressure Vessel Code, Section IX , Welding Qualifications, Edition and Addenda as shown on the specific WPS.

3.0 PROCEDURE QUALIFICATIONS:

3.1 Procedure qualifications have been made in accordance with the requirements of the ASME Code, Section IX and will be available for review.

4.0 PREPARATION OF BASE METAL:

4.1 The edges or surfaces of the pieces to be joined by welding shall be prepared by flame cutting, plasma arc cutting, arc gouging, machining, shearing, grinding, or chipping and shall be cleaned of detrimental oil, grease, scale and rust. The edges of the pieces may have a protective coating applied to them which need not be removed before they are welded unless specifically prohibited by the specific WPS.

5.0 WEATHER CONDITIONS FOR WELDING:

5.1 Welding shall not be performed when the surfaces in the welding area (within 6" (15.2 cm) of the arc) are wet; nor in periods of high winds unless the welder and the pieces to be welded are properly protected.

6.0 JOINTS: (QW-402)

6.1 Root Opening:

Normal root opening shall be 0-1/4" (0 mm-6.4 mm). See contract drawings for the specific joint detail. Spacer bar joints are considered 0" gap.

6.2 Wide Gaps:

The following technique shall be used for welding joints with wide gaps which exceed twice that specified on the applicable contract drawing. When zero gap is specified on the contract drawings, gaps exceeding 3/16" (4.8 mm) shall be reduced as outlined below to a 3/16" (4.8 mm) or smaller gap. Maximum weld build-up shall be T (where "T" is the thickness of the plate) for each plate edge or 1/2" (12.7 mm) whichever is smaller.

Method:

Plate edge build-up shall be done with a welding procedure approved for contract use. Weld passes shall be deposited utilizing a stringer bead technique to restore the plate edges to the gap and approximate joint configuration as shown on the contract drawings.

On single or square butt joints, a temporary back-up bar of compatible material may be used. The edges should be built-up using stringer beads to restore the joint to the gap and approximate joint configuration as shown on contract drawings, before tying the edges together.

The temporary back-up bar shall be removed by gouging, chipping or grinding to clean, sound-metal before welding the second side.

6.3 Narrow Gaps:

The following technique shall be used for correcting joints with gaps less than specified on the applicable contract drawing which are not sufficiently wide to allow free manipulation of the electrode in the joint.

Method:

The plate edges of the joint shall be prepared by flame cutting, plasma arc cutting, grinding, arc gouging, or chipping to restore the joint to the gap and approximate joint configuration shown on the contract drawings. Gouging dross, burning dross, or residue shall be removed by brushing or grinding before welding commences.

6.4 Retainers:

Nonmetallic retainers or nonfusing metal retainers may only be used when they are specified on the specific WPS.

6.5 Backing:

Double welded groove welds are considered welding with backing.

For single welded groove welds, the backing shall be as specified in the specific WPS.

7.0 FILLER METAL: (QW-404)

7.1 Supplemental filler metals or supplementary powdered filler metals may only be used when specified on the specific WPS.

7.2 Basic filler metal diameters for GTA welding are .45" (1.1mm), 1/16" (1.6mm), 3/32" (2.4mm) and 1/8" (3.2mm).

8.0 PREHEAT AND INTERPASS TEMPERATURE (When required by the specific WPS): (QW-406)

8.1 Method:

If required, preheat and/or interpass temperature shall be achieved by any suitable means which will keep the temperature of the joint within the specified limits shown on the specific WPS. The method of preheating and the heat source to be used may be changed or supplemented as deemed necessary or desirable.

8.2 Continuous Preheat:

When continuous preheat is required, it shall be a uniform preheat during the time of welding, obtained by pipe burners or strip heaters. On vertical joints or radial joints, the required preheat is necessary along the entire length. On circumferencial joints of larger diameter vessels, the required preheat is necessary along the area or areas being welded. When welders are spaced around the entire circumferential joint on small diameter vessels, the entire joint shall be preheated.

8.3 Monitoring:

Joints requiring preheat and/or interpass temperature control will be checked before and/or during welding of the joints to ensure that the minimum temperature is being maintained and that the maximum interpass temperature is not exceeded.

For temperatures greater than or equal to 150° F (66° C), temperature indicating crayons will normally be used to determine that the joint is at the required minimum temperature or above, but not exceeding the maximum interpass temperature.

9.0 SHIELDING GAS: (QW-408)

9.1 Care shall be taken to ensure that the shielding gas and shielding gas lines do not become contaminated with moisture or other detrimental particles.

10.0 ELECTRICAL CHARACTERISTICS: (QW-409)

10.1 Control of amperes and volts will be by amp and volt meters. Control of heat input/volume of weld metal will be by bead size where applicable.

10.2 The type of tungsten to be used in GTA welding may be pure tungssten (EW), 1% thoriated tungsten (EWTh-1), 2% thoriated tungsten (EWTh-2), or zirconia tungsten (EWZr).

10.3 Pulsing current on d.c. power may only be used when specified on the specific WPS.

11.0 TECHNIQUE: (QW-410)

11.1 Tack Welds:

Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly made and prepared so that they may be satisfactorily incorporated into the final weld. Defective tack welds shall be removed.

11.2 Cleaning:

Brushing or grinding may be used as an aid to clean the weld. Cleaning of stainless steel or Nickel-Chromium-Iron alloy weld metal or base metal shall be with uncontaminated stainless steel brushes, grinding discs or wheels or by other suitable means. All completed welds shall have the weld spatter removed and welds not ground shall be wire brushed.

11.3 Appearance of Welding:

Any defects that appear on the surface of any weld bead shall be removed by chipping, grinding, or arc gouging before depositing the next successive weld bead. The welding current and manner of depositing the weld metal shall be such that there shall be practically no undercutting of the finished joint except as permitted by the applicable Code. The surface of welds shall be free from coarse ripples or grooves, overlaps, and abrupt ridges or valleys. Reinforcement shall be according to the applicable Code.

11.4 Treatment of Backside of Welding Joint:

The backside of double butt welded groove welds shall be prepared by chipping, grinding, or arc gouging to clean sound metal. The root of the groove shall be sufficiently wide to permit fusion and allow free manipulation of the electrode. Gouging dross or residue shall be removed by brushing or grinding before welding commences.

11.5 Peening:

No peening shall be allowed unless specified on the specific WPS or unless specified in special instructions issued by the Welding and Q.C. Manager.

11.6 Cup Sizes:

The sizes of cups that are used for GTA welding are 3/8" (9.5mm)ø to 3/4" (19.1mm)ø.

TITLE: GENERAL WELDING PROCEDURE SPECIFICATION FOR THE GAS METAL ARC AND FLUX CORED ARC PROCESSES

1.0 SCOPE:

1.1 This is a general Welding Procedure Specification to be used with a specific Welding Procedure Specification (WPS) when referenced on the WPS. In cases of conflict between this document and the specific WPS, the specific WPS shall govern.

2.0 REFERENCE:

2.1 ASME Boiler and Pressure Vessel Code, Section IX , Welding Qualifications, Edition and Addenda as shown on the specific WPS.

3.0 PROCEDURE QUALIFICATIONS:

3.1 Procedure qualifications have been made in accordance with the requirements of the ASME Code, Section IX and will be available for review.

4.0 PREPARATION OF BASE METAL:

4.1 The edges or surfaces of the pieces to be joined by welding shall be prepared by flame cutting, plasma arc cutting, arc gouging, machining, shearing, grinding, or chipping and shall be cleaned of detrimental oil, grease, scale and rust. The edges of the pieces may have a protective coating applied to them which need not be removed before they are welded unless specifically prohibited by the specific WPS.

5.0 WEATHER CONDITIONS FOR WELDING:

5.1 Welding shall not be performed when the surfaces in the welding area (within 6" (15.2 cm) of the arc) are wet; nor in periods of high winds unless the welder and the pieces to be welded are properly protected.

6.0 JOINTS: (QW-402)

6.1 Root Opening:

Normal root opening shall be 0-1/4" (0 mm-6.4 mm). See contract drawings for the specific joint detail. Spacer joints are considered 0" gap.

6.2 Wide Gaps:

The following technique shall be used for welding joints with wide gaps which exceed twice that specified on the applicable contract drawing. When zero gap is specified on the contract drawings, gaps exceeding 3/16" (4.8 mm) shall be reduced as outlined below to a 3/16" (4.8 mm) or smaller gap. Maximum weld build-up shall be T (where "T" is the thickness of the plate) for each plate edge or 1/2" (12.7 mm) whichever is smaller.

Method:

Plate edge build-up shall be done with a welding procedure approved for contract use. Weld passes shall be deposited utilizing a stringer bead technique to restore the plate edges to the gap and approximate joint configuration as shown on the contract drawings.

On single or square butt joints, a temporary back-up bar of compatible material may be used. The edges should be built-up using stringer beads to restore the joint to the gap and approximate joint configuration as shown on contract drawings, before tying the edges together.

The temporary back-up bar shall be removed by gouging, chipping or grinding to clean, sound-metal before welding the second side.

6.3 Narrow Gaps:

The following technique shall be used for correcting joints with gaps less than specified on the applicable contract drawing which are not sufficiently wide to allow free manipulation of the electrode in the joint.

Method:

The plate edges of the joint shall be prepared by flame cutting, plasma arc cutting, grinding, arc gouging, or chipping to restore the joint to the gap and approximate joint configuration shown on the contract drawings. Gouging dross, burning dross, or residue shall be removed by brushing or grinding before welding commences.

6.4 Retainers:

Nonmetallic retainers or nonfusing metal retainers may only be used when they are specified on the specific WPS.

6.5 Backing:

Double welded groove welds are considered welding with backing.

For single welded groove welds, the backing shall be as specified in the specific WPS.

7.0 FILLER METAL: (QW-404)

7.1 Supplemental filler metals or supplementary powdered filler metals may only be used when specified on the specific WPS.

8.0 PREHEAT AND INTERPASS TEMPERATURE (When required by the specific WPS): (QW-406)

8.1 Method:

If required, preheat and/or interpass temperature shall be achieved by any suitable means which will keep the temperature of the joint within the specified limits shown on the specific WPS. The method of preheating and the heat source to be used may be changed or supplemented as deemed necessary or desireable.

8.2 Continuous Preheat:

When continuous preheat is required, it shall be a uniform preheat during the time of welding, obtained by pipe burners or strip heaters. On vertical joints or radial joints, the required preheat is necessary along the entire length. On circumferencial joints of larger diameter vessels, the required preheat is necessary along the area or areas being welded. When welders are spaced around the entire circumferential joint on small diameter vessels, the entire joint shall be preheated.

8.3 Monitoring:

Joints requiring preheat and/or interpass temperature control will be checked before and/or during welding of the joints to ensure that the minimum temperature is being maintained and that the maximum interpass temperature is not exceeded.

For temperatures greater than or equal to 150° F (66° C), temperature indicating crayons will normally be used to determine that the joint is at the required minimum temperature or above, but not exceeding the maximum interpass temperature.

9.0 SHIELDING GAS: (QW-408)

9.1 Care shall be taken to ensure that the shielding gas and shielding gas lines do not become contaminated with moisture or other detrimental particles.

10.0 ELECTRICAL CHARACTERISTICS: (QW-409)

10.1 Control of amperes and volts will be by amp and volt meters. Control of heat input/volume of weld metal will be by bead size where applicable.

11.0 TECHNIQUE: (QW-410)

11.1 Tack Welds:

Tack welds used to secure alignment shall either be removed completely, when they have served their purpose, or their stopping and starting ends shall be properly made and prepared so that they may be satisfactorily incorporated into the final weld. Defective tack welds shall be removed.

11.2 Cleaning:

Pneumatic or other mechanical tools may be used as an aid to cleaning slag or flux from the weld. Such mechanical cleaning is not considered peening. Slag or flux remaining on any weld bead shall be removed before laying down the next successive weld bead to the extent required to assure complete fusion. Cleaning of stainless steel or Nickel-Chromium-Iron alloy weld metal or base metal shall be with uncontaminated stainless steel brushes, grinding discs or wheels or by other suitable means. All completed welds shall have the weld spatter removed and welds not ground shall be wire brushed.

11.3 Appearance of Welding:

Any defects that appear on the surface of any weld bead shall be removed by chipping, grinding, or arc gouging before depositing the next successive weld bead. The welding current and manner of depositing the weld metal shall be such that there shall be practically no undercutting of the finished joint except as permitted by the applicable Code. The surface of welds shall be free from coarse ripples or grooves, overlaps, and abrupt ridges or valleys. Reinforcement shall be according to the applicable Code.

11.4 Treatment of Backside of Welding Joint:

The backside of double butt welded groove welds shall be prepared by chipping, grinding, or arc gouging to clean sound metal. The root of the groove shall be sufficiently wide to permit fusion and allow free manipulation of the electrode. Gouging dross or residue shall be removed by brushing or grinding before welding commences.

11.5 Peening:

No peening shall be allowed unless specified on the specific WPS or unless specified in special instructions issued by the Welding and Q.C. Manager.

11.6 Nozzle Sizes:

The sizes of nozzles that are used for gas shielding are 3/8" (9.5mm) Dia. to 1" (25.4mm) Dia.

CBI

WELDING PROCEDURE SPECIFICATION

WELDING PROCEDURE SPECIFICATION	IDENTIFICATION WPS ER308L/CIRC	CONTRACT 930212

PRODUCT LIGO BEAM TUBE MODULES
CUSTOMER CALTECH

REV. NO. 3
BY RWP DATE 03/11/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- GTAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
10029	3G	1/16" to 1/4"	All	0.105" to 1/8"

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

BACKING MATERIAL (QW-402)
None Required

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.9
ASME CLASSIFICATION: ER308L *
ASME ANALYSIS NO: A-8
ASME GROUP NO: F-6
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

CUSTOMER APPROVAL

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE 2

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	60% Ar - 40% He	100% Argon
FLOW RATE:	20-45 cfh	See page 2

2

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: Electrode Negative
OTHER: Straight Polarity
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER N/A

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2, 3
STRINGER OR WEAVE TECHNIQUE SEE PAGE 3
TYPE OF WELDING

MANUAL ☐ MACHINE ☒
SEMI-AUTOMATIC ☐ AUTOMATIC ☐

* ER308L in accordance with WMS-ER308L.

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	RWP	01/10/94
									CHECKED	BGG	01/31/94
									AUTHORIZED		/ /

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/CIRC	930212

REV. NO. 3

BY RWP DATE 03/11/94

PRODUCT LIGO BEAM TUBE MODULES

CUSTOMER CALTECH

LIMITATIONS:

3 1. *This WPS is to be used with Dimetrics Gold Track welding system.*

2. *Use a two pass technique on side one only.*
3. *Use a single EWTh-2 (2% thoriated tungsten) electrode.*
4. *No single pass shall exceed 1/8" in thickness.*
5. *Only stainless steel brushes shall be used on stainless steel.*
6. *Parameters on Page 3 shall be followed.*
7. *Only filler metal in accordance with WMS-ER308L shall be used.*
8. *Welding may progress uphill or downhill.*
9. *Welding may begin at any location along the weld joint.*
10. *See Procedure FPCIRCUMFERENTIAL for fitting/purging.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand (approx. 100øF) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/CIRC	930212

REV. NO. 3

BY RWP DATE 03/11/94

PRODUCT *LIGO BEAM TUBE MODULES*

CUSTOMER *CALTECH*

WELDING PARAMETERS FOR DIMETRICS GOLD TRACK II:

Parameter	First Pass	Second Pass
Position	5G	5G
Shielding Gas	60% Ar - 40% He	60% Ar - 40% He
Flow rate	20 - 45 cfh	20 - 45 cfh
Purge Gas	100% Argon	100% Argon
Flow rate	Note (1)	Note (1)
Filler Wire	Autogenous	ER308L (2)
Diameter	N/A	0.035"
Pulse Mode	Pulsed	Sync Pulsed
Pulse Width	50%	N/A
Pulse Frequency	3.0	3.0
AVC Response	20	0
AVC Mode	Samp	Cont
Upslope Time	2	2
Downslope Time	5	5
Travel Start Delay	2	2
Wire Start Delay	N/A	1
Oscillation Amplitude	0.00	0.15 - 0.20
Travel Speed	5.0 ipm	4.0 ipm
Primary		
Weld Current	120 amps	85 amps
Arc Voltage	9.5 volts	9.5 volts
Wire Feed Speed	N/A	25 ipm
Background		
Weld Current	85 amps	60 amps
Arc Voltage	9.5 volts	9.5 volts
Wire Feed Speed	N/A	13 ipm
Out Dwell Time	N/A	2
Excursion Time	N/A	3
In Dwell Time	N/A	Note (3)

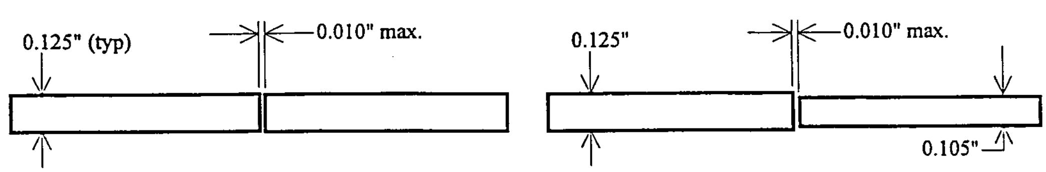
NOTES:

2 (1) See Procedure FPCIRCUMFERENTIAL for purge details.

(2) ER308L in accordance with WMS-ER308L.

2 (3) 2 for 1/8" thick plates.
3 for 0.105" thick plate welded to 1/8" thick plate.

3 (4) Welding parameters may vary +/- 10% from above values.



5G Position

CBI

PROCEDURE QUALIFICATION RECORD

To A. S. M. E. Section IX

ESSENTIAL VARIABLES

. No. 10029

ʻrocess GTAW | Manual [ ] | Machine [X] | Auto. [ ] | Semiauto. [ ]

Material specification: SA240 Type 304L together

ASME P No. 8, Gp. 1 To ASME P No. 8, Gp. 1

Thickness(if pipe, dia and wall thick): 0.11" to 1/8"

Filler metal group no. F: F-6

Weld metal analysis no. A: A-8

ASME specification no. SFA: SFA 5.9

AWS specification no. A: A 5.9

Flux or Atmosphere

Flux trade name: N/A

Inert gas composition: 60% Argon - 40% Helium

Flow rate: 20 - 45 cfh

Preheat temperature range: 70°F - 350°F (IPT)

Postweld heat treatment: None Required

WELDING PROCEDURE

Single or multiple pass: Multiple | Single or multiple arc: Single | Position: 3G

Mode of transfer for GMAW: Spray [ ] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW: ER308L | Filler metal diameter: 0.035"

Electrode: EWTh-2 | Electrode diameter: 1/8"

Type of backing: None Required | Welding current: Direct Current, Electrode Negative (Straight Polarity)

Consult WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions, in.		Area	Ultimate Total Load	Ultimate Unit Stress		Character of Failure and Location
	Width	Thickness	sq. in.	Kips	ksi	MPa	
ʻ11443-1	0.750	0.092	0.069	5.7	82.6	569.5	Ductile in weld metal
.11443-2	0.750	0.097	0.073	6.0	82.2	566.7	Ductile in weld metal

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name: W. Kelly Brawner | Social Security no.: 413-82-4060 | Welder's symbol: WKB

Welder's name: | Social Security no.: | Welder's symbol:

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H11443 Rev. 2

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

Signed CBI

By [signature] Date 1/24/94

Rick W. Prior

Remarks: Arcaloy (ER308L) by Alloy Rods

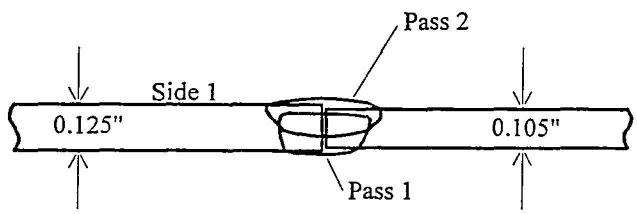
CBI

Page
Contract

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



Maximum gap 0.010"
Plates fit on centerlines
All passes welded from Side 1
In Dwell is on the 1/8" side.

Side	1	1							
Pass number	1	2							
Filler wire	N/A	ER308L							
Wire diameter (inches)	N/A	0.035"							
Pulse mode	Pulsed	Sync							
Pulse width	50%	N/A							
Pulse frequency	3.0	3.0							
AVC response	--	--							
AVC mode	Samp	Cont							
Upslope time (sec)	2	2							
Downslope time (sec)	5	5							
Travel start delay (sec)	2	2							
Wire start delay (sec)	N/A	1							
Oscillation amp	N/A	0.15							
Track travel speed (ipm)	5.0	4.0							
Torch travel speed (ipm)	5.0	4.0							
Primary weld current (amps)	120	85							
Primary voltage (volts)	9.5	9.5							
Primary wire speed (ipm)	N/A	25							
Background current (amps)	85	60							
Background voltage (volts)	9.5	9.5							
Background wire (ipm)	N/A	10							
Out dwell time (x 0.1 sec)	N/A	2							
Excursion time (x 0.1 sec)	N/A	3							
In dwell time (x 0.1 sec)	N/A	3							
Primary time (%)	0.50	0.45							
Background time (%)	0.50	0.55							
Heat input (kJ/in)	11.7	7.4							
Energy density (MJ/in3)	N/A	1.5							

Qualification No. 10029
Date: 1/24/94

By
Rick W. Prior

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION	CONTRACT
WPS ER308L/STIFFENER	930212

PRODUCT LIGO BEAM TUBE MODULES
CUSTOMER CALTECH

REV. NO. 3
BY RWP DATE 03/11/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- GMAW&FCAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
4858	2G	All size fillet welds	3F	1/8" to 3/8"

3

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

BACKING MATERIAL (QW-402)
None Required

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.9
ASME CLASSIFICATION: ER308L *
ASME ANALYSIS NO: A-8
ASME GROUP NO: F-6
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

CUSTOMER APPROVAL

PREHEAT/INTERPASS TEMPERATURE (QW-406) SEE ATTACHED PAGE 2

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	98% Ar - 2% O2	100% Nitrogen
FLOW RATE:	20-45 cfh	See page 2

2

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: Electrode Positive
OTHER: Reverse Polarity
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER Globular

2

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2, 3
STRINGER OR WEAVE TECHNIQUE SEE PAGE 3
TYPE OF WELDING

MANUAL ☐ MACHINE ☒
SEMI-AUTOMATIC ☐ AUTOMATIC ☐

* ER308L in accordance with WMS-ER308L.

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	RWP	01/10/94
									CHECKED	BGG	01/31/94
									AUTHORIZED		/ /

Printed in USA
WL100 REV JUL 87

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/STIFFENER	930212

PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. 2 OF 3
CUSTOMER *CALTECH*	REV. NO. 3
	BY RWP DATE 03/11/94

LIMITATIONS:

1. *Maintain a contact tip to work distance of 3/8" to 1".*
2. *Use a gas cup nozzle sizes between 3/8" to 1" diameter.*
3. *Use a single pass per side technique.*
4. *No single pass shall exceed 1/2" in thickness.*
5. *The WPS is limited to the welding of the stiffener to the tube modules only.* 3
6. *Only stainless steel brushes shall be used on stainless steel.*
7. *A purge of 100% nitrogen must be in place before any tacking or welding.*
8. *No welding over the spiral tube weld shall exist.*
9. *The length not welded over the spiral weld shall be minimized.*
10. *Miller 4-roll wire feeder shall be used.*
11. *Straight machine torch (approx. 3 feet in length) shall be used.*
12. *Use Procedure FPSTIFFENER for fitting/purging.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand (approx. 100øF) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

	WELDING PROCEDURE SPECIFICATION	IDENTIFICATION WPS *ER308L/STIFFENER*	CONTRACT *930212*

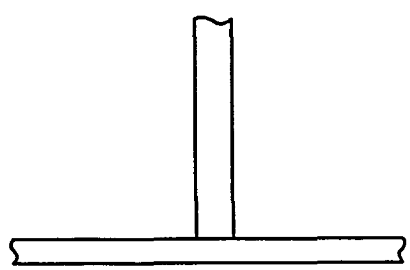
PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. *3* OF *3*
	REV. NO. *3*
CUSTOMER *CALTECH*	BY *RWP* DATE *03/11/94*

GENERAL WELDING TECHNIQUE

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Peak (Amps)	
Stringer Beads	*As Reqd*	*GMA*	*.035*	*ER308L*	*190-230*	*22-24*		

3 *Travel speed: 33 to 37 ipm.*
Wire feed speed: 490 to 520 ipm.

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.



3F
(vertical downhill)

CBI

Page

Contract

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
ESSENTIAL VARIABLES

PQR No. 4858

Process GMAW/GTAW

Material specification SA204 Type 304

ASME p. no. 8, Gp. 1 To ASME p. no. 8, Gp. 1

Thickness (if pipe, dia and wall thick) 1/4"

Filler metal group no. F. F-6

Weld metal analysis no. A. A-8

ASME specification no. SFA-5.9

AWS specification no. A-5.9

Manual [X] GTAW Machine [ ] Automatic [X] GTAW Semiautomatic [ ]

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition *

Flow rate GMAW-40 CFH, GTAW-20CFH

Preheat temperature range 70°F to 350°F IPT

Postweld heat treatment None

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 2G

Mode of transfer for GMAW: Spray [X] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW Not Required

Filler metal diameter Not Required

Electrode GMAW-ER308, GTAW-EWTh-2

Electrode diameter GMAW-.035", GTAW-3/32"Ø

Type of backing None**

Welding current GTAW-Direct Current, Elec. Neg. (Straight Polarity) GMAW-Direct Current, Elec. Pos. (Reverse Polarity)

Consult **WELDING VARIABLES** for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
H610R-1	1.498	0.222	0.332	29.5	88.9	612.9	Ductile in WM
H610R-2	1.502	0.220	0.330	29.1	88.2	608.1	Ductile in WM

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name Curtis Campbell Social Security no. 403-36-4037 Welder's Symbol CC

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H610R Rev. 0

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

Signed CBI

By J. S. Lee J. S. Lee Date 10/15/80

Remarks:

*GTAW - 100% Argon

GMAW - 98% Argon/2% Oxygen

**Temporary copper chill bar used.

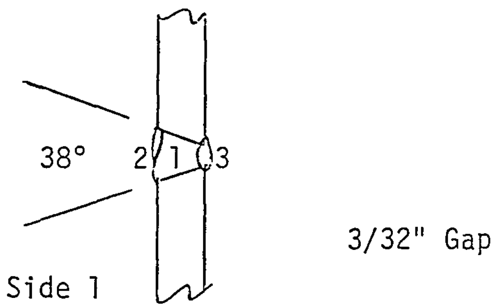
Updated to new form, 8/28/87, JSL JSL

Printed In USA WL 20 D REV JUL 87

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



HORIZONTAL

Layer	Electrode		Amps	Volts	Travel Speed in./min.	Remarks (Gas Flow etc)
	Type	Size				
1	ER308	.035	150	24	7	GMAW-Stringer
2	ER308	.035	150	24	19	Beads Side 1
3	EWTH-2	1/8"	120	12	– – –	GTAW with out filler
						metal Side 2.

alification No. 4858
te: 10-15-80

Alan E. Hudson
BY Alan E. Hudson

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS ER308L/PORT

CONTRACT 930212

PRODUCT LIGO BEAM TUBE MODULES
CUSTOMER CALTECH

REV. NO. 3
BY RWP DATE 03/11/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- GTAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
10029	3G	1/16" to 1/4"	All	0.120" to 1/8"

2

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

PREHEAT/INTERPASS TEMPERATURE (QW-406) SEE ATTACHED PAGE 2

BACKING MATERIAL (QW-402)
None Required

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	60% Ar - 40% He	100% Argon
FLOW RATE:	20-45 cfh	See page 2

2

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: Electrode Negative
OTHER: Straight Polarity
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER N/A

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.9
ASME CLASSIFICATION: ER308L *
ASME ANALYSIS NO: A-8
ASME GROUP NO: F-6
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2, 3
STRINGER OR WEAVE TECHNIQUE SEE PAGE 3
TYPE OF WELDING

MANUAL [X] MACHINE [ ]

SEMI-AUTOMATIC [ ] AUTOMATIC [ ]

2

CUSTOMER APPROVAL

* ER308L in accordance with WMS-ER308L.

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	RWP	01/03/94
									CHECKED	BGG	02/25/94
									AUTHORIZED		/ /

Printed in USA

WL100 REV JUL 87

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/PORT	930212

PRODUCT *LIGO BEAM TUBE MODULES*

CUSTOMER *CALTECH*

REV. NO. 3

BY RWP DATE 03/11/94

LIMITATIONS:

1. Pulsing current may be used.
2. Use a single pass on side 1.
3. Use multiple passes on side 2.
4. Use a single EWTh2 (2% thoriated tungsten) electode.
5. Only stainless steel brushes shall be used on stainless steel.
6. No single pass shall exceed 1/8" in thickness.
7. Only filler metal in accordance with WMS-ER308L shall be used.
8. A back purge of 100% Argon shall be used on opposite side of welding.
9. See Procedure FPPUMPPORT for fitting/purging.

3

2

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand (approx. 100øF) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/PORT	930212

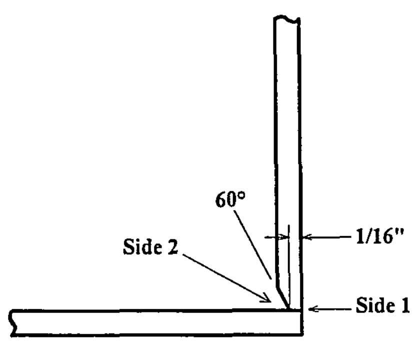
PRODUCT LIGO BEAM TUBE MODULES	PAGE NO. 3 OF 3
CUSTOMER CALTECH	REV. NO. 3
	BY RWP DATE 03/11/94

GENERAL WELDING TECHNIQUE

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Peak (Amps)	
Stringer	Inside Pass 1	GTA	N/A	Autog.	75-85	9-11	37-42*	
Stringer	Outside Pass 1	GTA	N/A	Autog.	75-85	9-11	37-42*	
Weave	Pass 2	GTA	0.035	ER308L	65-90	9-11		

* Pulse with background current 50% of primary.
1.0 pulse frequency.

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.



5G Position

Page
Contract

CBI

PROCEDURE QUALIFICATION RECORD

To A. S. M. E. Section IX

ESSENTIAL VARIABLES

. No. 10029

Process GTAW — Manual [ ] Machine [X] Auto. [ ] Semiauto. [ ]

Material specification SA240 Type 304L together

ASME P No. 8, Gp. 1 To ASME P No. 8, Gp. 1

Thickness(if pipe, dia and wall thick) 0.11" to 1/8"

Filler metal group no. F F-6

Weld metal analysis no. A A-8

ASME specification no. SFA SFA 5.9

AWS specification no. A A 5.9

Flux or Atmosphere

Flux trade name N/A

Inert gas composition 60% Argon - 40% Helium

Flow rate 20 - 45 cfh

Preheat temperature range 70°F - 350°F (IPT)

Postweld heat treatment None Required

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 3G

Mode of transfer for GMAW: Spray [ ] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW ER308L Filler metal diameter 0.035"

Electrode EWTh-2 Electrode diameter 1/8"

Type of backing None Required Welding current Direct Current, Electrode Negative

Consult WELDING VARIABLES for joint dimensions and welding current settings. (Straight Polarity)

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions, in.		Area	Ultimate Total Load	Ultimate Unit Stress		Character of Failure and Location
	Width	Thickness	sq. in.	Kips	ksi	MPa	
11443-1	0.750	0.092	0.069	5.7	82.6	569.5	Ductile in weld metal
11443-2	0.750	0.097	0.073	6.0	82.2	566.7	Ductile in weld metal

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name W. Kelly Brawner Social Security no. 413-82-4060 Welder's symbol WKB

Welder's name Social Security no. Welder's symbol

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H11443 Rev. 2

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

Signed CBI

By [signature] Date 1/24/94

Rick W. Prior

Remarks: Arcaloy (ER308L) by Alloy Rods

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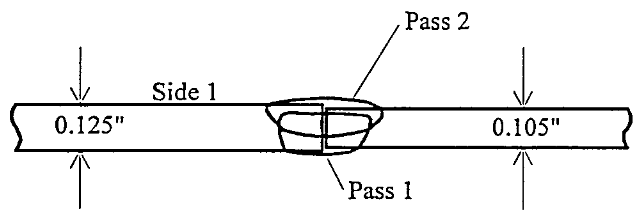
Contract

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



Maximum gap 0.010"
Plates fit on centerlines
All passes welded from Side 1
In Dwell is on the 1/8" side.

Side	1	1							
Pass number	1	2							
Filler wire	N/A	ER308L							
Wire diameter (inches)	N/A	0.035"							
Pulse mode	Pulsed	Sync							
Pulse width	50%	N/A							
Pulse frequency	3.0	3.0							
AVC response	--	--							
AVC mode	Samp	Cont							
Upslope time (sec)	2	2							
Downslope time (sec)	5	5							
Travel start delay (sec)	2	2							
Wire start delay (sec)	N/A	1							
Oscillation amp	N/A	0.15							
Track travel speed (ipm)	5.0	4.0							
Torch travel speed (ipm)	5.0	4.0							
Primary weld current (amps)	120	85							
Primary voltage (volts)	9.5	9.5							
Primary wire speed (ipm)	N/A	25							
Background current (amps)	85	60							
Background voltage (volts)	9.5	9.5							
Background wire (ipm)	N/A	10							
Out dwell time (x 0.1 sec)	N/A	2							
Excursion time (x 0.1 sec)	N/A	3							
In dwell time (x 0.1 sec)	N/A	3							
Primary time (%)	0.50	0.45							
Background time (%)	0.50	0.55							
Heat input (kJ/in)	11.7	7.4							
Energy density (MJ/in3)	N/A	1.5							

Qualification No. 10029
Date: 1/24/94

By [signature]
Rick W. Prior

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/GMA	930212

PRODUCT LIGO BEAM TUBE MODULES
CUSTOMER CALTECH

PAGE NO. 1 OF 3
REV. NO. 1
BY RWP DATE 03/11/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- GMAW&FCAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
4858	2G	All size fillet welds	All	1/8" to 3/8"

3

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

BACKING MATERIAL (QW-402)
None Required

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.9
ASME CLASSIFICATION: ER308L *
ASME ANALYSIS NO: A-8
ASME GROUP NO: F-6
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE 2

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	98% Ar - 2% O2	100% Nitrogen
FLOW RATE:	20-45 cfh	See page 2

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: Electrode Positive
OTHER: Reverse Polarity
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER Globular

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2, 3
STRINGER OR WEAVE TECHNIQUE SEE PAGE 3
TYPE OF WELDING

MANUAL ☐ MACHINE ☐
SEMI-AUTOMATIC ☒ AUTOMATIC ☐

CUSTOMER APPROVAL

* ER308L in accordance with WMS-ER308L.

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	RWP	03/01/94
									CHECKED	BGG	03/01/94
									AUTHORIZED		/ /

Printed in USA

WL100 REV JUL 87

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/GMA	930212

PRODUCT *LIGO BEAM TUBE MODULES*

CUSTOMER *CALTECH*

REV. NO. *1*

BY *RWP* DATE *03/11/94*

LIMITATIONS:

1. *Maintain a contact tip to work distance of 3/8" to 1".*
2. *Use a gas cup nozzle sizes between 3/8" to 1" diameter.*
3. *Use a single pass per side technique.*
4. *No single pass shall exceed 1/2" in thickness.*
5. *Only stainless steel brushes shall be used on stainless steel.*
6. *A purge of 100% nitrogen must be in place before any tacking or welding.*
7. *No welding over the spiral tube weld shall exist.*
8. *See procedure FPSTIFFENER for purging procedures.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand (approx. 100øF) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/GMA	930212

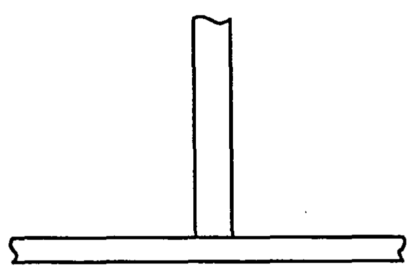
PRODUCT LIGO BEAM TUBE MODULES	PAGE NO. 3 OF 3
	REV. NO. 1
CUSTOMER CALTECH	BY RWP DATE 03/11/94

GENERAL WELDING TECHNIQUE

Operation Description	Beads	Weld	Electrode		Current	Voltage	Peak	
	Layer	Proc.	Size	Type	(amps)	(Volts)	(Amps)	
Stringer Beads	As Reqd	GMA	.035	ER308L	130-260	21-28		

* Vertical uphill welds & overhead welds may be deposited using a weave technique.

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.



All position fillet welds

Page

Contract

CBI

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
ESSENTIAL VARIABLES

PQR No. 4858

Process GMAW/GTAW

Material specification SA204 Type 304

ASME p. no. 8, Gp. 1 To ASME p. no. 8, Gp. 1

Thickness (if pipe, dia and wall thick) 1/4"

Filler metal group no. F. F-6

Weld metal analysis no. A. A-8

ASME specification no. SFA-5.9

AWS specification no. A-5.9

GTAW Manual [X] Machine [ ] GTAW Automatic [X] Semiautomatic [ ]

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition *

Flow rate GMAW-40 CFH, GTAW-20CFH

Preheat temperature range 70°F to 350°F IPT

Postweld heat treatment None

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 2G

Mode of transfer for GMAW: Spray [X] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW Not Required Filler metal diameter Not Required

Electrode GMAW-ER308, GTAW-EWTh-2 Electrode diameter GMAW-.035", GTAW-3/32"Ø

Type of backing None** Welding current GTAW-Direct Current, Elec. Neg. (Straight Polarity) GMAW-Direct Current, Elec. Pos. (Reverse Polarity)

Consult WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	MPa	Character of Failure and Location
H610R-1	1.498	0.222	0.332	29.5	88.9	612.9	Ductile in WM
H610R-2	1.502	0.220	0.330	29.1	88.2	608.1	Ductile in WM

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name Curtis Campbell Social Security no. 403-36-4037 Welder's Symbol CC

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H610R Rev. 0

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

Signed CBI

By J. S. Lee J. S. Lee Date 10/15/80

Remarks:

*GTAW - 100% Argon

GMAW - 98% Argon/2% Oxygen

**Temporary copper chill bar used.

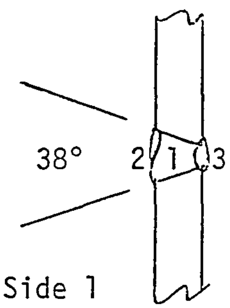
Updated to new form, 8/28/87, JSL JSL

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



3/32" Gap

HORIZONTAL

Layer	Electrode		Amps	Volts	Travel Speed in./min.	Remarks (Gas Flow etc)
	Type	Size				
1	ER308	.035	150	24	7	GMAW-Stringer
2	ER308	.035	150	24	19	Beads Side 1
3	EWTH-2	1/8"	120	12	— — —	GTAW with out filler
						metal Side 2.

Qualification No. 4858
Date: 10-15-80

BY Alan E. Hudson
Alan E. Hudson

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
ER308L/REPAIR	930212

PRODUCT LIGO BEAM TUBE MODULES CUSTOMER CALTECH	PAGE NO. 1 OF 4 REV. NO. 0 BY RWP DATE 02/10/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- GTAW&GMAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
10029 4858	3G 2G	1/16" to 1/4" 1/16" to 1/2"	All	0.105" to 1/4" All size fillet welds

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

BACKING MATERIAL (QW-402)

See page 2

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.9
ASME CLASSIFICATION: ER308L *
ASME ANALYSIS NO: A-8
ASME GROUP NO: F-6
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE 2

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408) SHIELDING BACK UP
COMPOSITION: See page 2 See Page 2
FLOW RATE:

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: See Page 2
OTHER:
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER Globular for GMAW

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2
STRINGER OR WEAVE TECHNIQUE SEE PAGE 3
TYPE OF WELDING
MANUAL [X] MACHINE [ ]
SEMI-AUTOMATIC [ ] AUTOMATIC [ ]

CUSTOMER APPROVAL

* ER308L in accordance with WMS-ER308L

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED CHECKED AUTHORIZED	RWP BGG	02/10/94 02/25/94 / /

ELECTRICAL CHARACTERISTICS:

GMAW	*GTAW*
Direct Current	*Direct Current*
Electrode Positive	*Electrode Negative*
(Reverse Polarity)	*(Straight Polarity)*

SHIELDING GAS:

GMAW: 98% Argon - 2% O2 *GTAW: 60% Argon - 40% Helium*

LIMITATIONS:

1. *This WPS is to be used for weld repairs only.*
2. *Pulsing current may be used for GTAW.*
3. *Use a single or multiple pass per side technique.*
4. *No single pass shall exceed 1/2" in thickness.*
5. *Use a single EWTh-2 (2% thoriated tungsten) electrode for GTAW.*
6. *Maintain a contact tip to work distance of 3/8" to 1" for GMAW.*
7. *Use gas cup nozzle sizes between 3/8" to 1" diameter.*
8. *Only stainless steel brushes shall be used on stainless steel.*
9. *Only filler metal in accordance with WMS-ER308L shall be used.*
10. *An inert gas back purge shall be used on opposite side of welding.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand (approx. 100øF) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

WELDING PROCEDURE SPECIFICATION	IDENTIFICATION WPS ER308L/REPAIR	CONTRACT 930212

PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. 3 OF 4
CUSTOMER *CALTECH*	REV. NO. 0
	BY RWP DATE 02/10/94

SPECIAL PROCEDURES:

1. *GTAW may be used for all types of welded repairs.*
2. *GMAW to be used only for weld repairs to the stiffener attachment welds.*
3. *For welded repairs requiring full thickness welding:*
   a. *Clean repair area by grinding or chipping large enough area to allow manipulation of the weld torch.*
   b. *Place repair jack on inside of tube with copper bar covering weld repair area.*
   c. *Apply pressure on jack to minimize shrinkage.*
   d. *Backing gas may be omitted.*
   e. *Weld using GTAW with ER308L.*
4. *For welded repairs to the inside pass of the pump port:*
   a. *Weld an autogenous GTA pass on inside of port to obtain full fusion of land at repair area.*

		IDENTIFICATION WPS	CONTRACT
CBI	WELDING PROCEDURE SPECIFICATION	ER308L/REPAIR	930212

PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. 4 OF 4
CUSTOMER *CALTECH*	REV. NO. 0
	BY RWP DATE 02/10/94

GENERAL WELDING TECHNIQUE

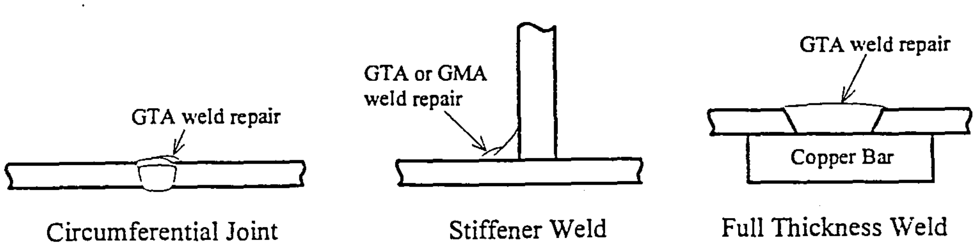
Operation Description	Beads Layer	Weld Proc.	Tungsten Diameter	Current (amps)	Voltage (Volts)	Travel (IPM)	B.O.R. Sec/12"
*GTA weld with or without filler metal **	*As Reqd*	*GTA*	*1/16"* *3/32"* *1/8"* *5/32"* *3/16"*	*50-140* *50-220* *50-300* *50-400* *50-525*	*10-18* *10-18* *10-18* *12-18* *12-18*	*As Reqd*	

Filler Metal: ER308L
Filler Metal Dia.: 1/16", 3/32", 1/8"
** Passes may be made with stringer or weave beads as required.*

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Peak (Amps)	
*Stringer Beads**	*As Reqd*	*GMA*	*.035*	*ER308L*	*130-260*	*21-28*		

** Vertical uphill welds and overhead welds may be deposited using a weave technique.*



Typical Weld Repairs (all positions)

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Contract

CBI

PROCEDURE QUALIFICATION RECORD

To A. S. M. E. Section IX

ESSENTIAL VARIABLES

No. 10029

Process GTAW

Manual [ ] Machine [X] Auto. [ ] Semiauto. [ ]

Material specification SA240 Type 304L together

ASME P No. 8, Gp. 1 To ASME P No. 8, Gp. 1

Thickness(if pipe, dia and wall thick) 0.11" to 1/8"

Filler metal group no. F F-6

Weld metal analysis no. A A-8

ASME specification no. SFA SFA 5.9

AWS specification no. A A 5.9

Flux or Atmosphere

Flux trade name N/A

Inert gas composition 60% Argon - 40% Helium

Flow rate 20 - 45 cfh

Preheat temperature range 70°F - 350°F (IPT)

Postweld heat treatment None Required

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 3G

Mode of transfer for GMAW: Spray [ ] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW ER308L Filler metal diameter 0.035"

Electrode EWTh-2 Electrode diameter 1/8"

Type of backing None Required Welding current Direct Current, Electrode Negative (Straight Polarity)

Consult WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions, in.		Area	Ultimate Total Load	Ultimate Unit Stress		Character of Failure and Location
	Width	Thickness	sq. in.	Kips	ksi	MPa	
11443-1	0.750	0.092	0.069	5.7	82.6	569.5	Ductile in weld metal
1443-2	0.750	0.097	0.073	6.0	82.2	566.7	Ductile in weld metal

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name W. Kelly Brawner Social Security no. 413-82-4060 Welder's symbol WKB

Welder's name Social Security no. Welder's symbol

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H11443 Rev. 2

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

Signed CBI

By [signature] Date 1/24/94

Rick W. Prior

Remarks: Arcaloy (ER308L) by Alloy Rods

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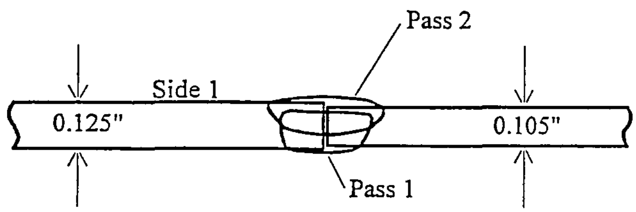
Contract

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



Maximum gap 0.010"
Plates fit on centerlines
All passes welded from Side 1
In Dwell is on the 1/8" side.

Side	1	1								
Pass number	1	2								
Filler wire	N/A	ER308L								
Wire diameter (inches)	N/A	0.035"								
Pulse mode	Pulsed	Sync								
Pulse width	50%	N/A								
Pulse frequency	3.0	3.0								
AVC response	--	--								
AVC mode	Samp	Cont								
Upslope time (sec)	2	2								
Downslope time (sec)	5	5								
Travel start delay (sec)	2	2								
Wire start delay (sec)	N/A	1								
Oscillation amp	N/A	0.15								
Track travel speed (ipm)	5.0	4.0								
Torch travel speed (ipm)	5.0	4.0								
Primary weld current (amps)	120	85								
Primary voltage (volts)	9.5	9.5								
Primary wire speed (ipm)	N/A	25								
Background current (amps)	85	60								
Background voltage (volts)	9.5	9.5								
Background wire (ipm)	N/A	10								
Out dwell time (x 0.1 sec)	N/A	2								
Excursion time (x 0.1 sec)	N/A	3								
In dwell time (x 0.1 sec)	N/A	3								
Primary time (%)	0.50	0.45								
Background time (%)	0.50	0.55								
Heat input (kJ/in)	11.7	7.4								
Energy density (MJ/in3)	N/A	1.5								

Qualification No. 10029
Date: 1/24/94

By [signature]
Rick W. Prior

CBI

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
ESSENTIAL VARIABLES

PQR No. 4858

Process GMAW/GTAW

Material specification SA204 Type 304

ASME p. no. 8, Gp. 1 To ASME p. no. 8, Gp. 1

Thickness (if pipe, dia and wall thick) 1/4"

Filler metal group no. F. F-6

Weld metal analysis no. A. A-8

ASME specification no. SFA-5.9

AWS specification no. A-5.9

Manual [X] GTAW Machine [ ] Automatic [X] GTAW Semiautomatic [ ]

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition *

Flow rate GMAW-40 CFH, GTAW-20CFH

Preheat temperature range 70°F to 350°F IPT

Postweld heat treatment None

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 2G

Mode of transfer for GMAW: Spray [X] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW Not Required

Filler metal diameter Not Required

Electrode GMAW-ER308, GTAW-EWTh-2

Electrode diameter GMAW-.035", GTAW-3/32"Ø

Type of backing None**

Welding current GTAW-Direct Current, Elec. Neg. (Straight Polarity) GMAW-Direct Current, Elec. Pos. (Reverse Polarity)

Consult WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in ^{2}	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
H610R-1	1.498	0.222	0.332	29.5	88.9	612.9	Ductile in WM
H610R-2	1.502	0.220	0.330	29.1	88.2	608.1	Ductile in WM

Guided Bend Test

Type	Result	Type	Result
2 Transverse Face Bends	OK	2 Transverse Root Bends	OK

Welder's name Curtis Campbell Social Security no. 403-36-4037 Welder's Symbol CC

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H610R Rev. 0

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

Signed CBI

By J. S. Lee J. S. Lee Date 10/15/80

Remarks:
*GTAW - 100% Argon
GMAW - 98% Argon/2% Oxygen

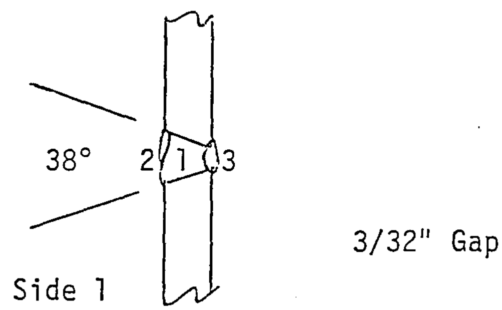
**Temporary copper chill bar used.
Updated to new form, 8/28/87, JSL JSL

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



HORIZONTAL

Layer	Electrode		Amps	Volts	Travel Speed in./min.	Remarks (Gas Flow etc)
	Type	Size				
1	ER308	.035	150	24	7	GMAW-Stringer
2	ER308	.035	150	24	19	Beads Side 1
3	EWTH-2	1/8"	120	12	– – –	GTAW with out filler
						metal Side 2.

alification No. 4858

.e: 10-15-80

BY Alan E. Hudson
Alan E. Hudson

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS E7018/STRUCT

CONTRACT 930212

PRODUCT LIGO BEAM TUBE MODULES
CUSTOMER CALTECH

REV. NO. 0
BY RWP DATE 02/10/94

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- SMAW

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
8903	3G	3/16" to 8"	All	3/16" to 1"

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA ASME Section VIII & IX, 1992 Edition, 92 Add.

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE 3

BACKING MATERIAL (QW-402)
None Required

BASE MATERIAL (QW-403)

A36 (ASME P-1, Gp. 1)
A283 Gr. C (ASME P-1, Gp. 1)
A516 Gr. 60 (ASME P-1, Gp. 1)

Any ASME P-1, Gp. 1 or Gp. 2 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: SFA 5.1
ASME CLASSIFICATION: E7018
ASME ANALYSIS NO: A-1
ASME GROUP NO: F-4
CONSUMABLE INSERT: N/A
SUPP. POWDER FILLER: N/A

FLUX (QW-404) N/A

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE 2

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED No
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	N/A	N/A
FLOW RATE:	N/A	N/A

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: Direct Current
POLARITY: Electrode Positive
OTHER: Reverse Polarity
AMPERAGE AND VOLTAGE RANGE. SEE PAGE 3
VOLUME OF WELD METAL REQUIRED No
SEE ATTACHED PAGE N/A
MODE OF TRANSFER N/A

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) 2
STRINGER OR WEAVE TECHNIQUE SEE PAGE 2, 3
TYPE OF WELDING

MANUAL [X] MACHINE [ ]
SEMI-AUTOMATIC [ ] AUTOMATIC [ ]

CUSTOMER APPROVAL

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	RWP	02/10/94
									CHECKED	BGG	02/17/94
									AUTHORIZED		/ /

Printed in USA WL100 REV JUL 87

LIMITATIONS:

1. *This WPS is limited to the welding of structural components. It shall not be used for welding to the vessel shell or nozzle assemblies (ASME Sec. VIII Code Boundary Components).*

2. *Vertical welds shall be deposited uphill except:*

   a. *The root pass may be welded downhill.*

   b. *Wash passes may be downhill.*

   c. *Material 3/8" thick and less may have all downhill passes.*

   d. *Material up to 9/16" thick may have the second side welded with all downhill passes.*

3. *No single pass shall exceed 1/2" in thickness.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 500øF.

PREHEAT REQUIREMENTS: ASME P-1, Gp. 1 Material

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 32øF. When the ambient temperature falls below 32øF, a preheat of warm to the hand is required within 3" of where the welding is started and maintained 3" ahead of the arc.

PREHEAT REQUIREMENTS: ASME P-1, Gp. 2 Material

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 50øF. When the ambient temperature falls below 50øF, a preheat of warm to the hand is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
E7018/STRUCT	*930212*

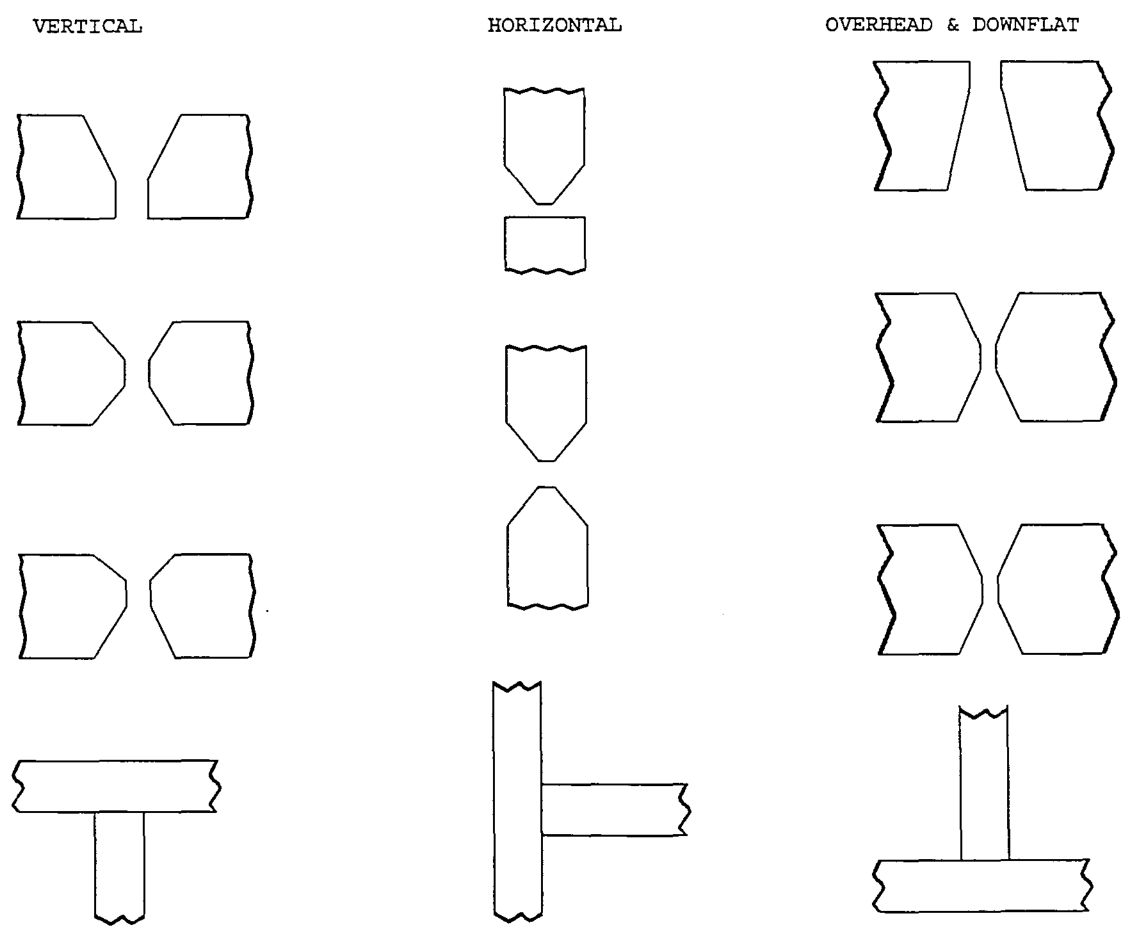
PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. *3* OF *3*
	REV. NO. *0*
CUSTOMER *CALTECH*	BY *RWP* DATE *02/10/94*

GENERAL WELDING TECHNIQUE

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Travel (IPM)	B.O.R. Sec/12"
*Stringer Beads**	*As Reqd*	*SMA*	*3/32*	*E7018*	*70-100*	*20-24*		*73-53*
			1/8		*100-175*	*16-28*		*90-48*
			5/32		*125-225*	*15-29*		*96-57*
			3/16		*180-290*	*16-28*		*89-57*
			7/32		*240-370*	*20-32*		*95-64*
			1/4		*275-410*	*20-32*		*96-67*

** Vertical Uphill Welds and Overhead Welds may be deposited using a weave technique.*

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.



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Contract

CBI

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
ESSENTIAL VARIABLES

PQR No. 8903

Process SMAW — Manual [X] Machine [ ] Automatic [ ] Semiautomatic [ ]

Material specification SA516 Gr. 60 to SA537 Cl. 1

ASME p. no. 1, Gp. 1 To ASME p. no. 1, Gp. 2

Thickness (if pipe, dia and wall thick) 1½"

Filler metal group no. F. 4

Weld metal analysis no. A. 1

ASME specification no. SFA 5.1

AWS specification no. A 5.1

FLUX OR ATMOSPHERE

Flux trade name N/A

Inert gas composition N/A

Flow rate N/A

Preheat temperature range 70°F to 500°F (IPT)

Postweld heat treatment None

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 3G

Mode of transfer for GMAW: Spray [ ] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW N/A Filler metal diameter N/A

Electrode E7018 Electrode diameter 1/8"

Type of backing None Welding current Direct Current, Electrode Positive (Reverse Polarity)

Consult **WELDING VARIABLES** for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress ksi	Ultimate Unit Stress MPa	Character of Failure and Location
H8266-1	.756	1.425	1.077	75.9	70.5	486.1	Ductile in SA 516-60 Plate
H8266-2	.756	1.426	1.078	76.0	70.5	486.1	Ductile in SA 516-60 Plate

Guided Bend Test

Type	Result	Type	Result
4 Transverse Side Bends	OK	- - -	- - -

Welder's name Otho Richardson Social Security no. 464-22-4511 Welder's Symbol OMR

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H8266 Rev. 1

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

Signed CBI

By C. Dwayne Baker Date 10-22-90

Remarks:

E7018 (AA7018) by Alloy Rods

Plate edges coated with deoxaluminite.

Material Heat Treatment: A516-60 and A537-CL. 1 Normalized

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Contract

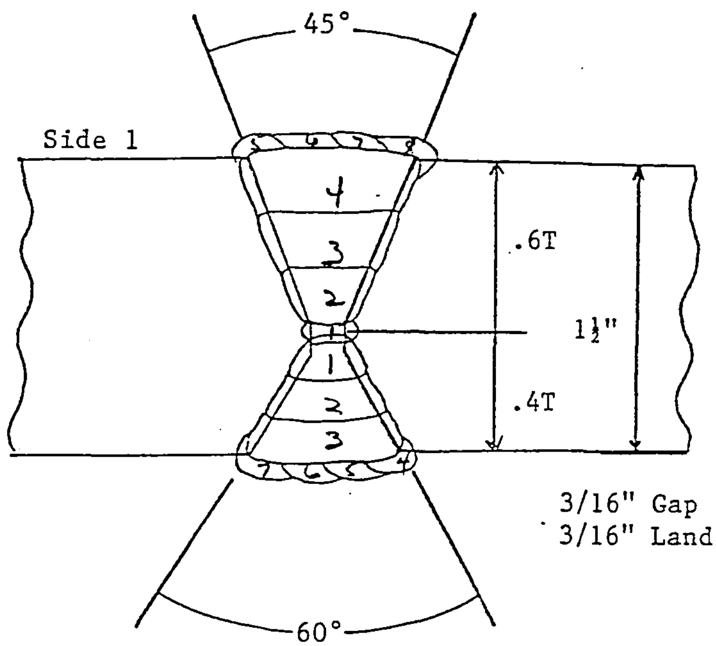
PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

WELDING VARIABLES

Downhill passes use stringer bead

Uphill passes use weave technique



3G Position

Side	Pass	Electrode Type	Electrode Size IN	Electrode Size mm	Amps	Volts	Travel Speed in./min.	Travel Speed cm/min	Heat Input KJ/in	Heat Input KJ/cm	Remarks Pass Dir.
1	1	E7018	1/8	3.2	135	24.0	3.0	7.6	64.8	25.5	DN
1	2	E7018	1/8	3.2	127	22.4	1.5	3.8	113.8	44.8	UP
1	3	E7018	1/8	3.2	127	22.5	1.3	3.3	131.9	51.9	UP
1	4	E7018	1/8	3.2	131	22.5	1.0	2.5	176.9	69.6	UP
1	5	E7018	1/8	3.2	133	25.5	12.0	30.5	17.0	6.7	DN
1	6	E7018	1/8	3.2	135	24.0	12.9	32.8	15.1	5.9	DN

Qualification No. 8903

Date: 10-22-90

BY [signature]
C. Dwayne Baker

Editorial clarification, TMJ, 5/6/93

Page
Contract

CBI

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

WELDING VARIABLES

Side	Pass	Electrode Type	Size IN	Size mm	Amps	Volts	Travel Speed in./min.	Travel Speed cm/min	Heat Input KJ/in	Heat Input KJ/cm	Remarks
1	7	E7018	1/8"	3.2	135	25.0	13.8	35.1	14.7	5.8	DN
1	8	E7018	1/8"	3.2	135	24.3	12.9	32.8	15.3	6.0	DN
2	1	E7018	1/8	3.2	130	22.0	1.7	4.3	100.9	39.7	UP
2	2	E7018	1/8"	3.2	130	22.5	1.7	4.3	103.2	40.6	UP
2	3	E7018	1/8"	3.2	130	22.5	1.5	3.8	117.0	46.1	UP
2	4	E7018	1/8"	3.2	135	23.2	12.0	30.5	15.7	6.2	DN
2	5	E7018	1/8"	3.2	135	23.9	11.3	28.7	17.1	6.7	DN
2	6	E7018	1/8"	3.2	135	26.0	13.8	35.1	15.3	6.0	DN
2	7	E7018	1/8"	3.2	135	23.9	13.8	35.1	14.0	5.5	DN

Qualification No. 8903
Date: 10-22-90

BY [signature]
C. Dwayne Baker

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
1 E308L/STRUCT	930212

PRODUCT *LIGO BEAM TUBE MODULES* CUSTOMER *CALTECH*	PAGE NO. 1 OF 3 REV. NO. 1 BY *RWP* DATE *03/11/94*

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- *SMAW*

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
9168	3G	3/16" to 1"	All	3/16" to 1"

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA *ASME Section VIII & IX, 1992 Edition, 92 Add.*

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE *3*

BACKING MATERIAL (QW-402)

None Required

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8, Gp. 1)
A240 Tp. 304 (ASME P-8, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: *SFA 5.4*
ASME CLASSIFICATION: *E308L* 1
ASME ANALYSIS NO: *A-8*
ASME GROUP NO: *F-5*
CONSUMABLE INSERT: *N/A*
SUPP. POWDER FILLER: *N/A*

FLUX (QW-404) *N/A*

CUSTOMER APPROVAL

PREHEAT/INTERPASS TEMPERATURE (QW-406) SEE ATTACHED PAGE *2*

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED *No*
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	*N/A*	*N/A*
FLOW RATE:	*N/A*	*N/A*

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: *Direct Current*
POLARITY: *Electrode Positive*
OTHER: *Reverse Polarity*
AMPERAGE AND VOLTAGE RANGE. SEE PAGE *3*
VOLUME OF WELD METAL REQUIRED *No*
SEE ATTACHED PAGE *N/A*
MODE OF TRANSFER *N/A*

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) *2*
STRINGER OR WEAVE TECHNIQUE SEE PAGE *2, 3*
TYPE OF WELDING

MANUAL [X] MACHINE [ ]
SEMI-AUTOMATIC [ ] AUTOMATIC [ ]

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	*RWP*	*02/10/94*
									CHECKED	*BGG*	*02/17/94*
									AUTHORIZED		/ /

LIMITATIONS:

1. This WPS is limited to the welding of structural components. It shall not be used for welding to the vessel shell or nozzle assemblies (ASME Sec. VIII Code Boundary Components).

2. Vertical welds shall be deposited uphill except:

   a. The root pass may be welded downhill.

   b. Wash passes may be downhill.

   c. Material 3/8" thick and less may have all downhill passes.

   d. Material up to 5/8" thick may have the second side welded with all downhill passes.

3. No single pass shall exceed 1/2" in thickness.

4. No flame burning is allowed on stainless steel materials.

5. Only stainless steel brushes may be used on stainless steel.

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS: ASME P-8, Gp. 1 Material

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0øF. When the ambient temperature falls below 0øF, a preheat of warm to the hand is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI

WELDING PROCEDURE SPECIFICATION

IDENTIFICATION WPS	CONTRACT
E308L/STRUCT	*930212*

PRODUCT *LIGO BEAM TUBE MODULES*	PAGE NO. *3* OF *3*
CUSTOMER *CALTECH*	REV. NO. *1*
	BY *RWP* DATE *03/11/94*

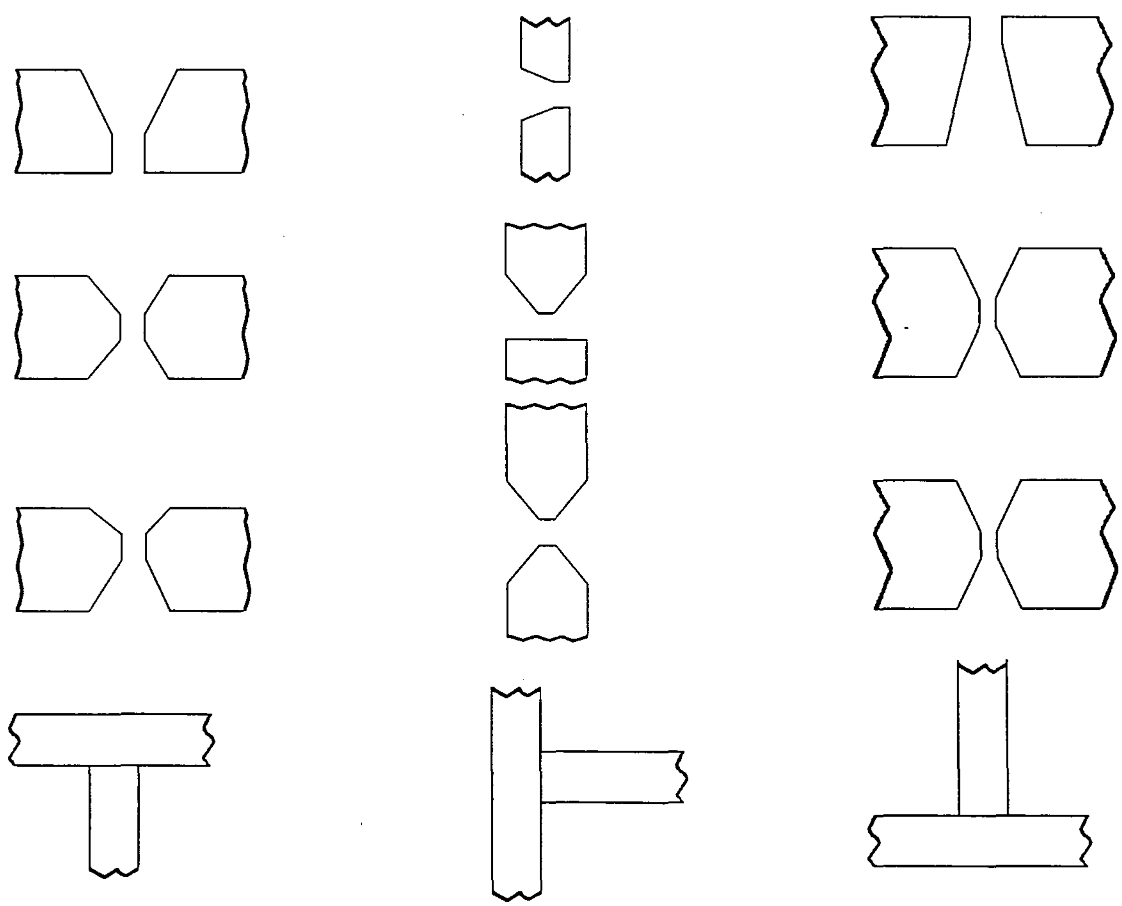
GENERAL WELDING TECHNIQUE

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Travel (IPM)	B.O.R. Sec/12"
*Stringer Beads**	*As Reqd*	*SMA*	*3/32*	*E308L-15*	*60-100*	*23-26*		*54-30*
			1/8		*60-125*	*23-27*		*100-44*
			5/32		*100-180*	*23-27*		*86-45*
			3/16		*130-240*	*24-28*		*90-46*
			1/4		*150-320*	*24-30*		*130-59*
			3/32	*E308L-16*	*60-100*	*19-22*		*65-40*
			1/8		*70-152*	*23-27*		*112-42*
			5/32		*110-196*	*24-31*		*105-49*
			3/16		*160-307*	*24-32*		*91-42*
			1/4		*180-390*	*24-34*		*127-52*

** Vertical Uphill welds may be deposited using a weave technique.*

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.

VERTICAL HORIZONTAL OVERHEAD & DOWNFLAT



CBI

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Contract

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX
ESSENTIAL VARIABLES

PQR No. 9168

Process SMAW — Manual [X] Machine [ ] Automatic [ ] Semiautomatic [ ]

Material specification SA240 Type 304

ASME p. no. P8, Gp. 1 To ASME p. no. P8, Gp. 1

Thickness (if pipe, dia and wall thick) 1/2" (12.7mm)

Filler metal group no. F. F5

Weld metal analysis no. A. A8

ASME specification no. SFA 5.4

AWS specification no. A 5.4

FLUX OR ATMOSPHERE

Flux trade name N/A

Inert gas composition N/A

Flow rate N/A

Preheat temperature range 70°F-350°F(IPT)(21°C-176°C)

Postweld heat treatment None

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 3G

Mode of transfer for GMAW: Spray [ ] Globular [ ] Pulsating [ ] Short Circuit [ ]

Filler Metal for GTAW or PAW N/A

Filler metal diameter N/A

Electrode E308

Electrode diameter 1/8" (3.2mm)

Type of backing None

Welding current Direct Current, Electrode Positive (Reverse Polarity)

Consult WELDING VARIABLES for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in		Area in 2	Ultimate Total Load Kips	Ultimate Unit Stress		Character of Failure and Location
	Width	Thickness			ksi	MPa	
H8914-1	0.758	0.472	0.358	30.6	85.5	589.5	Ductile in SA240 Tp.304 Plate
H8914-2	0.758	0.472	0.358	30.5	85.2	587.4	Ductile in SA240 Tp.304 Plate

Guided Bend Test

Type	Result	Type	Result
4 Transverse Side	OK	- - - -	- - -

Welder's name Glenn A. Adams Social Security no. 336-48-0346 Welder's Symbol GAA

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H8914 Rev. 1

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

Signed CBI

By Peter Gissel Date 10/9/91

Peter Gissel

Remarks: Arcaloy 308 Lime (E308) by Alloy Rods

Metric Values are calculated from English System

Contract Material Used - Avesta - Sweden

Ht. No. S10530-04073

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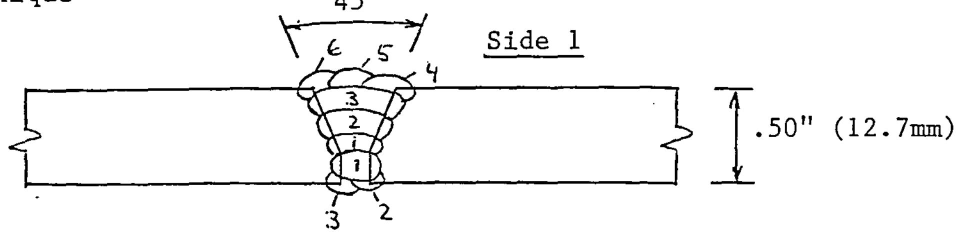
Contract

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

WELDING VARIABLES

NOTE: Uphill Passes - Weave Bead Technique
Downhill Passes - Stringer Bead Technique



3G POSITION

GAP = 1/8" (3.2mm)
LAND = 5/32" (4.0mm)

Side	Pass	Electrode Type	Electrode Size IN	Electrode Size mm	Amps	Volts	Travel Speed in./min.	Travel Speed cm/min	Heat Input KJ/in	Heat Input KJ/cm	Remarks Pass Direction
1	1	E308	1/8	3.2	116	27	5.9	15.0	31.9	12.6	DNHILL
1	2	E308	1/8	3.2	84	25	2.2	5.6	57.3	22.6	UPHILL
1	3	E308	1/8	3.2	88	24	2.7	6.9	46.9	18.5	UPHILL
1	4	E308	1/8	3.2	101	29	10.0	25.4	17.6	6.9	DNHILL
1	5	E308	1/8	3.2	101	28	9.1	23.1	18.6	7.3	DNHILL
1	6	E308	1/8	3.2	101	26	9.1	23.1	17.3	6.8	DNHILL
2	1	E308	1/8	3.2	88	27	13.1	7.9	46.0	18.1	UPHILL
2	2	E308	1/8	3.2	101	27	11.1	28.2	14.7	5.8	DNHILL
2	3	E308	1/8	3.2	101	26	10.0	25.4	15.8	6.2	DNHILL

Qualification No. 9168
Date: 10/9/91

BY Peter Gissel
Peter Gissel

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION	CONTRACT
WPS E309/STRUCT	930212

PRODUCT *LIGO BEAM TUBE MODULES*
CUSTOMER *CALTECH*

REV. NO. 0
BY *RWP* DATE *02/10/94*

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- *SMAW*

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
6190	*3G*	*3/16" to 2"*	*All*	*3/16" to 1"*

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA *ASME Section VIII & IX, 1992 Edition, 92 Add.*

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE *3*

BACKING MATERIAL (QW-402)

None Required

BASE MATERIAL (QW-403)

A240 Tp. 304L (ASME P-8. Gp. 1)
A240 Tp. 304L (ASME P-8, Gp. 1)
A36 (ASME P-1, Gp. 1)
A283 Gr. C (ASME P-1, Gp. 1)

Any ASME P-8, Gp. 1 material may be welded to any ASME P-1, Gp. 1 or Gp. 2 material in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO: *SFA 5.4*
ASME CLASSIFICATION: *E309*
ASME ANALYSIS NO: *A-8*
ASME GROUP NO: *F-5*
CONSUMABLE INSERT: *N/A*
SUPP. POWDER FILLER: *N/A*

FLUX (QW-404) *N/A*

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE *2*

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED *No*
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	*N/A*	*N/A*
FLOW RATE:	*N/A*	*N/A*

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: *Direct Current*
POLARITY: *Electrode Positive*
OTHER: *Reverse Polarity*
AMPERAGE AND VOLTAGE RANGE. SEE PAGE *3*
VOLUME OF WELD METAL REQUIRED *No*
SEE ATTACHED PAGE *N/A*
MODE OF TRANSFER *N/A*

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) *2*
STRINGER OR WEAVE TECHNIQUE SEE PAGE *2, 3*
TYPE OF WELDING

MANUAL [X] MACHINE [ ]
SEMI-AUTOMATIC [ ] AUTOMATIC [ ]

CUSTOMER APPROVAL

REVIEWED	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	*RWP*	*02/10/94*
									CHECKED	*BGG*	*02/17/94*
									AUTHORIZED		/ /

LIMITATIONS:

1. *This WPS is limited to the welding of structural components. It shall not be used for welding to the vessel shell or nozzle assemblies (ASME Sec. VIII Code Boundary Components).*
2. *Vertical welds shall be deposited uphill except:*
   a. *The root pass may be welded downhill.*
   b. *Wash passes may be downhill.*
   c. *Material 3/8" thick and less may have all downhill passes.*
   d. *Material up to 5/8" thick may have the second side welded with all downhill passes.*
3. *No single pass shall exceed 1/2" in thickness.*
4. *No flame burning is allowed on stainless steel materials.*
5. *Only stainless steel brushes may be used on stainless steel.*

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350øF.

PREHEAT REQUIREMENTS: ASME P-1, Gp. 1 to ASME P-8, Gp. 1

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 32øF. When the ambient temperature falls below 32øF, a preheat of warm to the hand is required within 3" of where the welding is started and maintained 3" ahead of the arc.

PREHEAT REQUIREMENTS: ASME P-1, Gp. 2 to ASME P-8, Gp. 1

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 50øF. When the ambient temperature falls below 50øF, a preheat of warm to the hand is required within 3" of where the welding is started and maintained 3" ahead of the arc.

IDENTIFICATION WPS	CONTRACT
E309/STRUCT	930212

WELDING PROCEDURE SPECIFICATION

PRODUCT *LIGO BEAM TUBE MODULES*

CUSTOMER *CALTECH*

PAGE NO. *3* OF *3*

REV. NO. *0*

BY *RWP* DATE *02/10/94*

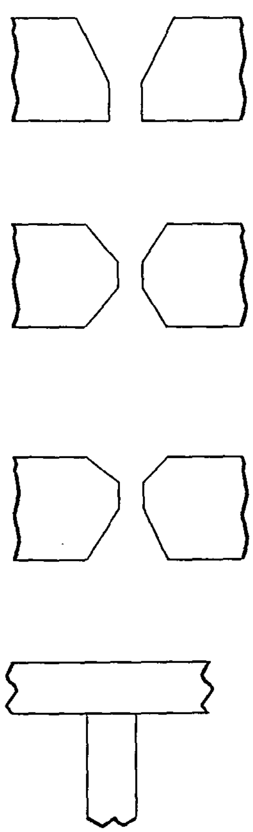
GENERAL WELDING TECHNIQUE

Operation Description	Beads Layer	Weld Proc.	Electrode Size	Electrode Type	Current (amps)	Voltage (Volts)	Travel (IPM)	B.O.R. Sec/12"
*Stringer Beads**	*As Reqd*	*SMA*	*3/32*	*E309-15*	*60-100*	*23-26*		*54-30*
			1/8		*60-125*	*23-27*		*100-44*
			5/32		*100-180*	*23-27*		*86-45*
			3/16		*130-240*	*24-28*		*90-46*
			1/4		*150-320*	*24-30*		*130-59*
			3/32	*E309-16*	*60-100*	*19-22*		*65-40*
			1/8		*70-152*	*23-27*		*112-42*
			5/32		*110-196*	*24-31*		*105-49*
			3/16		*160-307*	*24-32*		*91-42*
			1/4		*180-390*	*24-34*		*127-52*

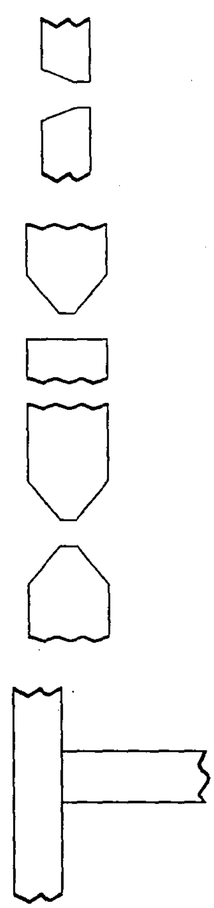
* *Vertical Uphill welds may be deposited using a weave technique.*

JOINT DETAIL - See contract drawings for applicable joint details and dimensions.

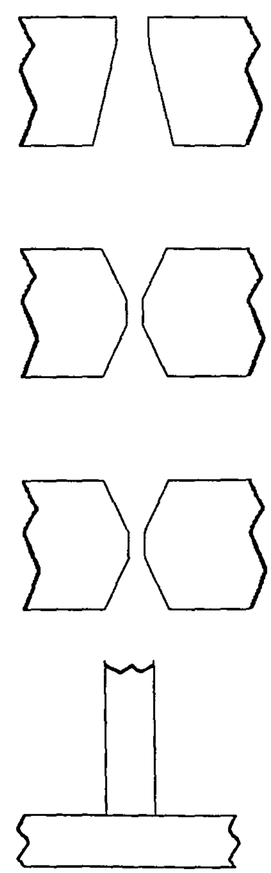
VERTICAL



HORIZONTAL



OVERHEAD & DOWNFLAT



Page

Contract

CBI

PROCEDURE QUALIFICATION RECORD
TO A.S.M.E. SECTION IX

PART II ESSENTIAL VARIABLES

PQR No. 6190

Date 2-3-83

Process SMAW

Manual [X] Machine [ ] Automatic [ ] Semiautomatic [ ]

Material specification A283 GR.C to A240 TP304

ASME p. no. P1-Gp.1 To ASME p. no. P8-Gp.1

Thickness (if pipe, dia and wall thick) 1.0"

Filler metal group no. F. 5

Weld metal analysis no. A. 8

ASME specification no. SFA 5.4

AWS specification no. A 5.4

FLUX OR ATMOSPHERE

Flux trade name None Required

Inert gas composition None Required

Flow rate None Required

Is backing strip used? No

Preheat temperature range 70°F - 350°F (IPT)

Postweld heat treatment None Required

WELDING PROCEDURE

Single or multiple pass Multiple Single or multiple arc Single Position 3G

Electrode E309-15*

Filler wire diameter 1/8", 5/32"

Type of backing None Required

Welding current Direct Current, Electrode Positive (Reverse Polarity)

Consult **PART III WELDING VARIABLES** for joint dimensions and welding current settings.

TEST RESULTS

Reduced Section Tensile Results

Specimen No.	Dimensions in Width	Dimensions in Thickness	Area in ^{2}	Ultimate Total Load Lb	Ultimate Unit Stress PSI	Character of Failure and Location
H943W-1	1.003	0.871	0.874	64,900	74,300	Ductile in SA283 material
H943W-2	1.003	0.871	0.874	64,900	74,300	Ductile in SA283 material

Guided Bend Test

Type	Result	Type	Result
4 Transverse Side Bends	Okay	------	---

Welder's name C. Campbell Social Security no. 403-36-4037 Welder's Symbol CC

Who by virtue of these tests meets welder performance requirements.

Work Order (Orig. WPS) No. H943W Rev. 0 Date 1-17-83

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

Signed CBI

By J W Bransford J. W. Bransford Date 2-3-83

Remarks: *Arcaloy

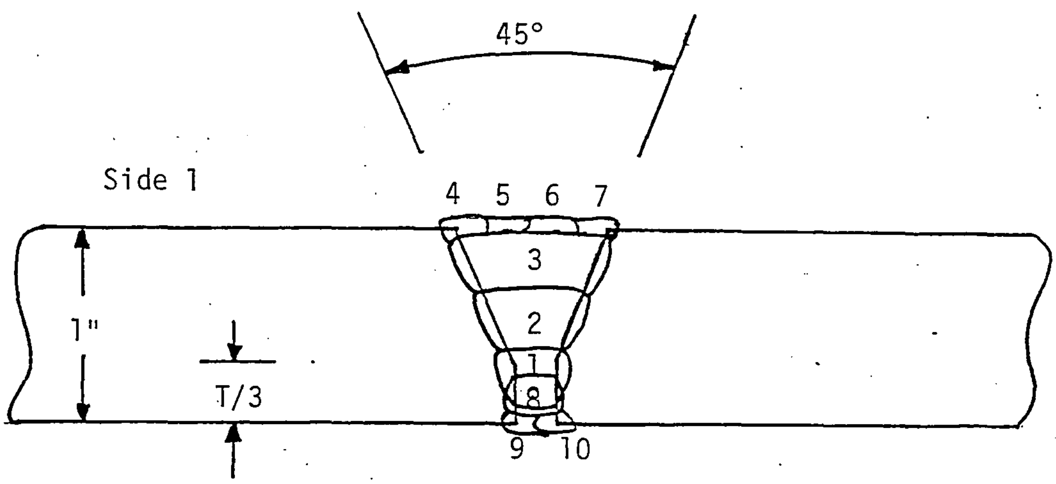
Printed In USA

WL 20 D REV DEC 82

PROCEDURE QUALIFICATION RECORD

To A.S.M.E. Section IX

PART III WELDING VARIABLES



Gap: 3/16
Land: T/3

3G POSITION

Layer	Electrode		Amps	Volts	PASS DIR.	Remarks
	Type	Size				(Gas Flow etc)
1	E309-15	1/8"Ø	125	28	DN	Root Pass
2-3	E309-15	5/32"Ø	110	25	UP	
4-7	E309-15	1/8"Ø	110	25	DN	Wash Pass
8	E309-15	1/8"Ø	90	25	UP	
9-10	E309-15	1/8"Ø	110	25	DN	Wash Pass

Qualification No. 6190
Date: 2-3-83

BY J. W. Bransford J. W. Bransford

CBI WELDING PROCEDURE SPECIFICATION

IDENTIFICATION
WPS
WELDCOUP

CONTRACT
930212

PRODUCT	*OUTGASSING TEST COUPONS*	PAGE NO.	*1* OF *3*
CUSTOMER	*CALTECH*	REV. NO.	*1*
		BY RWP	DATE *12/17/93*

WORK THIS DOCUMENT WITH GENERAL WELD PROCEDURE SPEC. GWPS- *GTAW*

REFERENCE PROCEDURE QUALIFICATION RECORD			SPECIFIC CONTRACT	
NO.	POSITION QUALIFIED (QW-405)	THICKNESS QUALIFIED (QW-403)	POSITION (QW-405)	THICKNESS RANGE (QW-403)
PQR to be done for LIGO at a later date.			*1G*	*1/8"*

SPECIFIC CONTRACT WPS REQUIREMENTS

CODE EDITION AND ADDENDA *ASME Section VIII & IX, 1992 Edition, 92 Add.*

JOINTS (QW-402) SEE GENERAL WELDING TECHNIQUE PAGE *3*

BACKING MATERIAL (QW-402)
None Required

BASE MATERIAL (QW-403)

.240 Tp. 304L *(ASME P-8, Gp. 1)*

Any ASME P-8, Gp. 1 material may be welded together or to each other in any combination.

FILLER METAL (QW-404)

ASME SPECIFICATION NO:	*SFA 5.9*
ASME CLASSIFICATION:	*ER308L*
ASME ANALYSIS NO:	*A-8*
ASME GROUP NO:	*F-6*
CONSUMABLE INSERT:	*N/A*
SUPP. POWDER FILLER:	*N/A*

FLUX (QW-404)
N/A

PREHEAT/INTERPASS TEMPERATURE (QW-406)
SEE ATTACHED PAGE *2*

POST WELD HEAT TREATMENT (QW-407)
PWHT REQUIRED *No*
IF PWHT IS REQUIRED, SEE APPROVED CONTRACT PWHT PROCEDURE FOR DETAILS AND EXTENT OF PWHT.

GAS (QW-408)	SHIELDING	BACK UP
COMPOSITION:	*60%Ar/40%He*	*100%Ar*
FLOW RATE:	*20-45 cfh*	*10-20 cfh*

ELECTRICAL CHARACTERISTICS (QW-409)
CURRENT: *Direct Current*
POLARITY: *Electrode Negative*
OTHER: *Straight Polarity*
AMPERAGE AND VOLTAGE RANGE. SEE PAGE *3*
VOLUME OF WELD METAL REQUIRED *No*
SEE ATTACHED PAGE *N/A*
MODE OF TRANSFER *N/A*

TECHNIQUE (QW-410)/ SPECIAL LIMITATIONS
SEE ATTACHED PAGE(S) *2, 3*
STRINGER OR WEAVE TECHNIQUE SEE PAGE *2, 3*
TYPE OF WELDING

MANUAL	☐	MACHINE	☒
SEMI-AUTOMATIC	☐	AUTOMATIC	☐

CUSTOMER APPROVAL

REVIEW	OB ENGR	DIST ENGR	WELDING SERVICES HOUSTON	CORP QA	REG CONST QA	REG MFG QA				BY	DATE
									PREPARED	*RWP*	*12/6/93*
									CHECKED	*BGG*	*12/6/93*
									AUTHORIZED		

Printed in USA

WL100 REV JUL 87

CBI WELDING PROCEDURE SPECIFICATION

	IDENTIFICATION WPS *WELDCOUP*	CONTRACT *930212*

		PAGE NO.	2 OF 3
PRODUCT	*OUTGASSING TEST COUPONS*	REV. NO.	1
CUSTOMER	*CALTECH*	BY RWP	DATE 12/17/93

LIMITATIONS:

1) *This WPS to be used with Dimetrics Gold Track II weld unit.*
2) *All welding is to be done in the downflat (1G) position.*
3) *Pulsing current may be used.*
4) *Use a single pass per side technique.*
5) *Use a single EWTh-2 (2% thoriated Tungsten) electrode.*
6) *No single pass shall exceed 1/2" in thickness.*
7) *Only stainless steel brushes shall be used on stainless steel.*
8) *Parameters on Page 3 shall be followed.*
9) *Only filler material in accordance with WMS-ER308L shall be used.*

CLEANING:

Cleaning of coupons to be done in accordance with cleaning procedure CLCOUP.

INTERPASS TEMPERATURE:

The interpass temperature shall not exceed 350°F.

PREHEAT REQUIREMENTS (ASME P-8, Gp. 1):

No preheat is required except as an aid to remove moisture unless the ambient temperature falls below 0°F. When the ambient temperature falls below 0°F, a preheat of warm to the hand (approx. 100°F) is required within 3" of where the welding is started and maintained 3" ahead of the arc.

CBI WELDING PROCEDURE SPECIFICATION	IDENTIFICATION WPS *WELDCOUP*	CONTRACT *930212*

PRODUCT	*OUTGASSING TEST COUPONS*	REV. NO.	*1*
CUSTOMER	*CALTECH*	BY RWP	DATE *12/17/93*

WELDING PARAMETERS FOR GOLD TRACK II:

Parameter	*First Pass*	*Second Pass*
Position	*1G*	*1G*
Shielding Gas	*60% Argon - 40% Helium*	*60% Argon - 40% Helium*
Flow rate	*20 - 45 cfh*	*20 - 45 cfh*
Purge Gas	*100% Argon*	*100% Argon*
Flow rate	*10 - 25 cfh **	*10 - 25 cfh **
Filler Wire	*Autogenous*	*ER308L ***
Diameter	*N/A*	*0.035"*
Pulse Mode	*Off*	*Off,*
Pulse Width	*N/A*	*N/A*
Pulse Frequency	*N/A*	*N/A*
AVC Response	*20*	*20*
AVC Mode	*N/A*	*N/.A*
Upslope Time	*3*	*3*
Downslope Time	*2*	*2*
Travel Start Delay	*1*	*1*
Wire Start Delay	*N/A*	*1*
Oscillation Amplitude	*Zero*	*Zero*
Travel Speed (ipm)	*18*	*18*
Primary Weld Current (amps)	*230*	*230*
Primary Arc Voltage (volts)	*10.0*	*10.5*
Primary Wire Speed (ipm)	*N/A*	*18*
Background Weld Current (amps)	*N/A*	*N/A*
Background Arc Voltage (volts)	*N/A*	*N/A*
Background Wire Speed (ipm)	*N/A*	*N/A*
Out Dwell Time (sec x .1)	*N/A*	*N/A*
Excursion Time (sec x .1)	*N/A*	*N/A*
In Dwell Time (sec x .1)	*N/A*	*N/A*

Notes:

* *Flow rate necessary to achieve < 0.5% oxygen level.*

** *ER308L to be cleaned and baked out per WMS-ER308L.*

CBI

DOC. ID	WMS-ER308L/COUP
REV. NO.	0
CONTRACT	930212

TITLE CLEANING AND BAKE OUT OF WELD WIRE FOR USE DURING WELDING OF OUTGASSING TESTS CALTECH

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	RWP	12/9/93
					REVISED		
					AUTHORIZED	BGG	12/9/93
					REFERENCED STANDARD	REV. NO.	

1.0 SCOPE:

This procedure covers the purchasing specifications, cleaning, bake out and handling of weld wire to be used during the welding of the 0.115" x 1" x 18" outgassing test coupons.

2.0 REFERENCES:

2.1 ASME Section II, Part C, latest edition.

2.2 California Institute of Technology Technical Specification Number 1100007 for Low Hydrogen, Type 304L Stainless Steel Vacuum Products.

3.0 MATERIAL:

3.1 ASME Specification SFA 5.9, latest edition in Part C, Section II Material Specification.

3.2 AWS Classification - ER308L.

3.3 Unit Package Type - 25 lb. spool of 0.035" diameter.

4.0 CERTIFIFICATION AND TESTING per SFA 5.01, latest edition in Part C, Section II Material Specification:

4.1 Lot Classification - S3.

4.2 Level of Testing - Schedule F.

5.0 CLEANING:

Weld wire in accordance with sections 3 and 4 above shall be cleaned with Scotch Brite, Mirachem 500 cleaner/degreaser to remove hydrocarbon contamination followed by Scotch Brite. The wire shall be wiped dry using lint free clothes or paper towels and re-spooled onto a stainless steel, 2 1.2 lb. spool.

6.0 BAKE OUT:

6.1 The spooled onto the 2 1/2 lb. stainless steel spool shall undergo a bake out at 440°C +/- 8°C (825°F +/- 15°F) for 36 hours.

6.2 The bake out shall be an air bake with the stainless steel spool positioned on a raised grating with its surface vertical to promote convective flow over the surface.

7.0 POST CLEANING:

The weld wire after bake out shall be re-spooled and cleaned with Scotch Brite to remove residual contamination due to the bake out procedure.

8.0 STORAGE:

8.1 If welding does not commence immediately, the re-cleaned wire shall be wrapped in a plastic bag, purged with 100% argon gas and sealed until further use.

8.2 To use sealed, cleaned and baked out wire, remove spool from the plastic bag. To store remainder of wire, follow steps outlined in section 8.1 above.

9.0 HANDLING OF CLEANED WIRE:

9.1 All handling of the wire after the initial cleaning procedure, section 5.1, shall be done wearing cloth gloves. No contact with skin shall occur.

9.2 All wire feed equipment shall use liners, rolls and contract tips that are either new or have only been in contact with stainless steel wire.

CBI

DOC. ID	WMS-ER308L
REV. NO.	1
CONTRACT	930212

TITLE CLEANING AND BAKE OUT PROCEDURE OF ER308L TO BE USED FOR CONSTRUCTION OF THE LIGO BEAM TUBE MODULES

Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	RWP	12/9/93
REVISED	RWP	1/13/94
AUTHORIZED	BGG	1/28/94
REFERENCED STANDARD	REV. NO.	

1.0 SCOPE:

This procedure covers the purchasing specifications, cleaning, bake out and handling of weld wire to be used during the construction of the LIGO Beam Tube Modules.

2.0 REFERENCES:

2.1 ASME Section II, Part C, latest edition.

2.2 California Institute of Technology Technical Specification Number 1100007 for Low Hydrogen, Type 304L Stainless Steel Vacuum Products.

3.0 MATERIAL:

3.1 ASME Specification SFA 5.9, latest edition in Part C, Section II Material Specification.

3.2 AWS Classification - ER308L.

3.3 Unit Package Type - 25 lb. and 2 1/2 lb. spools of 0.035" diameter.

4.0 CERTIFICATION AND TESTING per SFA 5.01, latest edition in Part C, Section II Material Specification:

4.1 Lot Classification - S3.

4.2 Level of Testing - Schedule F.

5.0 CLEANING:

Weld wire in accordance with sections 3 and 4 above shall be cleaned with Scotch Brite, Mirachem 500 cleaner/degreaser to remove hydrocarbon contamination followed by Scotch Brite. The wire shall be wiped dry using lint free clothes or paper towels.

6.0 BAKE OUT:

6.1 The cleaned wire shall undergo a bake out at 440°C +/- 8°C (825°F +/- 15°F) for 36 hours. During bake out, the wire must only be in contact with stainless steel.

6.2 The bake out shall be an air bake with the stainless steel spool positioned on a raised grating with its surface vertical to promote convective flow over the surface

7.0 POST CLEANING:

The weld wire after bake out shall be re-cleaned with Scotch Brite to remove residual contamination due to the bake out procedure.

8.0 STORAGE:

8.1 If welding does not commence immediately, the re-cleaned wire shall be wrapped in a plastic bag, purged with 100% argon gas and sealed until further use. The wire may also be vacuum packaged.

8.2 To use sealed, cleaned and baked out wire, remove spool from its sealed package. To store remainder of wire, follow steps outlined in section 8.1 above.

9.0 HANDLING OF CLEANED WIRE:

9.1 All handling of the wire after the initial cleaning procedure, section 5.1, shall be done wearing cloth gloves. No contact with skin shall occur.

9.2 All wire feed equipment shall use liners, rolls and contract tips that are either new or have only been in contact with stainless steel wire.

DOC. ID	GR-8X
REV. NO.	1
CONTRACT	930212

TITLE GENERAL REPAIR PROCEDURE FOR MATERIALS AND WELDS FOR LIGO BEAM TUBE MODULES

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	RWP	2/9/94
					REVISED		
					AUTHORIZED	BGG	2/15/94
					REFERENCED STANDARD	GR-8 REV. NO.	3

1.0 SCOPE:

1.1 BASE METAL SURFACE NONCONFOMITIES - For repairs of all nonconformities in base metal surfaces not exceeding 24 sq. in.

1.2 EDGE PREPARATION NONCONFORMITIES - For repairs of all nonconfomities in edge preparation.

1.3 WELDS - For repair of unacceptable defects in inspected weld joints.

2.0 PROCEDURES:

2.1 REPAIRS TO BASE METAL SURFACE NONCONFORMITIES (1.1)

2.1.1 For Repairs Not Requiring Welding (those which can be removed without reducing the material thickness more than 0.01 inch under the ordered thickness shown on the contract drawings.)

A. Surface defects shall be removed by grinding to sound metal. The cavity shall be blended uniformly into surrounding surfaces.

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

C. The reduced material thickness shall be checked by depth gauge, ultrasonics, or other acceptable methods to verify that the remaining material thickness is not reduced below the minimum required.

2.1.2 For Repairs Requiring Welding

A. Remove the defect by grinding or chipping to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with WPS-ER308L/REPAIR.

D. Welded repairs shall be visually inspected.

2.2 REPAIRS TO EDGE PREPARATION NONCONFORMITIES (1.2)

2.2.1 For Repairs Not Requiring Welding

A. Defects shall be removed by grinding to sound metal. The cavity shall be blended uniformly into the surrounding surfaces.

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

2.2.2 For Repairs Requiring Welding

A. Remove the defect by grinding or chipping to an acceptable level.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with WPS-ER308L/REPAIR.

D. Welded repairs shall be visually inspected.

2.3 REPAIRS TO WELDS (1.3)

2.3.1 For Repairs Not Requiring Welding

A. Defects shall be removed as required by grinding and the depression shall be blended uniformly into the surrounding surface.

B. Visually inspect the blend ground area to ensure that the defect has been removed or the indication reduced to an acceptable limit.

C. The reduced material thickness shall be checked by depth gauge, ultrasonics, or other acceptable methods to verify that the remaining material thickness is not reduced below the minimum specified on the contract drawings.

2.3.2 For Repairs Requiring Welding

A. Remove the defect as required by grinding or chipping.

B. Visually inspect the area prepared for welding.

C. Weld in accordance with WPS-ER308L/REPAIR.

D. The repaired area surface shall be blended uniformly into the surrounding surface.

E. Inspection of a weld repair shall be repeated as required for the original weld.

2.3.3 For Fillet Weld Repairs Requiring Welding

A. Remove the unacceptable weld metal.

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

C. Weld in accordance with WPS-ER308L/REPAIR.

D. Re-inspect per the original NDE method.

3.0 DOCUMENTATION:

Documentation shall be in accordance with the Quality Assurance Manual (QAM).

CBI

DOC. ID	CUP-8X	
REV. NO.	1	
CONTRACT	930212	

TITLE	PLATE CLEAN-UP PROCEDURE FOR LIGO BEAM TUBE MODULES	PAGE NO.	1	OF 2

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	RWP	2/18/94
					REVISED		
					AUTHORIZED	BGG	3/1/94
					REFERENCED	CUP-8	
					STANDARD	REV. NO.	4

1.0 SCOPE:

This procedure describes the methods of plate (forgings, pipe, etc.) clean-up.

This includes removal of such things as:

1.1 Temporary attachments.

1.2 Usual handling marks such as clamp marks, fit-up marks, etc.

1.3 Arc strikes.

2.0 TEMPORARY ATTACHMENTS:

2.1 Remove temporary attachments.

2.2 Grind remaining weld smooth.

2.3 Small surface imperfections shall be welded per WPS-ER308L/REPAIR.

2.4 Visually inspect all areas.

3.0 HANDLING AND FIT-UP MARKS:

3.1 Weld per WPS-ER308L/REPAIR.

3.2 Visually inspect all areas.

4.0 ARC STRIKES:

4.1 Grind smooth.

4.2 Small surface imperfections shall be welded per WPS-ER308L/REPAIR.

4.3 Visually inspect all areas.

5.0 DOCUMENTATION:

None required.

CBI

DOC. ID	FABSEQ
REV. NO.	1
CONTRACT	930212

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	GLW	2/3/94
					REVISED	KHF	4/5/94
					AUTHORIZED		
					REFERENCED STANDARD	REV. NO.	

1.0 Scope

This procedure outlines the fabrication sequences to be followed during the stiffener attachment, expansion bellows installation, pump port installation, testing and cleaning of the beam tube assemblies. Detail or supporting procedures for welding, testing, cleaning, etc. are referenced as required.

The following section headings are included:

2.0 Fabrication Sequence
3.0 Testing Sequence
4.0 Cleaning Sequence
5.0 Referenced Procedures
6.0 Sequence Diagram and Sketches

2.0 Fabrication Sequence

2.1 Deliver factory tube sections, stiffeners, pump port materials, weld materials, etc. to receiving area. Valves, blind flanges and associated bolting furnished by others will also be received at the storage area and handled in a similar manner.

2.2 Visually inspect factory tubes, stiffeners, pump port materials, welding materials, etc. for shipment damage and compare to shipping papers or packing list.

****

Note

Factory Tubes, Expansion Bellows, Stiffeners, Pump Port Materials and Valves will have inspection and factory release papers with shipment.

****

2.3 Complete material receiving reports for all contract materials received at the site will be prepared. The receiving report will have attached any applicable inspection, certification, release, shipping manifests or other related documents.

2.4 Store beam tube cans or other materials in designated receiving storage area.

****

Warning

Do not perform any welding or tacking on beam tubes until proper backing purge has been established.

****

Use nylon slings and designated rigging for handling beam tubes and expansion bellows.

****

Do not use screw clamps for handling beam tubes.

****

2.5 Move beam tube to desired stiffener fitting and weld area. make painted

2.6 Mark beam tube serial number identification on beam tube exterior using CBI approved ball point paint markers or paint stencil with 3" high letters. Markings to be a minimum of three places approximately 120° around on each end of bare beam tube can section.

Mark location of machined support stiffener and all other stiffeners. Indicate beam tube can section final installation direction at each end of beam tube can section and location of expansion bellows and pump port, if applicable.

****

Note

For convention, beam tube direction is outward from apex.

****

****

Note

Pump port layout to be between spiral welds so that reinforcing ring welding does not cross spiral weld. Rotate tube as required to obtain required spacing.

****

2.7 Slide on and rough position near final location all vacuum stiffeners.

****

Reference

See
Fitting/Purge Procedure for Stiffener Attachment Welds for LIGO
Doc ID "FPStiffener"

****

2.8 Install machined support stiffener. Machined stiffener halves to be placed in final position.

2.9 Set beam tube in stiffener fit-up and weld area. Position end turning trunnion and opposite end support.

2.10 Purge beam tube interior with nitrogen gas. Purge until oxygen level is less than 1.0% oxygen. End point to be verified with oxygen analyzer. Upon reaching 1.0% oxygen, establish nitrogen flow rate to a minimum flow rate necessary to maintain adequate purge level (light positive flow).

Purge to be maintained at less than 1.0% oxygen within tube. Check periodically during any tacking and welding operation.

2.11 Tack machined support stiffener.

2.12 Final position, fit and tack balance of stiffeners. Stiffener splice to be positioned over tube spiral weld. Do not tack within 2" of spiral weld.

2.13 Weld machined support and vacuum stiffeners.

****

Note:

Do not weld on or over the beam tube can section spiral weld.

****

Reference

See
Weld Procedure Specification for Stiffener Welds
Doc ID "WPS-ER308L/Stiffener"

****

2.14 Fit and weld pump port reinforcing ring, if applicable. Verify prior to welding that pump port reinforcing ring does not cross spiral weld.

****

Reference

See
Weld Procedure Specification for
GMA Welding for 304L Materials
Doc ID "WPS-ER308L/GMA"

****

2.15 Steps 2.16 thru 2.29 are for installation of expansion bellows. Skip if not applicable to specific beam tube can section.

2.16 Move stiffened tube section can section to expansion bellows fit/weld area.

****

Reference

See
Fitting/Purge Procedure for
Circumferential Butt Welds for LIGO
Doc ID "FPCircumferential"

****

2.17 Start aligning expansion bellows using mechanical alignment jig. The expansion bellows needs to be mechanical rough aligned (no tacking or welding) to allow installation of the weld joint purge/helium hood ring.

****

Warning

Do not perform any tacking or welding at this time.

****

2.18 Install weld joint purge/helium hood ring, centered on weld seam, and connect 3/8" diameter stainless steel purge/evacuation lines listed below:

a) Annular space vent line (weld purge gas).

b) Ring seal pressure line (nitrogen ring seal gas).

c) Annular space pressure/purge line (weld purge gas).

See "Weld Joint Purging Arrangement" or sketch on page 12 of 17 of this fabrication sequence.

2.19 Inflate purge ring outer seals by opening valve on nitrogen ring seal gas supply holding weld joint purge/helium hood ring in position centered on the beam tube/expansion joint weld joint to be welded. Regulator should be set at 5 psig.

2.20 Open evacuation line valve and annular space pressure line valve allowing 100% Argon backing purge gas to purge annular space. Purge until oxygen level is less than 1.0% oxygen. End point to be verified with oxygen analyzer. Upon reaching 1.0% oxygen, establish Argon flow rate to a minimum flow necessary to maintain adequate purge level (light positive flow).

****

Warning

Welding or tack welding at weld joint to be only performed after completion of the above weld purge.

****

2.21 Complete fit up of weld joint. Tack welding is allowed at this step.

****

Reference

See
Weld Procedure Specification
for Circumferential Welds
Doc ID "WPS-ER308L/Circumferential"

****

2.22 Set up and position automatic weld equipment and complete welding of beam tube weld joint.

2.23 Shut valve on annular space pressure/purge line to 100% Argon weld purge gas.

2.24 Valve on annular space evacuation line should be open and remain open.

2.25 Shut nitrogen ring seal gas supply.

2.26 Open purge ring outer seal vent valve

2.27 Close both evacuation valves associated with annular space evacuation line and purge ring outer seals after venting stops and weld joint purge ring has slackened.

2.28 Disconnect and remove the three (3) 3/8" diameter stainless steel purge/evacuation lines.

2.29 Remove weld joint purge/helium hood ring.

2.30 Steps 2.31 thru 2.41 are for installation of pump port. Skip if not applicable to specific beam tube can section.

2.31 Move stiffened tube section to pump port fit and weld area.

****

Reference

See
Fitting/Purge Procedure for Pump
Port Attachment Welds for LIGO
Doc ID "FPPumpPort"

****

2.32 Set-up and bore nozzle opening for 10" nominal pump port nozzle.

2.33 Install and fit pump port nozzle. Tack on inside using hand held back purge of 100% Argon.

2.34 Install external purge unit and purge with 100% Argon until oxygen level is less than 1.0% oxygen.

2.35 Weld inside of pump port nozzle.

****

Reference

See
Weld Procedure Specification
for Pump Port Welds
Doc ID "WPS-ER308L/Port"

****

2.36 Remove external purge unit.

2.37 Perform visual inspection to assure 100% penetration and fusion and repair suspect areas using WPS-ER308L/REPAIR.

2.38 Install internal purge diaphragm and purge with 100% Argon until oxygen level is less than 1.0% oxygen.

2.39 Complete external welding of pump port nozzle.

2.40 Visually inspect and repair per procedure any required areas using 100% Argon purge on the appropriate side.

2.41 Install temporary pump port blind flanges.

2.42 Install end caps.

2.43 Move beam tube assembly to post fab storage area.

3.0 Testing Sequence

3.1 Move beam tube assembly to test area and remove end caps.

3.2 Perform pretest cleaning and black light testing cleaning procedure.

****
Reference

See
Cleaning of Completed Tube Can Sections
Doc ID "CL1N"
****

3.3 Perform visual examination noting any suspect areas.

3.4 Perform leak test on beam tube can section.

****
Reference

See
Helium Mass Spectrometer Hood Test
of Beam Tube Can Sections
Doc ID "HMST1N"
****

3.5 Complete test records for beam tube can section.

3.6 Steps 3.7 thru 3.11 are for repeat Time of Flight testing and repair of beam tube assemblies that have failed previous test. Skip if not applicable to specific beam tube section.

3.7 Perform visual examination noting any suspect areas.

3.8 Perform "Time of Flight" test noting any leak or leaks.

3.9 Perform weld repair using appropriate purge method depending upon area to be repaired.

Repair per specific contract welding procedures.

3.10 Perform leak test on beam tube can section per "Helium Mass Spectrometer Hood Test of Beam Tube Can Sections".

3.11 Complete test records for all repaired beam tube can sections.

3.12 Install end caps.

3.13 Move beam tube can section to post test storage area.

4.0 Beam Tube Can Section Cleaning

4.1 Move beam tube assembly to cleaning area and remove end caps.

****

Note:

Beam tube can sections should be cleaned as required by installation requirements with limited storage time between final cleaning and installation.

****

4.2 Set-up for beam tube assembly cleaning locating movable end clean enclosures at each end of beam tube assembly. Cleaning rack to be sloped to allow drainage from beam tube assembly. Drainage to be towards opposite end from expansion bellows, if applicable.

****

Reference

See
Cleaning of Completed Tube Can Sections
Doc ID "CL1N"
****

4.3 Clean interior of beam tube can section.

4.4 Dry interior of beam tube can section.

4.5 Install cleaned end protection caps and polyethylene bagged double seal.

4.6 Complete cleaning records for beam tube can section.

4.7 Move cleaned and sealed beam tube can section to post clean storage area.

5.0 Referenced Procedures

This fabrication sequence is to be used in conjunction with the following procedures:

5.1 Planned Approach to Leak Testing for LIGO Project
Doc ID "LIGOTP"

5.2 Helium Mass Spectrometer Hood Test of Beam Tube Can Sections
Doc ID "HMST1N"

5.3 Cleaning of Completed Tube Can Sections
Doc ID "CL1N"

5.4 Fitting/Purge Procedure for Circumferential Butt Welds for LIGO
Doc ID "FPCircumferential"

5.5 Welding Procedure Specification for Circumferential Welds
Doc ID "WPS-ER308L/Circumferential"

5.6 Welding Procedure Specification for Pump Port Welds
Doc ID "WPS-ER308L/Port"

5.7 Welding Procedure Specification for Stiffener Welds
Doc ID "WPS-ER308L/Stiffener"

5.8 Welding Procedure Specification for GMA welding of 304L materials
Doc ID "WPS-ER308L/GMA"

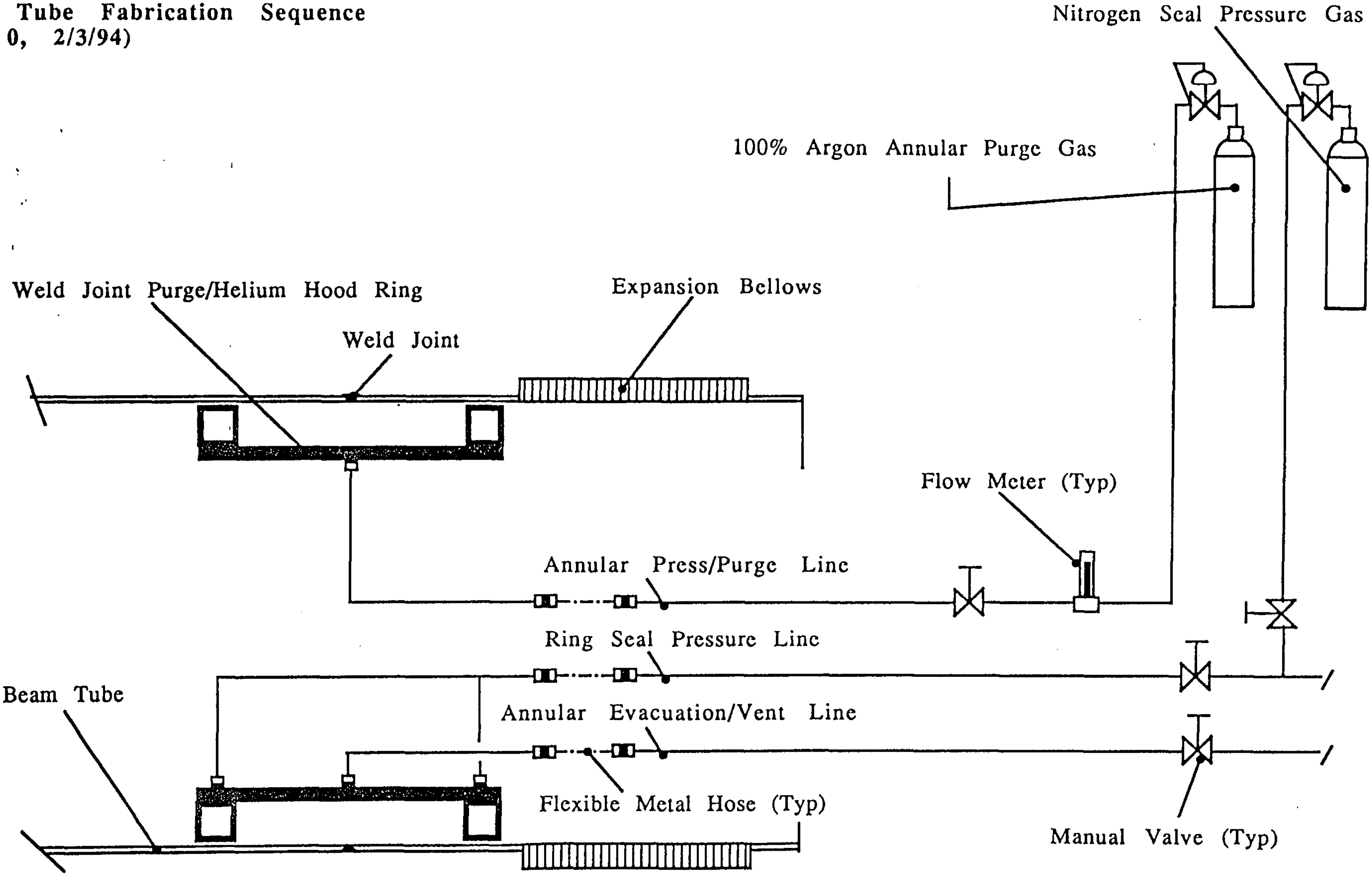
5.9 Welding Procedure Specification for repair welding of 304L materials
Doc ID "WPS-ER308L/REPAIR"

6.0 Sequence Diagram and Sketches

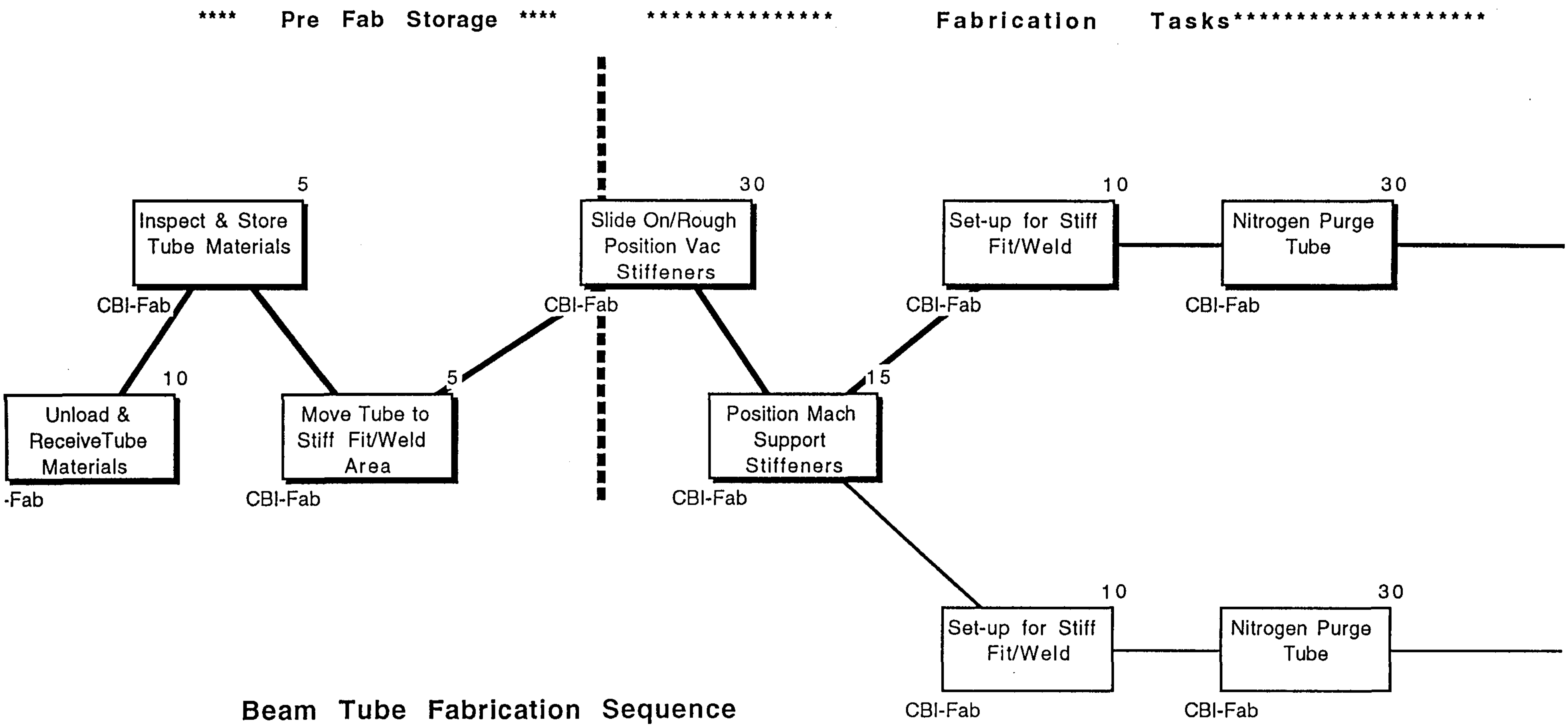
Attached find the following related to this fabrication sequence:

6.1 Weld Joint Purging Arrangement
(Page 12 of 17)

6.2 Beam Tube Fabrication Sequence Logic Diagram
(Page 13 of 17 to Page 17 of 17)



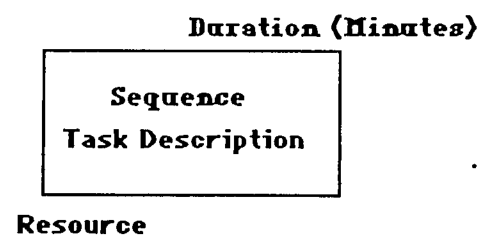
<u>Weld Joint Purging Arrangement</u>



Beam Tube Fabrication Sequence
LIGO

CBI

Hanford, WA & Livinsgston, LA
Rev 0, Jan 20, 1994

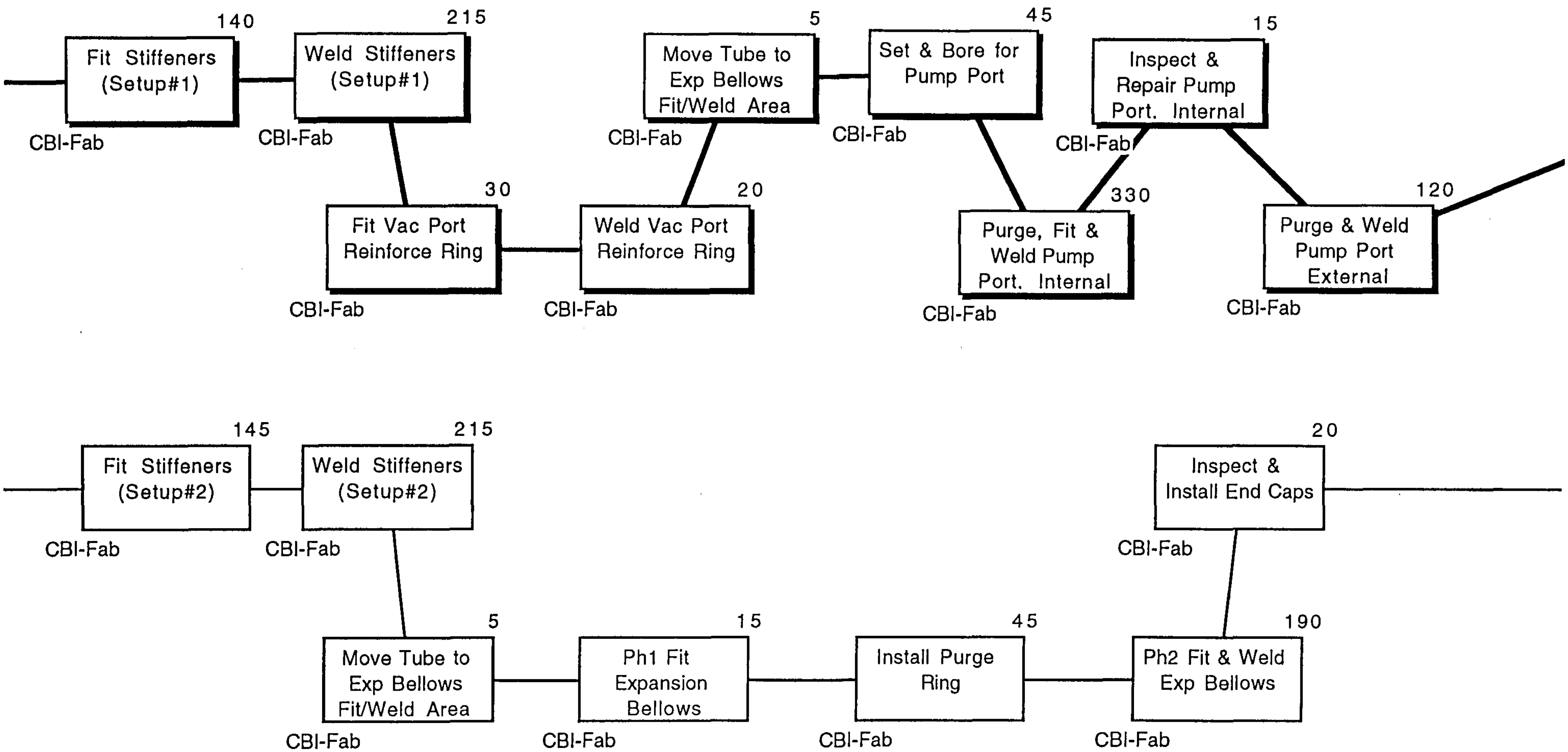


Fabrication Sequence
Legend

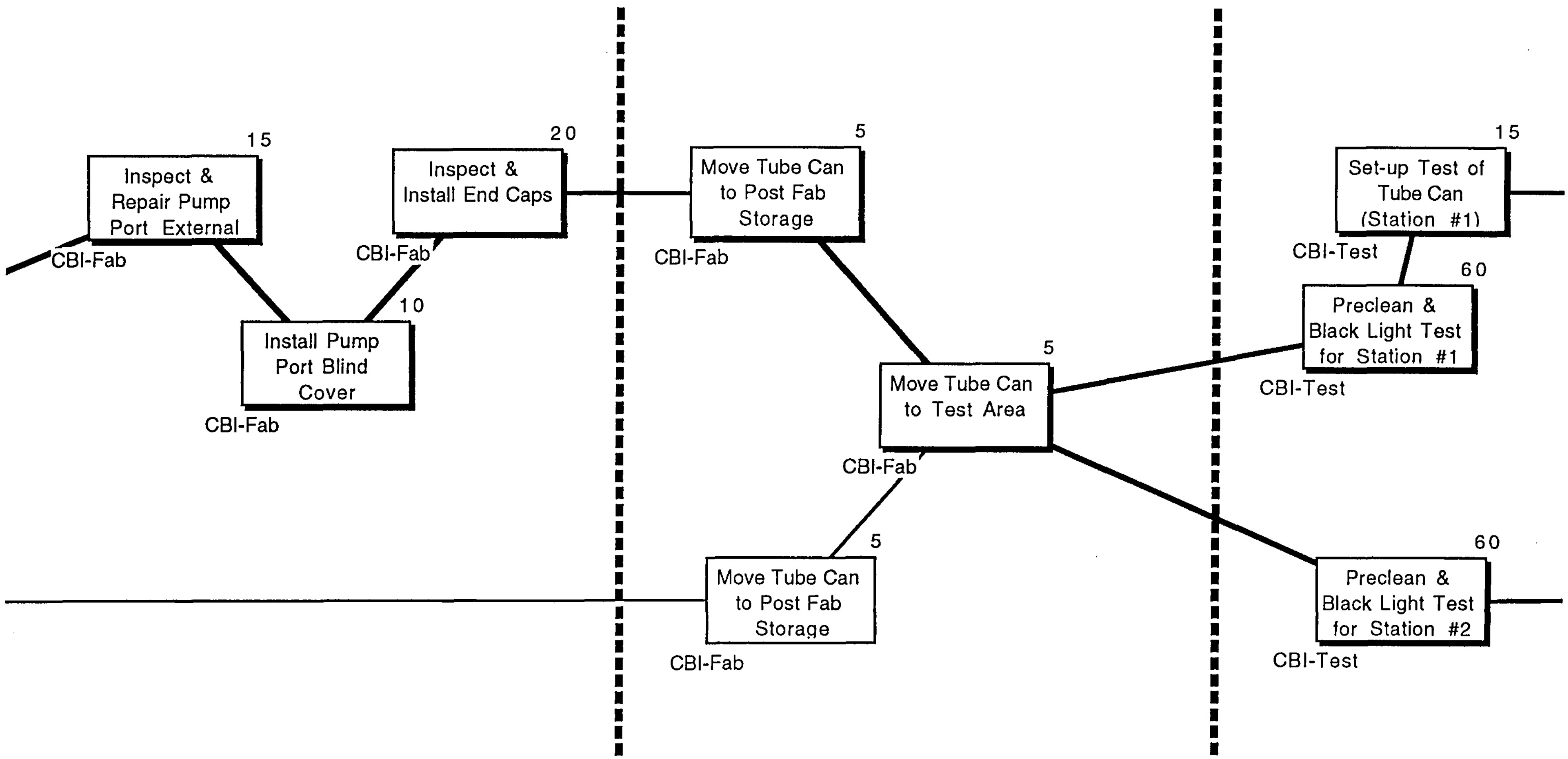
Page 13 of 17

****************************** Fabrication Tasks (Continued)******************************

Estimated Duration of 9 Hr 0 Min With Exp Bellows
Estimated Duration of 6 Hr 25 Min Without Exp Bellows
(Does not include Vacuum Port)

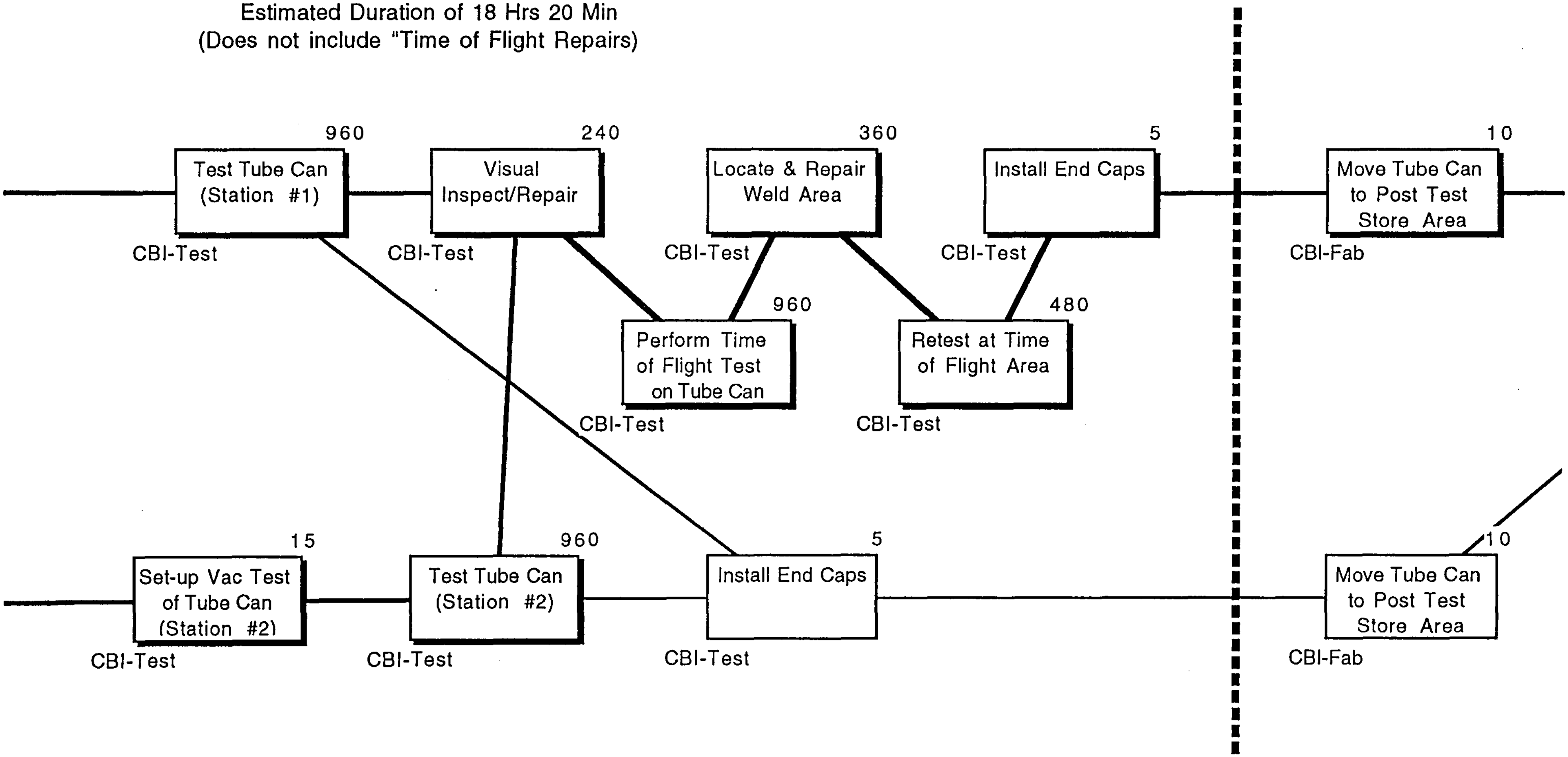


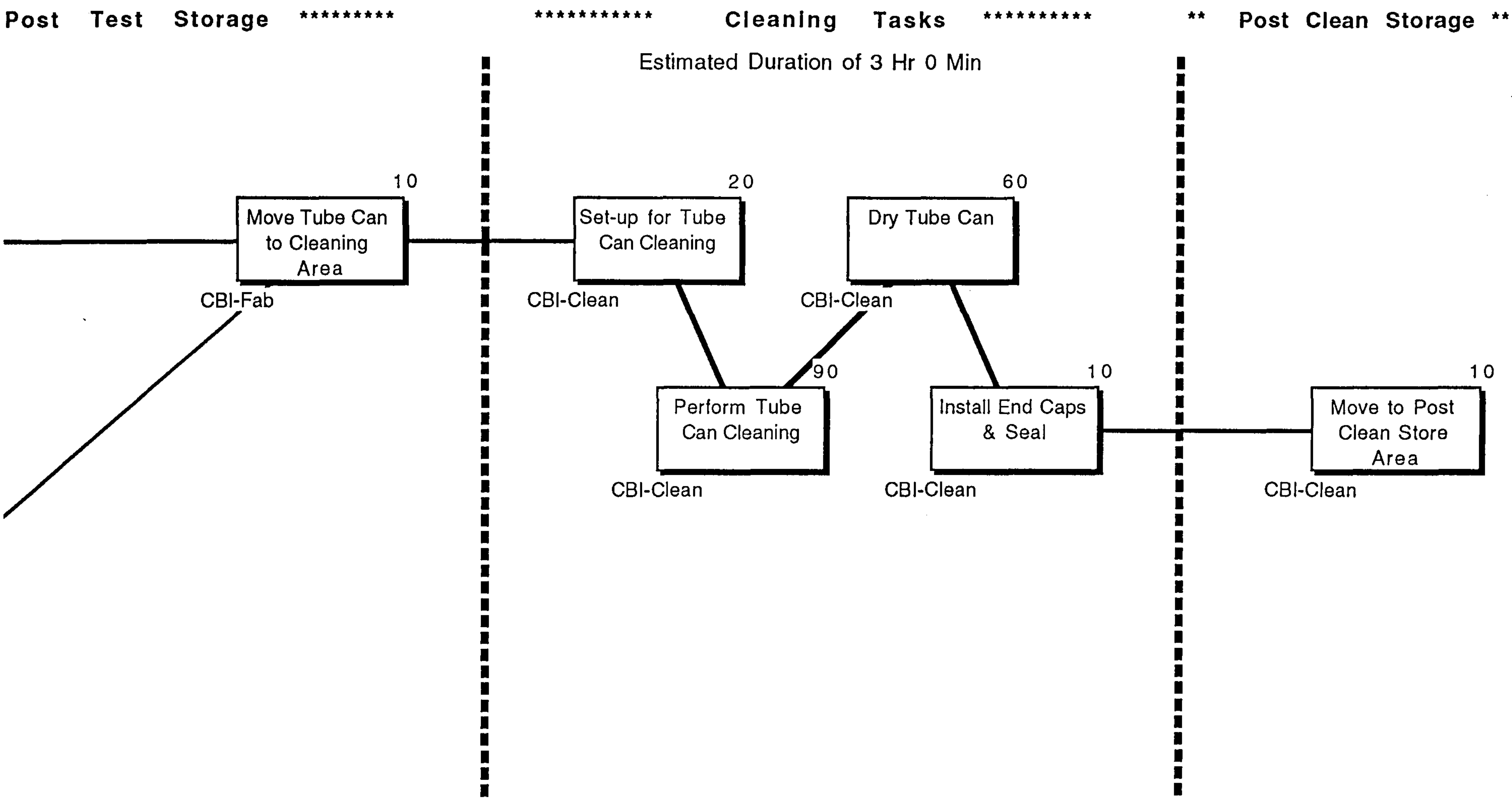
**** Fabrication Tasks (Cont)***** ********* Post Fab Storage ********* ******************



**************** Testing Tasks ********************************* **********

Estimated Duration of 18 Hrs 20 Min
(Does not include "Time of Flight Repairs)




Post Test Storage *********
*********** Cleaning Tasks **********
** Post Clean Storage **
Estimated Duration of 3 Hr 0 Min
10
Move Tube Can to Cleaning Area
CBI-Fab
20
Set-up for Tube Can Cleaning
CBI-Clean
60
Dry Tube Can
CBI-Clean
90
Perform Tube Can Cleaning
CBI-Clean
10
Install End Caps & Seal
CBI-Clean
10
Move to Post Clean Store Area
CBI-Clean

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	GLW	2/1/94
					REVISED	KHF	4/5/94
					AUTHORIZED		
					REFERENCED STANDARD	REV. NO.	

1.0 Scope

This procedure outlines the installation sequences to be followed during the installation of the beam tube can sections.

Detail or supporting procedures for welding, cleaning, testing, alignment, etc. are referenced as required. See paragraph 3.0 for listing.

2.0 Installation Sequence

2.1 Deliver beam tube can section to installation site.

See the "Beam Tube Can Section Fabrication Sequence" procedure (Doc ID "FabSeq") for the specific sequences and procedures that are followed during the fabrication sequence.

The beam tubes are delivered to the installation site in a tested and internally cleaned condition with sealed end caps installed on both ends. The expansion bellows are restrained and blind flanges are installed on pump port nozzles.

Additionally, the previously installed beam tube can sections are maintained under a positive clean air flow.

****

Reference

See
"Positive Blower/Dryer/Filtration System
Installation & Maintenance"
Doc ID "BDF1"

****

2.2 Move or roll clean room and associated equipment forward allowing sufficient room to set beam tube can section into position.

2.3 Set beam tube can section on temporary adjustable supports located clear of the contract structural support areas. Position beam tube can section approximately eight (8) inches from end of previously installed beam tube can section allowing sufficient end clearance to remove the two adjoining end caps.

2.4 Move or roll weld enclosure over open joint.

2.5 Remove end caps and seal protection at weld joint to be made and position beam tube can section to existing beam tube can section. Do not remove the internal tube access plug from the previously installed beam tube can section.

2.6 Start aligning weld joint using special CBI fitup clamp. See drawing ER45 for details of the fitup clamp.

****

Warning

Do not perform any welding or tacking at this time.

****

Reference

See "Fitting/Purge Procedure for Circumferential Butt Welds for LIGO" Doc ID "FPCircumferential"

****

2.7 Align beam tube can section centerline and elevation to the previously installed alignment reference pads.

****

Reference

See
"Initial and Final Alignment During
Installation of LIGO Beam
Tube Modules using GPS System"
Doc ID "ALI-1"

****

2.8 Remove polyethylene secondary seal from end of beam tube can section at clean room end.

2.9 Move or roll clean room into position at beam tube can section end and make seal connections to beam tube end.

****

Reference

See
"Clean Room Transporting,
Storage and Maintenance Instructions"
Doc ID"CR1TSM"
for specific safety precautions and
procedures to be adhered to within
the clean room and beam tube.

****

2.10 Remove end cap from end of beam tube can section now inside clean room.

2.11 Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry.

2.12 Install weld joint purge/helium hood ring, centered on weld joint, and connect 3/8" diameter stainless steel purge/evacuation lines listed below:

a) Annular space evacuation/vent line (weld purge gas and helium test gas).

b) Inflatable seal pressure line (nitrogen ring seal gas).

c) Annular space pressure/purge line (weld purge gas and helium test gas).

See weld joint purging/helium hood arrangement on page 10 of 13 of this installation sequence.

2.13 Inflate purge/helium hood ring outer seals by opening valve on nitrogen inflatable seal gas supply holding weld joint purge/helium hood ring in position centered on the beam tube weld joint to be welded. Regulator should be set at 5 psig.

2.14 Open evacuation line valve and annular space pressure line valve allowing 100% Argon backing purge gas to purge annular space. Purge until oxygen level is less than 1.0% oxygen. End point to be verified with oxygen analyzer. Upon reaching 1.0% oxygen, establish Argon flow rate at a minimum value (light positive flow) to maintain less than 1.0% oxygen.

****

Warning

Welding or tack welding at weld joint to be only performed after completion of the above weld purge.

****

2.15 Complete fit up of weld joint. Tack welding is allowed at this step.

****

Reference

See
"Welding Procedure Specification
for Circumferential Welds"
Doc ID "WPS-ER308L/Circ".
****

2.16 Set up and position automatic weld equipment and complete welding of beam tube weld joint.

****

Reference

See
"Welding Procedure Specification
for Circumferential Welds"
Doc ID "WPS-ER308L/Circ".
****

2.17 Visually inspect closing weld joint.

2.18 Shut valve on annular space pressure/purge line from 100% Argon weld purge gas.

2.19 Shut valve on annular space evacuation line.

2.20 Evacuate annular space using vacuum pump to 29.9" Hg.

2.21 Immediately close vacuum pump valve and open valve to helium test gas. Flow helium for 5 mins at flow rate of 100 cfh (approximately four volumes or until the helium gas returns the annular space to atmospheric pressure) Then reduce flow maintaining helium test gas flow at 10-15 cfh (light positive flow) or just enough to maintain a positive outward flow of helium at the inflated seals.

2.22 Move or roll weld enclosure forward a minimum of 10 feet.

2.23 Move test enclosure forward and position over just completed beam tube weld joint.

2.24 Install helium mass spectrometer vacuum cover and test beam tube weld joint.

****

Reference

See
"Helium Mass Spectrometer Hood Testing
of Closing Weld Joints Between Beam
Tube Can Sections"
Doc ID "HMST2N"

****

2.25 If leak is detected, vent, repair and retest in accordance with the applicable steps of procedure HMST2N.

2.26 Remove helium mass spectrometer vacuum cover from weld joint exterior.

2.27 Shut helium test gas and nitrogen ring seal gas supply.

2.28 Open purge/helium hood ring outer seal vent valve.

2.29 Close both evacuation valves associated with annular space evacuation line and purge ring outer seals after venting stops and weld joint purge ring has slackened.

2.30 Disconnect and remove the three (3) 3/8" diameter stainless steel purge/evacuation lines.

2.31 Remove weld joint inflatable purge/helium hood ring.

2.32 Steps 2.33 thru 2.35 are for installation and testing of valve at the pump port. Skip if not applicable to specific beam tube can section.

2.33 Locally clean area associated with pump port.

2.34 Remove pump port blind flange and install valve with blind flange.

****

Reference

See
"Helium Mass Spectrometer Hood Test
of Valve and Blind Flange Seals
to Pump Ports"
Doc ID "HMST3N"

****

2.35 Perform helium mass spectrometer test of installed valve and blind flange.

2.36 Remove tube access plug from end of previously installed beam tube.

2.37 Inspect and clean beam tube interior as workman "backs out" of beam tube from completed weld joint.

****

Reference

See
"Final Cleaning and Inspection of
Internal Surfaces Including Baffles"
Doc ID "CL3N"

****

Also during "back out" step install internal baffles as required per contract drawings for the respective beam tube.

2.38 Perform dimensional check information and complete records on beam tube can sections at support locations and installed baffles.

2.39 Install tube access plug 8" from clean room end of just installed beam tube immediately upon completion of cleaning, baffle installation and exit from clean room end of beam tube.

2.40 Install clean room end cap and secure in position with band.

2.41 At this point installation is complete and next beam tube installation may be started.

****

Note

Do not move clean room from end of installed beam tube until just prior to installation of next beam tube.

****

2.42 Install contract structural support on proceeding beam tube section after rolling equipment has been moved forward of structural support point.

2.43 Remove the temporary adjustable supports.

2.44 Remove expansion bellows restraints (if applicable) after contract structural supports have been installed and prior to verification of alignment using the preliminary alignment pads.

2.45 Grout contract structural supports. Grouting can be left until a number of supports can be grouted at one time.

3.0 Referenced Procedures and Specifications

This installation sequence is to be used in conjunction with the following procedures and/or specifications:

3.1 Blower-Dryer Filtration System Operation and Maintenance
Doc ID "BDF1"

3.2 Initial and Final Alignment During Construction and Installation of Beam Tube Modules using GPS System
Doc ID "ALI-1"

3.3 Planned Approach to Leak Testing for LIGO Project
Doc ID "LIGOTP"

3.4 Helium Mass Spectrometer Hood Test of Closing Weld Joints Between Beam Tube Cans
Doc ID "HMST2N"

3.5 Helium Mass Spectrometer Hood Test of Valve and Blind Flange Seals to Pump Ports
Doc ID "HMST3N"

3.6 Cleanroom Transporting, Storage and Maintenance
Doc ID "CR1TSM"

3.7 Final Cleaning and Inspection of Internal Surfaces Including Baffles
Doc ID "CL3N"

3.8 Fitting/Purge Procedure for Circumferential Butt Welds for LIGO
Doc ID "FPCirc"

3.9 Welding Procedure Specification for Circumferential Welds
Doc ID "WPS-ER308L/Circ"

4.0 <u>Sequence Diagram and Sketches</u>

Attached find the following related to this installation sequence:

4.1 Weld Joint Purging/Hood Arrangement.
(Page 10 of 13)

4.2 Beam Tube Installation Sequence Logic Diagram
(Page 11 of 13 to Page 13 of 13)

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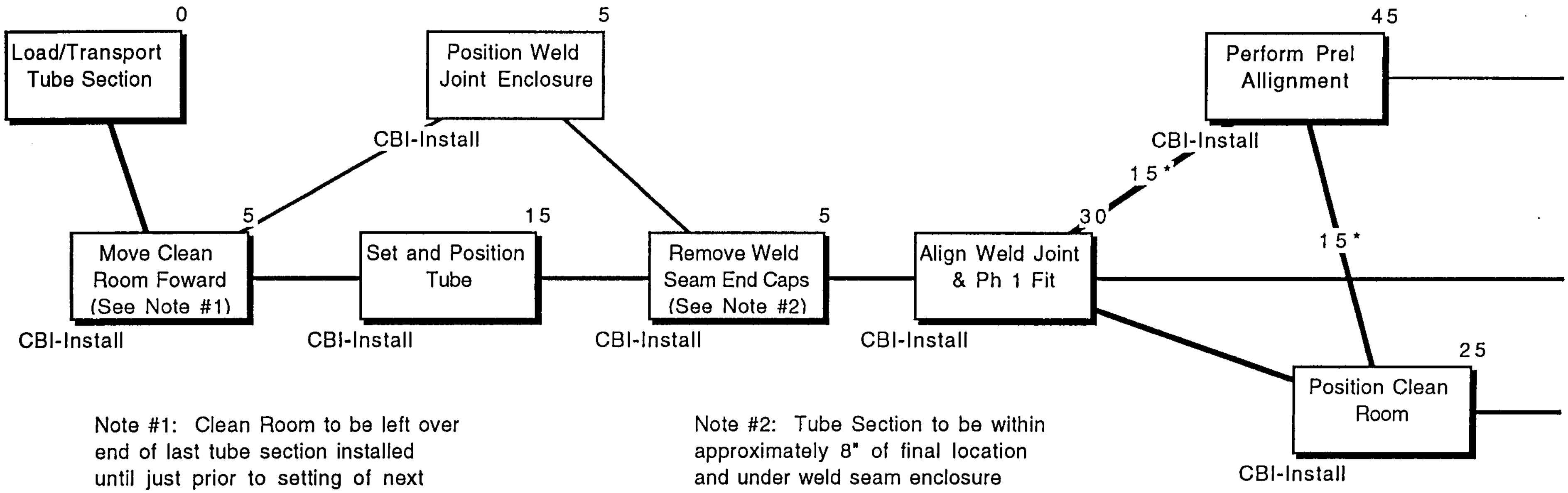


Note #1: Clean Room to be left over end of last tube section installed until just prior to setting of next tube section.

Note #2: Tube Section to be within approximately 8" of final location and under weld seam enclosure prior to removal of end caps.

Beam Tube Can Section Installation Sequence
LIGO

CBI

Hanford, WA & Livinsgston, LA
Rev 0, Jan 18, 1994

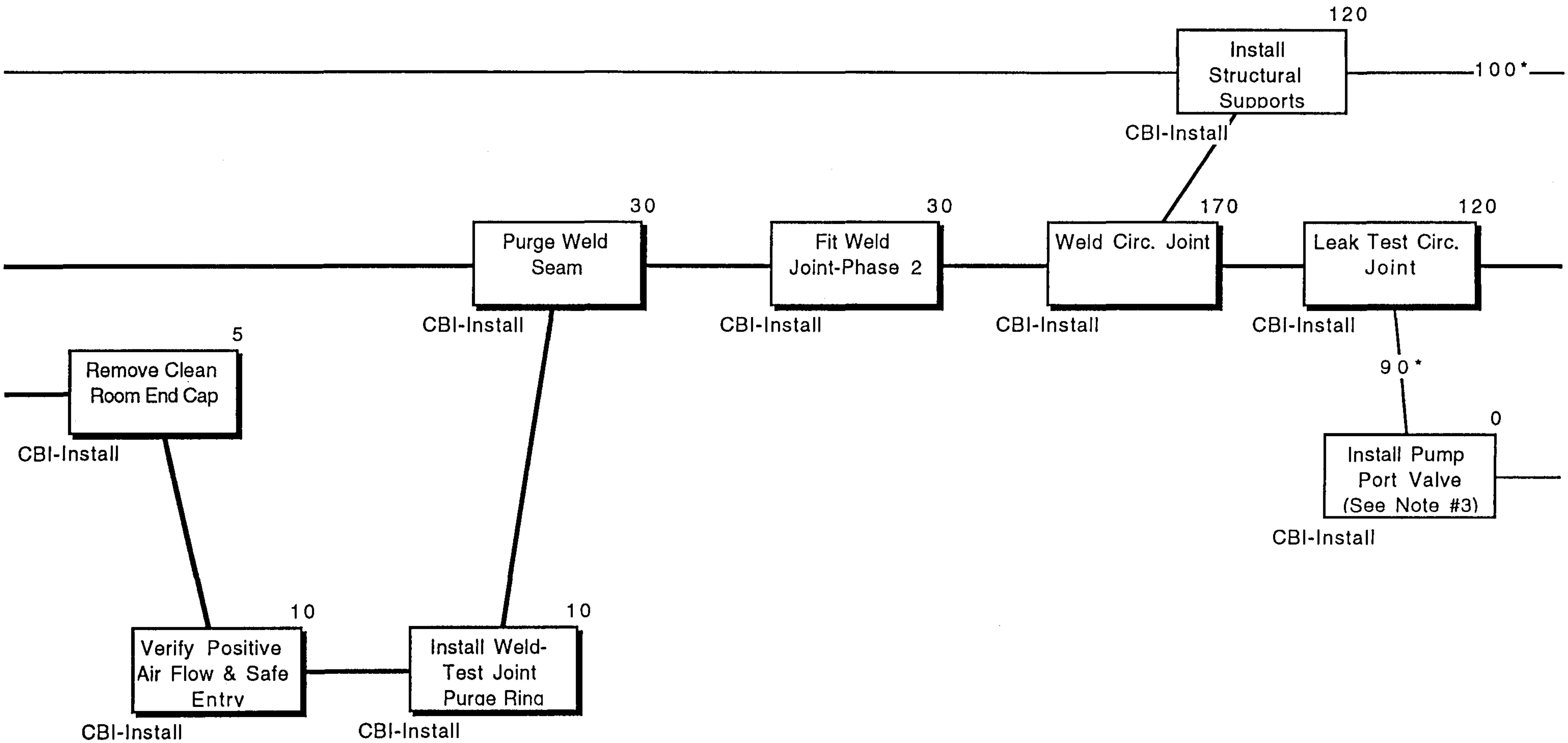
Duration (Minutes)

Sequence
Task Description

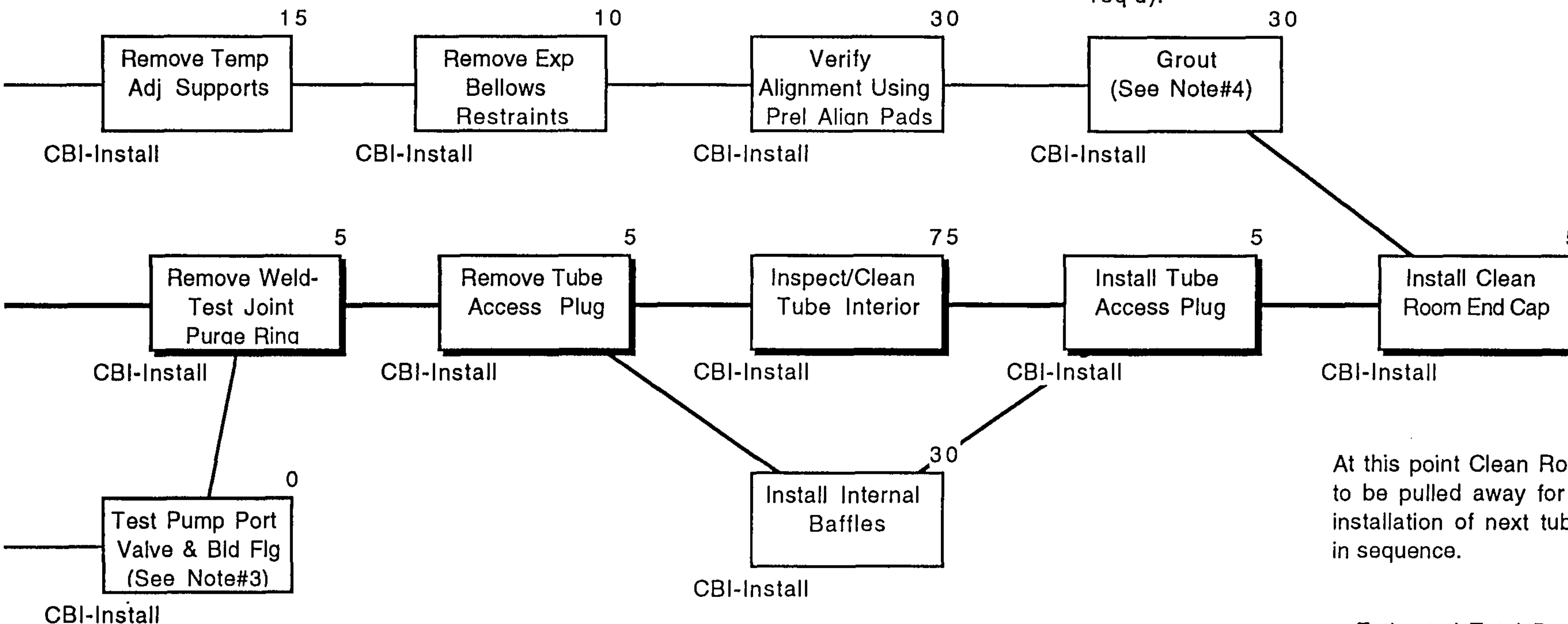
Resource

Installation Sequence Legend

Page 11 of 13


120
Install Structural Supports
100*
CBI-Install
30
Purge Weld Seam
CBI-Install
30
Fit Weld Joint-Phase 2
CBI-Install
170
Weld Circ. Joint
CBI-Install
120
Leak Test Circ. Joint
CBI-Install
90*
0
Install Pump Port Valve (See Note #3)
CBI-Install
5
Remove Clean Room End Cap
CBI-Install
10
Verify Positive Air Flow & Safe Entry
CBI-Install
10
Install Weld-Test Joint Purge Ring
CBI-Install

Note #4: Grouting May Be Performed In Groups Prior to Cover Installation (if grouting req'd).



At this point Clean Room is ready to be pulled away for starting installation of next tube section in sequence.

Estimated Total Duration is 7 hours 50 minutes

Note #3: Installation Tasks as Required. Duration for Pump Port Valve Installation and Test Not Shown for Typical Sequence Presented.

DOC. ID	FPCIRCUMFERENTIAL
REV. NO.	2
CONTRACT	930212

TITLE FITTING / PURGE PROCEDURE FOR CIRCUMFERENTIAL BUTT WELDS FOR LIGO.

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	RWP	1/24/94
					REVISED	RWP	3/11/94
					AUTHORIZED	BGG	1/31/94
					REFERENCED STANDARD	REV. NO.	

1.0 PURPOSE:

This procedure is to be used in conjunction with WPS-ER308L /CIRC. It is to be used for the welding of butt joints between expansion joints-to-tube and for tube-to-tube.

2.0 LIST OF EQUIPMENT:

2.1 Weld joint inflatable purge/helium hood ring device.

2.2 Fitting device.

3.0 PURGING:

3.1 Place fitting device on one end of tube, in the case of tube-to-expansion joint, the device shall be placed on the tube end.

3.2 Round out tube end by turning the adjusting screws.

3.3 Place other tube, or expansion joint, into clamp and tighten using adjusting screws.

3.4 Adjust screws to rough align the weld joint and tape the outside of the weld joint.

3.5 Install weld joint inflatable purge/helium hood ring on inside of tube centered over the weld joint.

3.6 Inflate purge ring outer seals with nitrogen. Regulator should be set at 5 psig.

3.7 Open evacuation line valve and annular space pressure line valve allowing 100% argon purge gas to purge annular space. Purge until oxygen level is less than 1.0%.

3.8 Reduce flow rate into purge area to a minimum level to maintain adequate purge, less than 1.0% oxygen.

4.0 FITTING:

4.1 Adjust screws for flush outside fit with a maximum allowable offset of 1/16".

4.2 The gap shall not exceed 0.010". If the gap is greater than the allowable 0.010", the tubes may be pulled together by means of a turnbuckle.

4.3 All tacking shall be done by the manual GTAW process without the use of filler metal spaced approximately every 4 to 5 inches. Small "button" tacks shall be used with a diameter no larger than 1/8".

4.4 When the offset and gap are acceptable, tack the joint and replace the tape to help keep adequate purge.

5.0 WELDING:

5.1 Mount 56" diameter welding track exactly 10" from the weld joint. Take extra care to assure the track is parallel to the weld joint.

5.2 Place the welding unit on the track and check to see that all cables are in place. (See the Operators Manual for instructions)

5.3 Weld the joint using WPS-ER308L/CIRC. removing the tape ahead of the welding arc.

6.0 VISUAL INSPECTION:

6.1 Perform a visual inspection of the circumferential joint. If there are to be any welded repairs, use WPS-ER308L/REPAIR.

6.2 Repeat step 6.1 above until no welded repairs are required.

6.3 Shut valve on annular space pressure/purge line to 100% argon purge gas.

6.4 If during field installation, proceed with procedure HMST2N.

Steps 6.5 through 6.7 are for fabrication of tube sub-modules only.

6.5 Shut nitrogen ring seal gas supply valve.

6.6 Open purge ring outer seal vent valve.

6.7 Remove weld joint purge unit, welding unit and welding track.

DOC. ID	FPSTIFFENER
REV. NO.	2
CONTRACT	930212

TITLE FITTING / PURGE PROCEDURE FOR STIFFENER ATTACHMENT WELDS FOR LIGO.

Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	RWP	1/25/94
REVISED	RWP	3/11/94
AUTHORIZED	BGG	1/31/94
REFERENCED STANDARD	REV. NO.	

1.0 PURPOSE:

This procedure is to be used in conjunction with WPS - ER308L / STIFFENER. It is to be used for the fitting / purging and welding of the vacuum stiffeners and support stiffeners to the spiral welded tube.

2.0 STIFFENER PLACEMENT:

2.1 Tube shall be marked for stiffener location per contract drawings.

2.2 Vacuum stiffeners may be "locked" open using stiffener fitting device. The vacuum stiffeners shall be placed in their approximate location prior to end seals.

2.3 Support stiffeners shall be bolted together in position per contract drawings. Verify that the correct support stiffener is used for the specific tube section.

3.0 PURGING:

3.1 Headstock and tailstock shall be placed in position.

3.2 Outlet valve to tube assembly should be open. Nitrogen shall be pumped into inlet valve, using a liquid nitrogen dewar with vaporizer, until the oxygen level within the tube falls below 1.0%.

3.3 When the oxygen level falls below 1.0%, reduce the flow of nitrogen to a minimum flow rate necessary to maintain less than 1.0% oxygen. Check periodically during any tacking and welding operation.

4.0 FITTING STIFFENERS:

4.1 Pull the splice together of the vacuum stiffeners by cranking the fitting device making sure the stiffener is in the proper location. The vacuum stiffener may vary by +/- 1/2" from the design location. The splice of the stiffener shall be positioned over the spiral weld with the lap of the splice positioned to minimize the length of unwelded stiffener.

4.2 All tacking shall be done by the semi-automatic GMAW process using ER308L spaced approximately every 18". The tacks shall be on the opposite side of welding and shall be a minimum of 1/2" in length with all craters backfilled.

4.3 Tack the vacuum stiffener, tightening the fitting device if necessary.

4.4 After the vacuum stiffener is tacked, equally spaced approximately every 18", weld a 3/16" fillet on both sides of the lap leaving 1/4" not welded against the tube wall.

4.5 A minimum of 1" shall be welded across the top of the splice.

4.6 Repeat steps 4.1 through 4.5 for all the remaining vacuum stiffeners.

4.7 For the support stiffeners, tack as in step 4.2 above at approximately 18" intervals.

5.0 WELDING:

5.1 Weld the stiffeners using WPS-ER308L/STIFFENER. The weld shall start at the splice continuing around the tube ending at the opposite side of the splice. For the support stiffeners, an extra start/stop must be made at the second splice.

5.2 No welding over the spiral weld shall exist. Care must be taken to minimize the length of unwelded stiffener.

5.3 The maxiumum tilt angle of the welded stiffener shall not exceed six (6) degrees.

5.4 Repeat steps 5.1 and 5.2 for all remaining stiffeners.

5.5 If a pump port is to be installed in this stiffened tube section, proceed to step 7.0.

6.0 <u>VISUAL INSPECTION:</u>

6.1 Perform a visual inspection of the stiffener welds. If there are to be any welded repairs use WPS-ER308L/REPAIR.

6.2 Repeat step 6.1 above until no welded repairs are required.

6.3 When the welding of the stiffened tube is complete, vent the tube and remove headstock and tailstock.

7.0 <u>PUMP PORT REINFORCING RING:</u>

7.1 Position reinforcing ring at design location verifing before fitting that the ring does not cross any spiral weld. Rotate tube as necessary to avoid the spiral weld.

7.2 Fit ring using tacks where necessary.

7.3 Weld reinforcing ring per WPS-ER308L/PORT. Continue with step 6.0 above.

Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
					PREPARED	RWP	1/25/94
					REVISED	RWP	3/11/94
					AUTHORIZED	BGG	1/31/94
					REFERENCED STANDARD	REV. NO.	

1.0 PURPOSE:

This procedure is to be used in conjunction with WPS-ER308L/PORT. It is to be used for the fitting / purging and welding of the pump port fittings to the stiffened spiral welded tube.

2.0 LIST OF EQUIPMENT:

2.1 Pump port fitting device.

2.2 External purging unit.

2.3 Jack/purge device.

2.4 Internal purge diaphragm.

3.0 JACKING:

3.1 The jack/purge device shall be placed within the tube at the design location and jacked out to apply outward pressure with the jack screw.

4.0 DRILLING:

4.1 The tube shall be rotated so the place to be drilled is on the bottom of the tube.

4.2 Drill the hole and clean/prepare the weld edges.

5.0 FITTING:

5.1 Install fitting device to jack / purge device.

5.2 Place and level pump port in location by tightening screw clamps on fitting device.

5.3 Tack on the inside of the joint using small autogenous "button" tacks no larger than 1/8" in diameter with a hand held back purge of 100% argon.

5.4 No gap shall exceed 0.010" and mismatch shall be no greater than +/- 1/32".

5.5 Tacks shall be space approximately every 4 to 5". Remove fitting device from jack/purge device.

6.0 WELDING:

6.1 After the pump port is tack welded in position, place the external purge unit on the outside of the joint.

6.2 Purge with 100% argon until the oxygen level falls below 1.0%.

6.3 Weld the inside pass of the pump port per WPS-ER308L/PORT.

6.4 Remove external purge unit and perform a visual inspection of the outside of the weld joint. The outside of the port must have a smooth contour with no linear indications.

6.5 All repairs shall have a purge on the outside. Make repairs using WPS-ER308L/REPAIR and repeat step 6.4.

6.6 Insert internal purge diaphragm. Purge internal area with 100% argon until the oxygen level falls below 1.0%.

6.7 Weld the two outside passes using WPS-ER308L/PORT.

7.0 FINAL INSPECTION:

7.1 Perform a visual inspection of pump port welds. If there are to be any welded repairs, purge the appropriate side and repair using WPS-ER308L/REPAIR.

7.2 Repeat step 7.1 above until no welded repairs are required.

7.3 Remove purge units and jack / purge device from within the tube.

CBI

DOC ID	CR1TSM
REV. NO.	1
CONTRACT	930212

TITLE:	CLEAN ROOM TRANSPORTING, STORAGE AND MAINTENANCE PROCEDURE - CALTECH	PAGE NO. 1 OF 21

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH 06-	Nov-93
					REVISED	0	
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO.

1.0 SCOPE:

1.1 This procedure covers the activities associated with clean room operations.

1.2 The following activities are described in this procedure:

1.2.1 Transportation of the clean room modules

1.2.2 Storage of clean room modules at site.

1.2.3 Maintenance Procedures for clean room equipment.

2.0 REFERENCES:

2.1 The construction and operation of the clean room is based on the following references:

2.1.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.

2.1.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.

2.1.3 CBI Cleaning Procedure CL1N

3.0 EQUIPMENT:

3.1 Equipment referenced in other CBI procedures will be incorporated into this procedure. For specific items, see applicable references.

3.2 Equipment specific to the clean room are listed as systems or assemblies below.

3.2.1 Clean Room Module & Transporting Trucks
3.2.2 Rolling frame and Track Assembly
3.2.3 HVAC System
3.2.4 Exhaust System
3.2.5 Storage and Shelving Equipment
3.2.6 Safety Systems
3.2.7 Electrical & Lighting System
3.2.8 Purge Gas Manifold and Rack System
3.2.9 Inflatable & Secondary Sealing System

4.0 Storage of Clean Room Module:

4.1 The clean room shall be received from the manufacturer in a "conference room" cleaned condition.

4.1.1 All interior surfaces shall be wiped down with an approved cleaning agent.

4.1.2 A Cover shall be placed over the tube penetration opening and sealed with a gasket material to prevent any leakage into the building.

4.1.3 All Motorized dampers shall be closed on HVAC and Exhaust ducts.

4.1.4 All Doors and windows shall be locked before transportation and/or storage.

4.2 Short term storage shall shall comply with all activities noted per 4.1.

4.3 Long term storage shall comply with all activities in 4.1 and include the following:

4.3.1 Remove all materials from inside the building.

4.3.2 Remove battery powered emergency lighting equipment from the building.

4.3.3 Seal HVAC and Exhaust vents with taped covers.

4.3.4 Remove outside lighting and electrical equipment, ie:, cords, receptacles, etc. and store inside entry way of change room door.

5.0 Transportation of Clean Room Module:

Clean Room transportation ~~is~~ is broken down into three activities. The first is loading and unloading from the container truck. Second, is during construction activities when removed from a completed Beam tube section and towed away using the tow vehicle. The third type of transportation is from the rolling frame to another area or site.

5.1 During loading and unloading activities associated with installation and removal of the Clean Room, all safety precautions and National, State, and Local requirements shall be met.

5.1.1 Remove from container truck and mount clean room module onto rolling frame. The frame is equipped with 8"Ø 45° Vee groove wheels and moves on an angle frame turned on support plates. See attached detail.

5.1.2 Install bottle racks and step assemblies to rolling frame.

5.1.3 The tow vehicle shall be connected to the clean room module with a bar sized for towing and breaking forces.

5.2 The Clean Room will be moved using a tow vehicle along a track system during construction activities at site.

5.2.1 The inside "screen door" at the tube opening shall be secured in the closed position with a Plexiglass cover in place.

5.2.2 The inflatable seal shall be de-pressurized and locked in a negative pressure with the air valve.

5.2.3 Inspect all bottles in the rack to assure they are properly chained in place.

5.2.4 Inspect and secure all loose items in the Clean Room Container.

5.2.5 Disconnect the power cord from the generator and coil it inside the clean room entry way.

5.2.6 Remove any braking effect used to secure clean room into position.

5.2.7 The clean room shall be vacated during the moving and positioning activities.

The clean room shall be transportable from one area or site to another. This is accomplished by a container trailer.

5.3.1 Remove bottle racks from rolling frame.

5.3.2 Remove steps assemblies from rolling frame.

5.3.3 Lift the clean room module from the rolling frame and install on container truck.

5.3.4 Secure all equipment inside the building before moving.

5.3.5 Clean all surfaces of the room and lock and seal doors for transportation.

5.3.6 For transporting over public roadways, obtain all required permits and licenses.

6.0 Maintenance Clean Room Module:

6.1 The maintenance of the clean room is broken down into the following categories:

6.1.1 Cleaning and janitorial functions

6.1.2 HVAC and Exhaust System Preventative Maintenance, troubleshooting and Repair

6.1.3 Bag Type filter maintenance and replacements

6.1.4 Roller Frame and wheel maintenance.

6.1.5 Purge gas System maintenance

6.1.6 Compressed air system Maintenance

6.1.7 Electrical and Control Maintenance

6.1.8 Safety Equipment Inspection and Maintenance

6.2 Cleaning and janitorial functions shall be performed at the end of each shift. These include the following tasks:

- 6.2.1 Wipe down all surfaces including walls, storage bins, hoses, tools, etc., in the controlled area with an approved cleaning agent and lint free cloths or paper towels.
- 6.2.2 Return all solvents to their containers for proper storage and dispose of all wiping cloths and/or paper towels.
- 6.2.3 Wipe down all tables and inspection surfaces in the cleaning and inspection area.
- 6.2.4 Perform general cleaning, sweep and mop change room and storage room floors.
- 6.2.5 Re-stock all inventories and remove all soiled clothing from clean room module.
- 6.2.6 Remove all soiled wiping cloths and paper towels from the clean room module.

6.3 Perform periodic maintenance on clean room module HVAC systems. These include but are not limited to the following. See equipment manufacturer's O&M Manual for greater detail.

- 6.3.1 Perform air balance tests and adjustments each 20 days of clean room use.
- 6.3.2 Lubricate all equipment bearings, bushings and linkages each 20 days of clean room use. Do not over lubricate.
- 6.3.3 Perform electrical inspections for loose connections, electrical load, etc. each 20 days of operation.

6.4 The following is a listing of filter requirements for the clean room module Bag Type and Pre-filter maintenance.

- 6.4.1 Pre-filters will be inspected each day and replaced when an estimated 50% blockage is noted. This will be determined by a method of holding the filter to a light and comparing it to a clean filter.

6.4.2 Bag Type filters will be replaced when the pressure drop between the up and down stream Bag Type filter reaches 1.0" or greater.

6.5 Roller Frame inspection and maintenance is to be conducted each week. These activities include but are not limited to the following:

6.5.1 Inspect the frame for any damage due to handling, corrosion, etc. Repair and paint areas as required.

6.5.2 Inspect alignment of all wheels on the track assembly. Check wheel grooves for foreign material and clean as required.

6.5.3 Lubricate wheel axles as required. Do not over lubricate. Wipe any excess noted.

6.6 Inspect purge and test gas systems, bottle racks, handling equipment, etc.

6.6.1 Calibrate all gages every six(6) months.

6.6.2 Leak test by means of solution film testing of each joint on a periodic basis.

6.6.3 Inspect all hoses for leaks and breaks in the stainless steel braid on a DAILY basis. Replace as required.

6.6.4 Inspect chains and guards on the bottle racks for damage periodically. Repair as required.

6.8 Electrical and control systems include the electrical distribution system, lighting and HVAC control system. These item will require minimum inspection and maintenance but not be limited to the following.

6.8.1 Perform an initial load test on each circuit and record on log sheet.

6.8.2 Inspect all connections for heat and corrosion each 30 days of operation.

6.8.3 Test all indicating lights, alarms, and calibrate all gages each 6 mo. of operation.

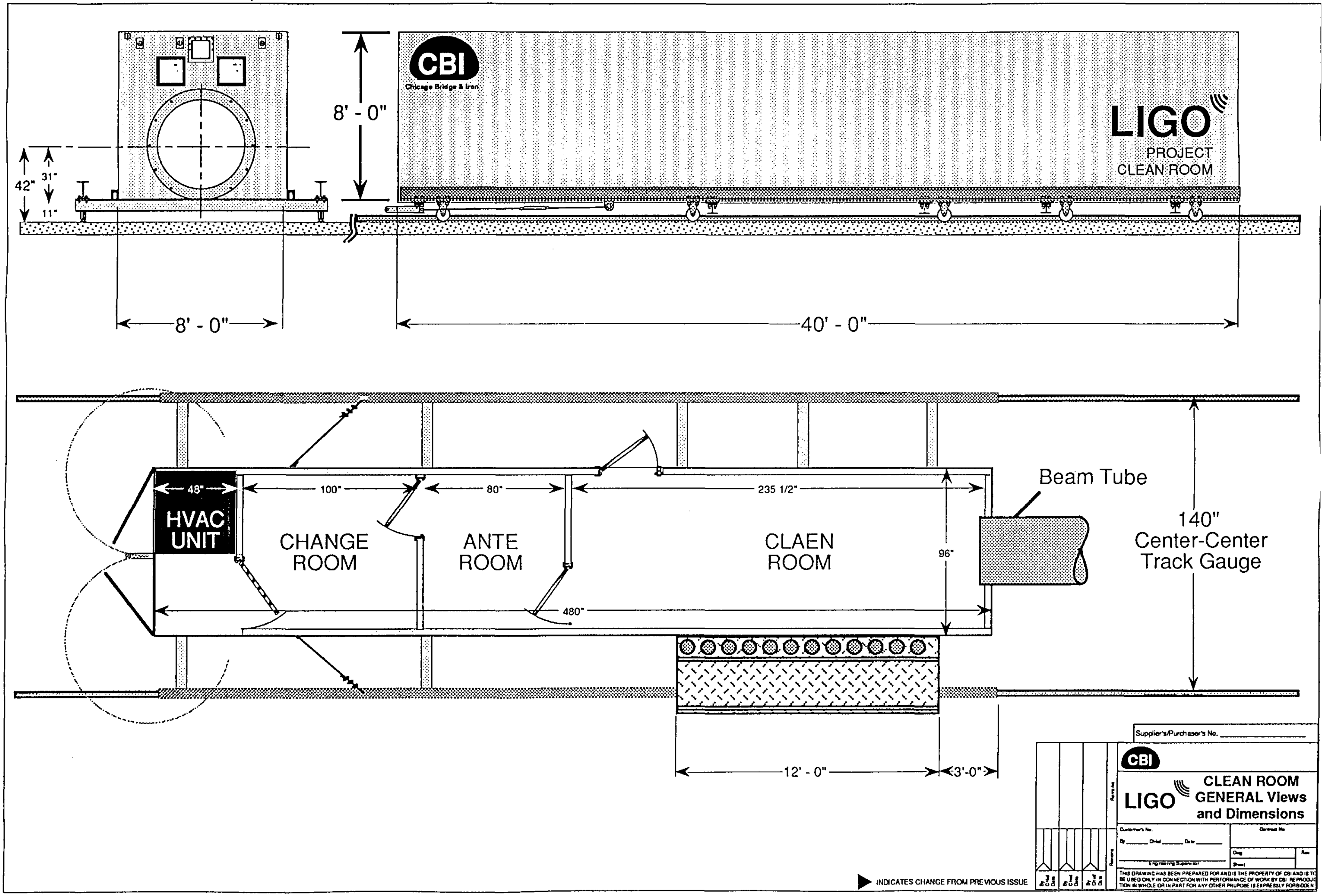
6.9 Safety Systems shall be tested each day. These systems consist of the following:

- 6.9.1 Fire alarms shall be tested. Replace batteries each 30 days of operation or per the manufacturer's instructions(which ever is less).
- 6.9.2 Test emergency lighting/exit system. Replace batteries as suggested by the manufacturer.

7.0 Outline Drawings

The following is a listing of Clean Room Outline drawings.

Sketch 01	General Views and Dimensions
Sketch 02	Equipment Plan View and Listing
Sketch 03	Lower Framing Framing Plan
Sketch 04	Upper and Ceiling Framing Plan
Sketch 05	Bulkhead Elevations
Sketch 06	Electrical Power Plan
Sketch 07	Emergency Equipment Plan
Sketch 08	Electrical Lighting Plan
Sketch 09	Electrical Receptacle Plan
Sketch 10	Inflatable Seal System 1 of 2
Sketch 11	Inflatable Seal System 2 of 2
Sketch 12	Rolling Frame Plan View
Sketch 13	Rolling Frame Track Assembly
Sketch 14	Bottle Rack Details


CBI
Chicago Bridge & Iron
LIGO
PROJECT
CLEAN ROOM
8' - 0"
42"
31"
11"
8' - 0"
40' - 0"
48"
HVAC
UNIT
100"
CHANGE
ROOM
80"
ANTE
ROOM
235 1/2"
CLAEN
ROOM
96"
480"
Beam Tube
140"
Center-Center
Track Gauge
12' - 0"
3'-0"
Supplier's/Purchaser's No.
CBI
LIGO
CLEAN ROOM
GENERAL Views
and Dimensions
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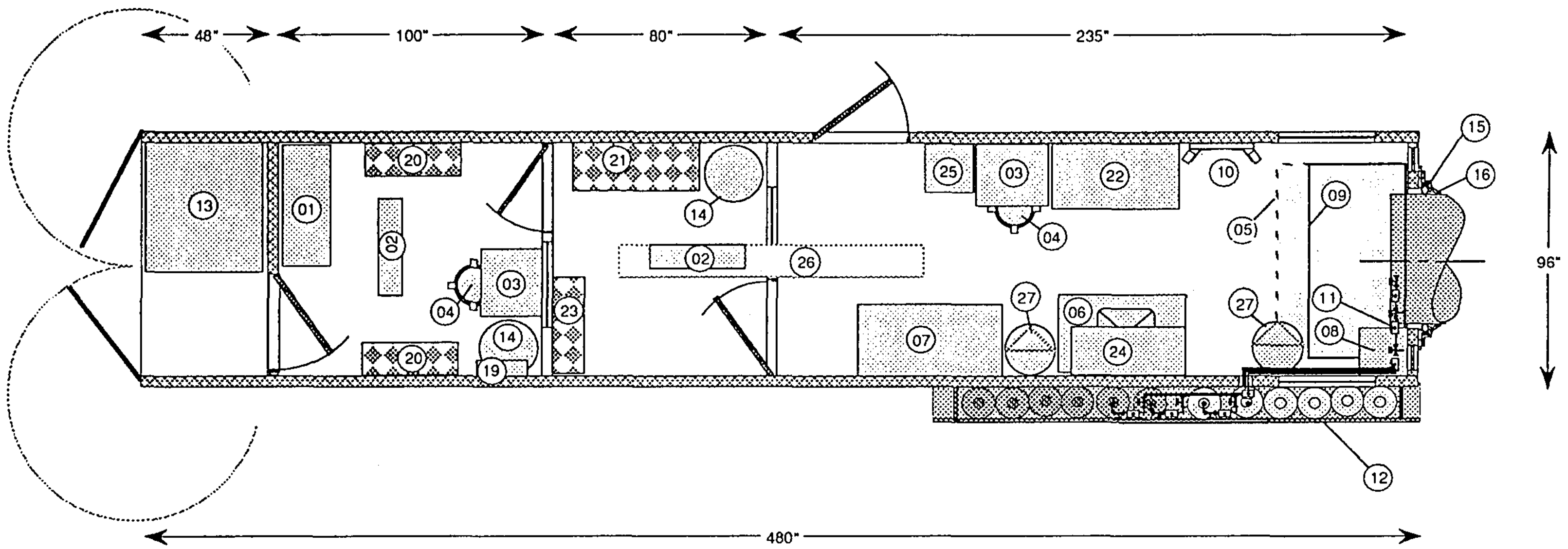

EQUIPMENT LISTING

MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
01	1	Hanging Lockers with Bar	4 comp		MMC4692T1
02	2	Changing Bench	36"	Incls Pedistals	MMC4854T13
03	2	Wall Attachment Desk	24x23"	Lift Top	MMC4894T36
04	2	Clean Room Stool	30" h		MMC5096T53
05	1	Overhead Hood	48"x72"	See HVAC	HVAC EX04
06	1	Mobile Drain-off Workbench	48x28"	with Castners	MMC4785T24
07	1	Baffle Storage Cart	27x54	with Castners	MMC2559T31
08	1	Gas Hose Bin 18" Deep	18x18"	18ga.S.S	CRS-1-GHB
09	1	Floor Tray Drain Mat	36"x72"	18ga.S.S	HVAC EX07
10	2	Personnel/Equip Creepers	18"x36"	Teflon Wheels	CRS-2-PEC
11	4	Purge Manifold Systems	N/A	S.S.Const	CRS-3-PMS
12	1	Gas Bottle Rack	Later	Per OSHA	CRS-4-GBR
13	1	HVAC/Filter Unit	N/A	See HVAC	HVAC AHU-1
14	2	Trash Container	N/A	Per NFPA	MMC4388T4

MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
15	1	Inflatable Seal for Tube Penet.	48" Ø	See Seal Det	CRS-5-ISTP
16	1	Secondary Gasket Seal	48" Ø	See Seal Det	CRS-6-SGF
17		Open			
18	1	Screen Door Assembly	50"Ø	100 Mesh	CRS-7-SDA
19	1	First Aid Equipment Cabinet	18x24"	with Supplies	Masuen 53500M
20	6	Chrome Wire Mesh Shevling	36x12"	2units/3 shlvs	MMC4717T22 & 17
21	4	Chrome Wire Mesh Shevling	48x18"	1unit/4 shlvs	MMC4717T25 & 44
22	1	Inflatable Purge Dam Storage	48x24"	48" Heigth	MMC2559T21
23	2	Chrome Wire Mesh Shevling	48x12"	1unit/2 shlvs	MMC4717T23 & 15
24	1	Flamable Mat'l Strge Cabinet	43x18"	Per OSHA	MMC4477T16
25	1	Tool Storage Cabnet	18x18"	66" Heigth	MMC4451T52
26	1	S.S. Tube Storage Container	12x12	114" Length	CRS-8-TSC
27	2	Oily Waste Cans	21"Ø	Per OSHA	MMC4070T8
28	2	S.S. Dispensing Plunger Cans	1 qt	Not Shown	MMC40075T51
29	2	Type II Safety Can with Spout	2 qt	Not Shown	MMC4289T7

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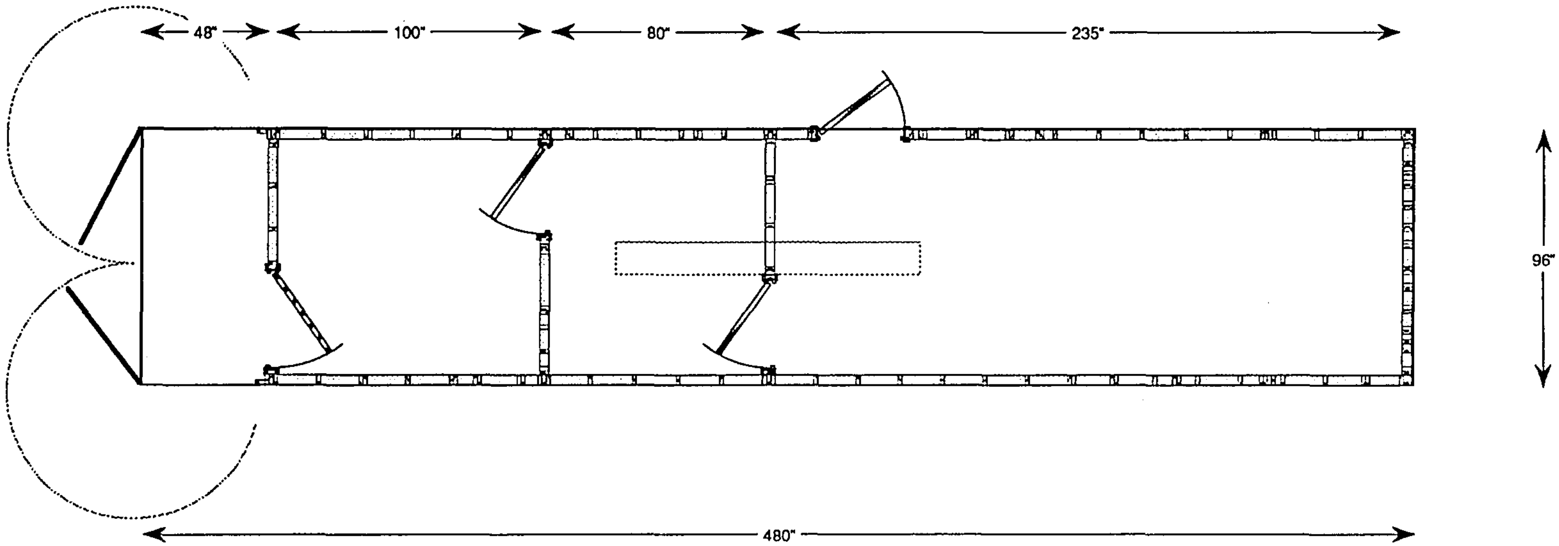
Supplier's/Purchaser's No. ____________

CBI

LIGO

CLEAN ROOM EQUIPMENT PLAN VIEW



Notes:

1) Framing is shown as 2"x4" construction. Metal Framing is also acceptable at 1 1/2" x 3 1/2" size.
2) Insulate outer walls using a foil or vinyl faced material conforming to applicable codes and requirements of NFPA, Factory Mutual, etc.
3) Fasteners for side wall shall be stainless steel and sealed with silicone and/or gasketed for a No Leak Condition.
4) No drilling thru roof material is allowed. If attachment is required, epoxy is acceptable.

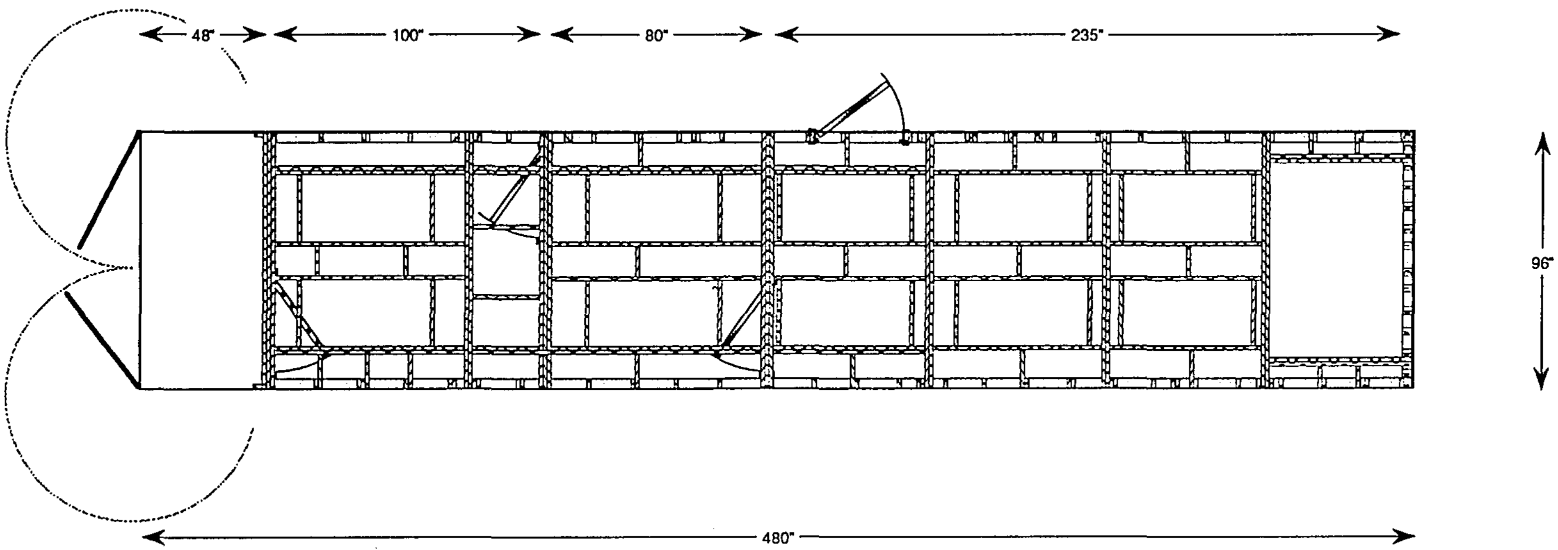
INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No.

CBI

LIGO

CLEAN ROOM
Lower Framing
PLAN VIEW



Notes:

1) Framing is shown as 2"x4" construction. Metal Framing is also acceptable at 1 1/2" x 3 1/2" size.
2) Insulate outer walls using a foil or vinyl faced material conforming to applicable codes and requirements of NFPA, Factory Mutual, etc.
3) Fasteners for side wall shall be stainless steel and sealed with silicone and/or gasketed for a No Leak Condition.
4) No drilling thru roof material is allowed. If attachment is required, epoxy is acceptable.

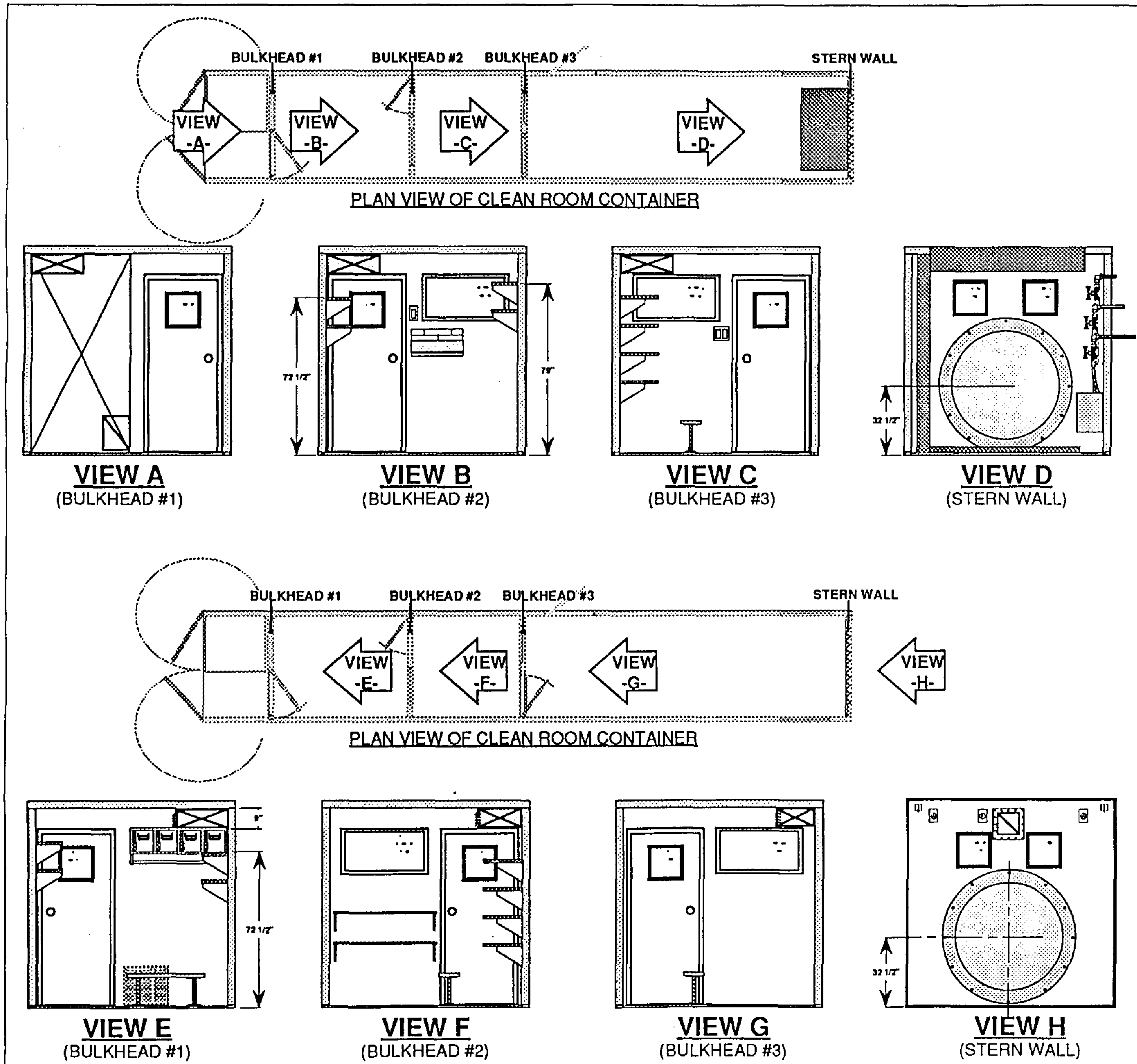
▶ INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ______

CBI

LIGO

CLEAN ROOM
Upper & Ceiling
Framing Plan



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Supplier's/Purchaser's No. ____________

CBI

LIGO

CLEAN ROOM BULKHEAD ELEVATIONS

Remarks

Revisions

By Chkd Date | By Chkd Date | By Chkd Date

Customer's No.

By ______ Chkd ______ Date ______

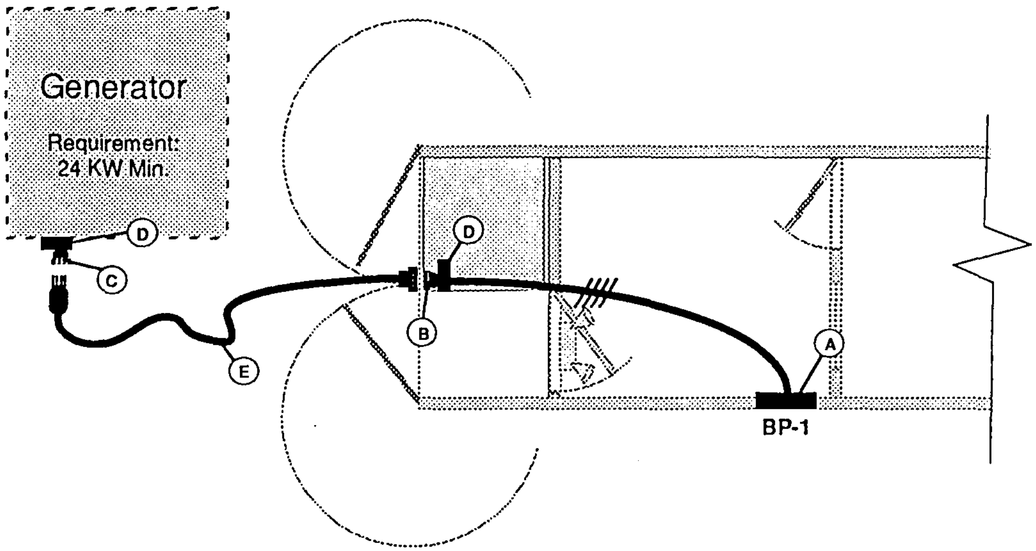
Engineering Supervisor

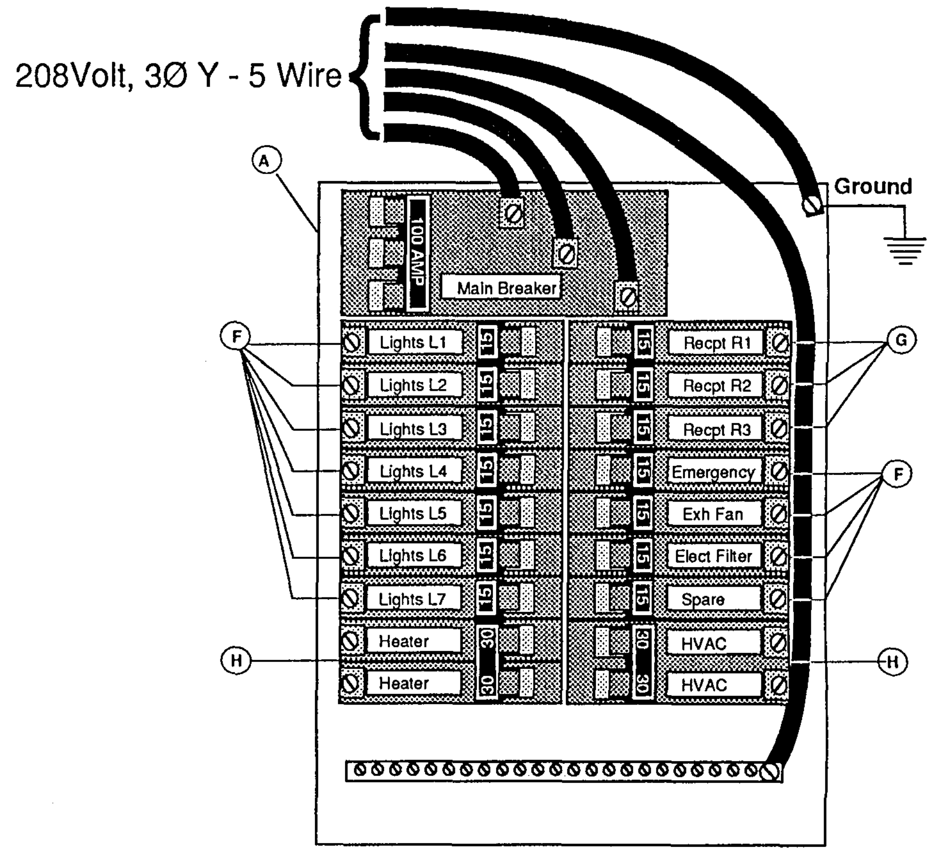
Contract No.

Dwg

Rev.

Sheet





BP-1

MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
A	1	100 Amp Breaker Panel	18 spcs	240/1Ø	Flush WWG# 4A562
B	1	100Amp Marine Receptacle	5 wire	with Cover	Hubbell 5100B9R Watertight Receptacle
C	1	100Amp Plug for Generator	5 wire	with Cover	Hubbell 5100R9 Watertight Plug
D	1	15° Angle Back Box & Spacer	4x4"	NEMA 4X	Hubbell #BB1002W and FW60/100
E	1	100Amp Marine Cord Set	100'	Watertight	Hubbell 5100CS100
F	11	15 Amp Breaker	1"		WWG#4A585
G	3	15 Amp Breaker with GFI	1"		WWG#4A583
H	2	30 Amp Breaker	1"		WWG#4A588
I		Spare			

INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No.

CBI

LIGO

CLEAN ROOM ELECTRICAL POWER PLAN

Customer's No.

Contract No.

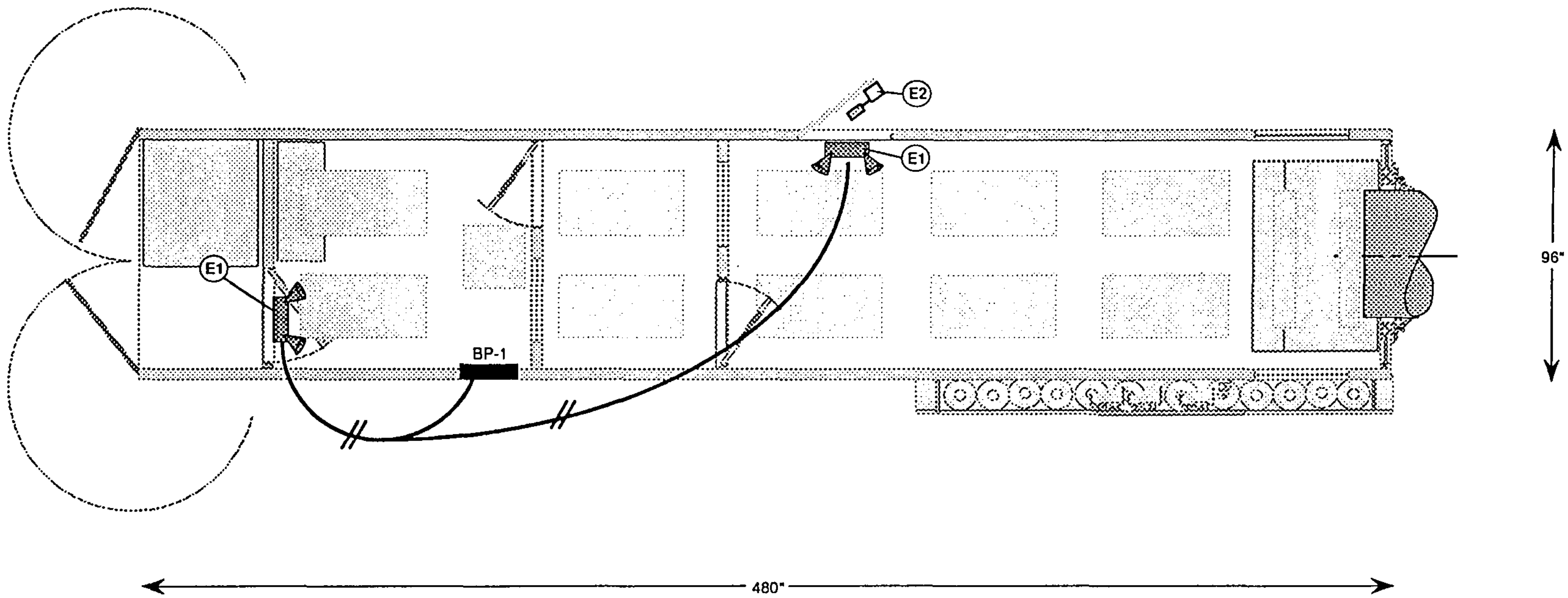
By ______ Chkd ______ Date ______

Engineering Supervisor

Dwg

Sheet

Rev



MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
E1	2	Combination Emergency & Exit Lighting	16x12"	120 volt	WWG#4V324
E2	1	Emergency Escape Bolt Ass'y	32"	Battery Pwrd	WWG#1U037(left Hand Door)

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ____________

CBI

LIGO

CLEAN ROOM EMERGENCY EQUIPMENT PLAN

Customer's No

Contract No

By ______ Chkd ______ Date ______

Engineering Supervisor

Dwg

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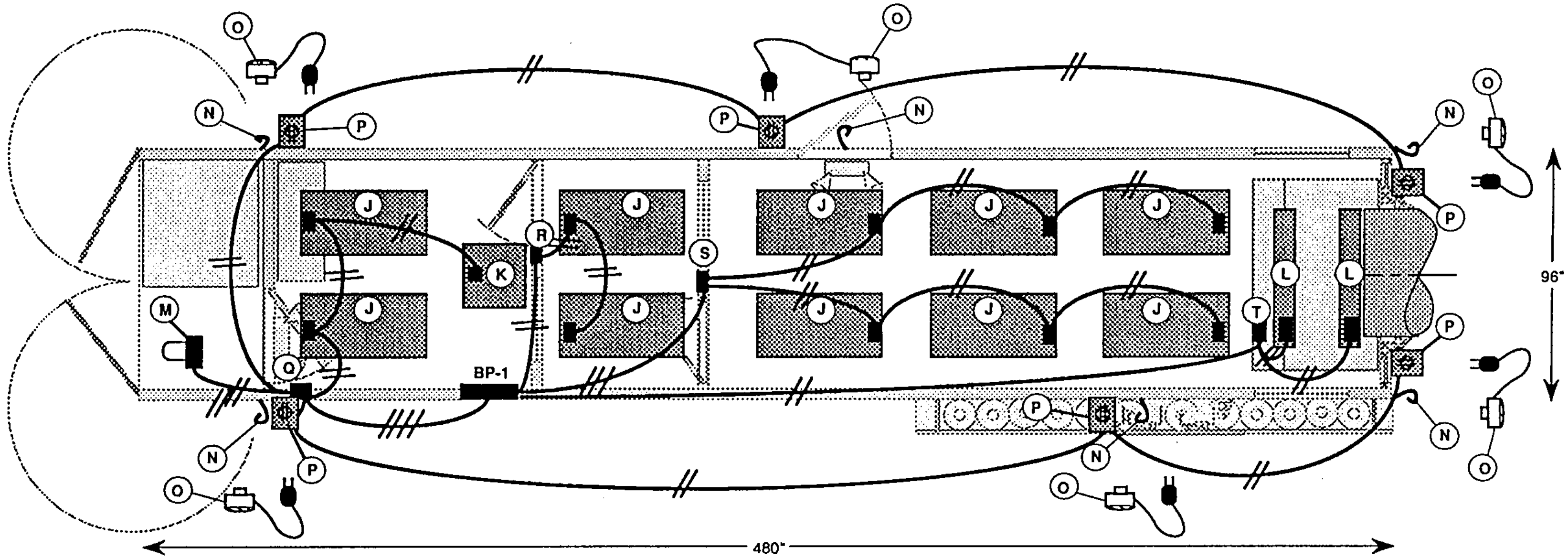


MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
J	10	Fluorescent Recessed Fixtures	24x48"	4-F40 Tubes	WWG#3V420
K	1	Fluorscent Recessed Fixture	24x24"	2-FU20 Tubes	WWG#4V375
L	2	Fluorscent Vapor Resistent Fix	12x48"	2-F40 Tubes	WWG#3V424
M	1	Incandescent Vapor Res. Fix	6x10"	Ceiling Mount	WWG#2V565
N	6	Ext. Light Pad Mount Hook	3/8"Ø	To fit "F"	Fabricate to support Item "F"
O	6	100W HPS Portable Area Light	100w	Wet Location	WWG#4V256
P	6	5-15 Single Receptacle & Cover	15 amp	NEMA 4X	Single 5-15 Receptacle with Weather Cover
Q	-	Single Pole Rocker Switches	15 amp	3 switches	WWG#6A678 with 3 switch wall plate
R	-	Single Pole Rocker Switch	15 amp	1 switch	WWG#6A678 with single switch wall plate
S	-	Single Pole Rocker Switches	15 amp	2 switches	WWG#6A678 with 2 switch wall plate
T	-	Hood Mounted Switch	15 amp	UL List	Per Hood Manufacturer Specification
U		Open			

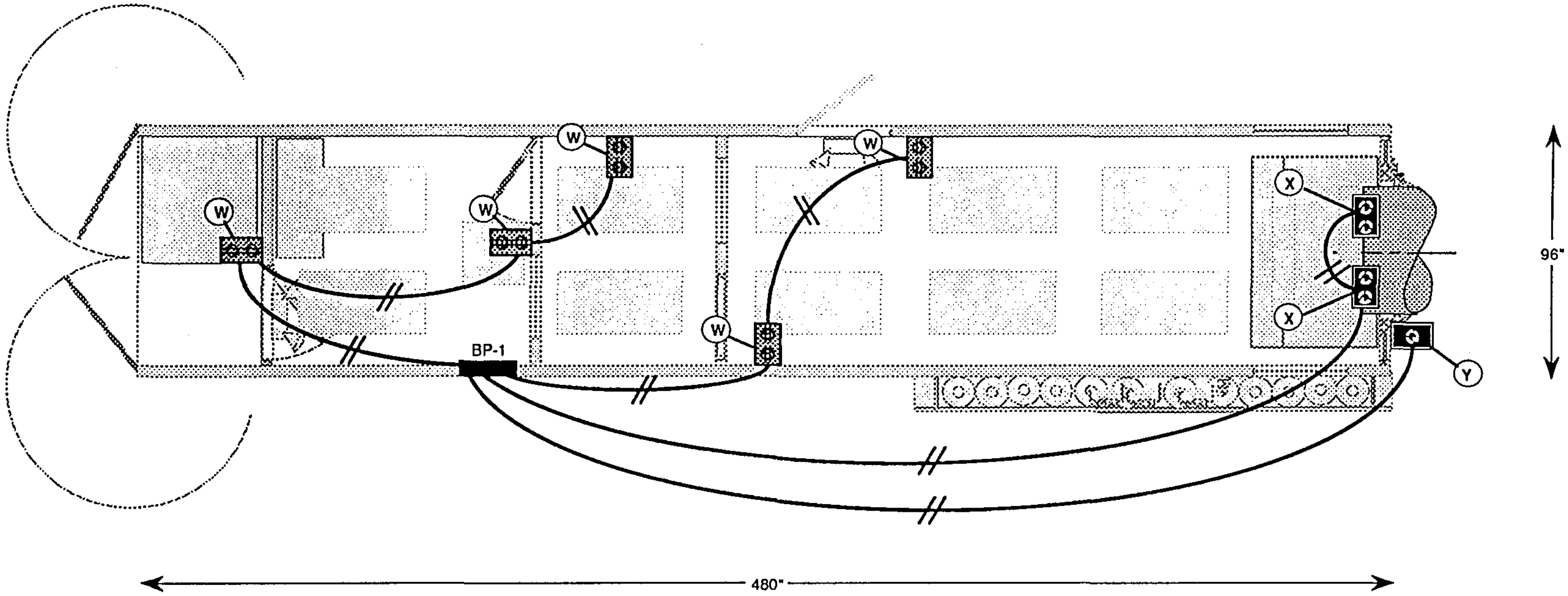
INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ____________

CBI

LIGO

CLEAN ROOM
ELECT. LIGHTING
PLAN VIEW



MARK	QTY	DESCRIPTION	SIZE	COMMENTS	REFERENCE NO.
W	5	5-15 Duplex Receptacles	15 amp	Straight Blade	Flush WWG#6A680, Wall Plate = 6A677
X	2	L5-15 Duplex Receptacles	15 amp	Twist Locking	WWG#6A664, Orange Wall Plate = 1A558
Y	2	L5-15 Duplex Receptacles	15 amp	Twist Locking	WWG#6X057, NEMA 4X Wall Plate = 2V704
Z		Open			

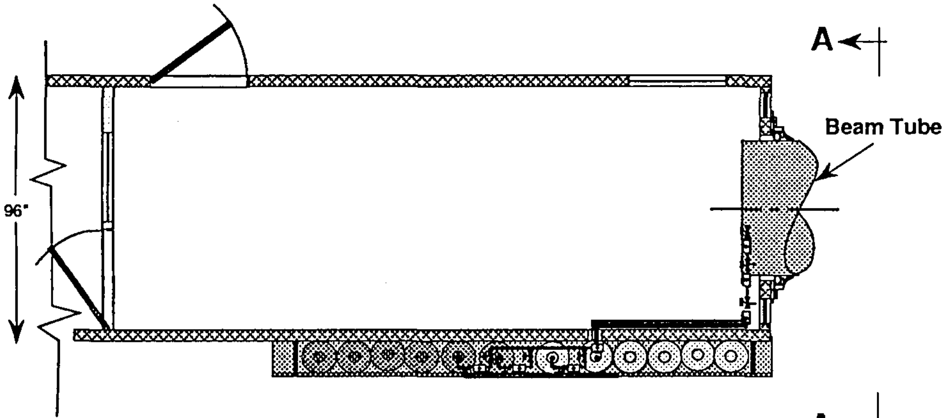
INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ____________

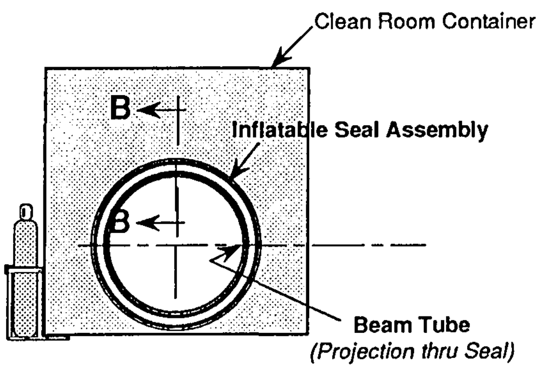
CBI

LIGO

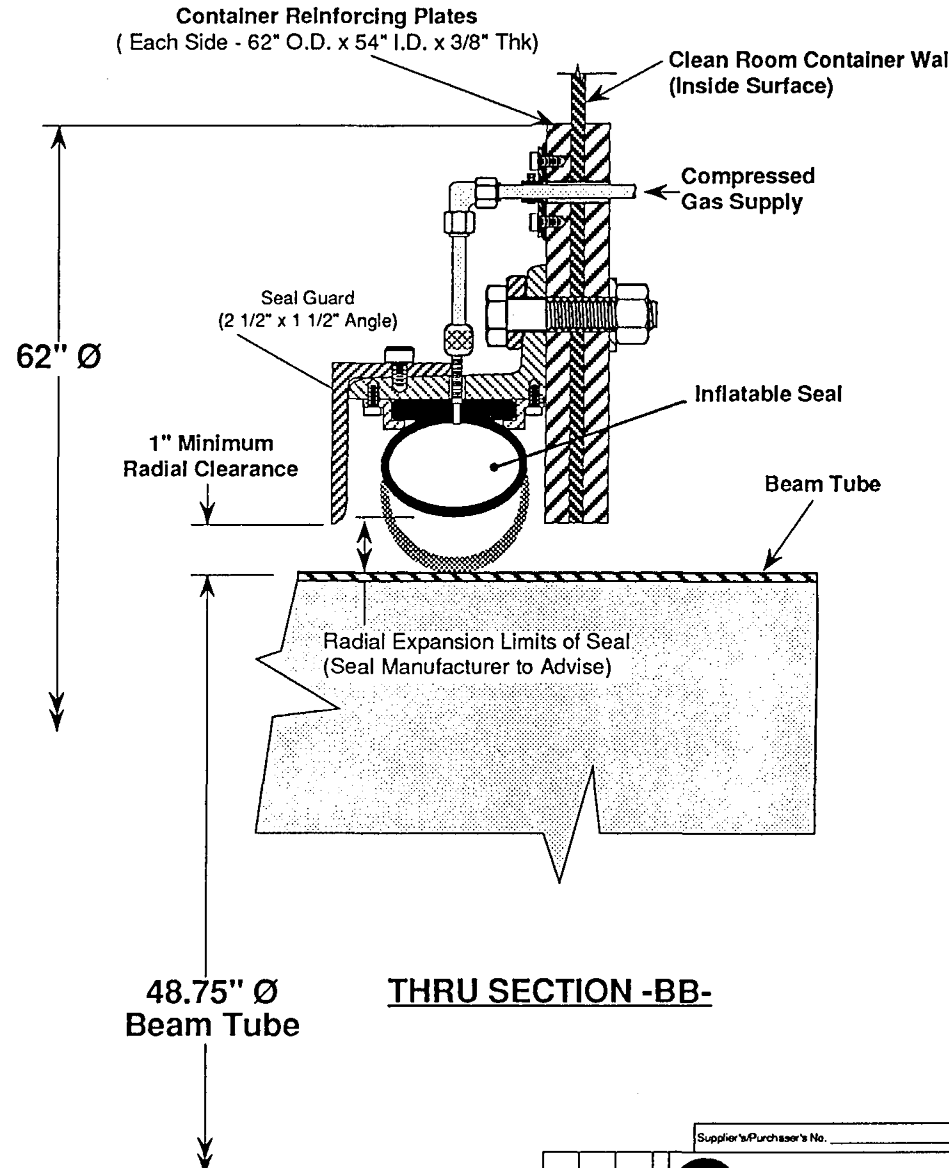
CLEAN ROOM RECEPTACLE PLAN VIEW



Plan View
Section of Clean Room



END VIEW -AA-



THRU SECTION -BB-

INDICATES CHANGE FROM PREVIOUS ISSUE

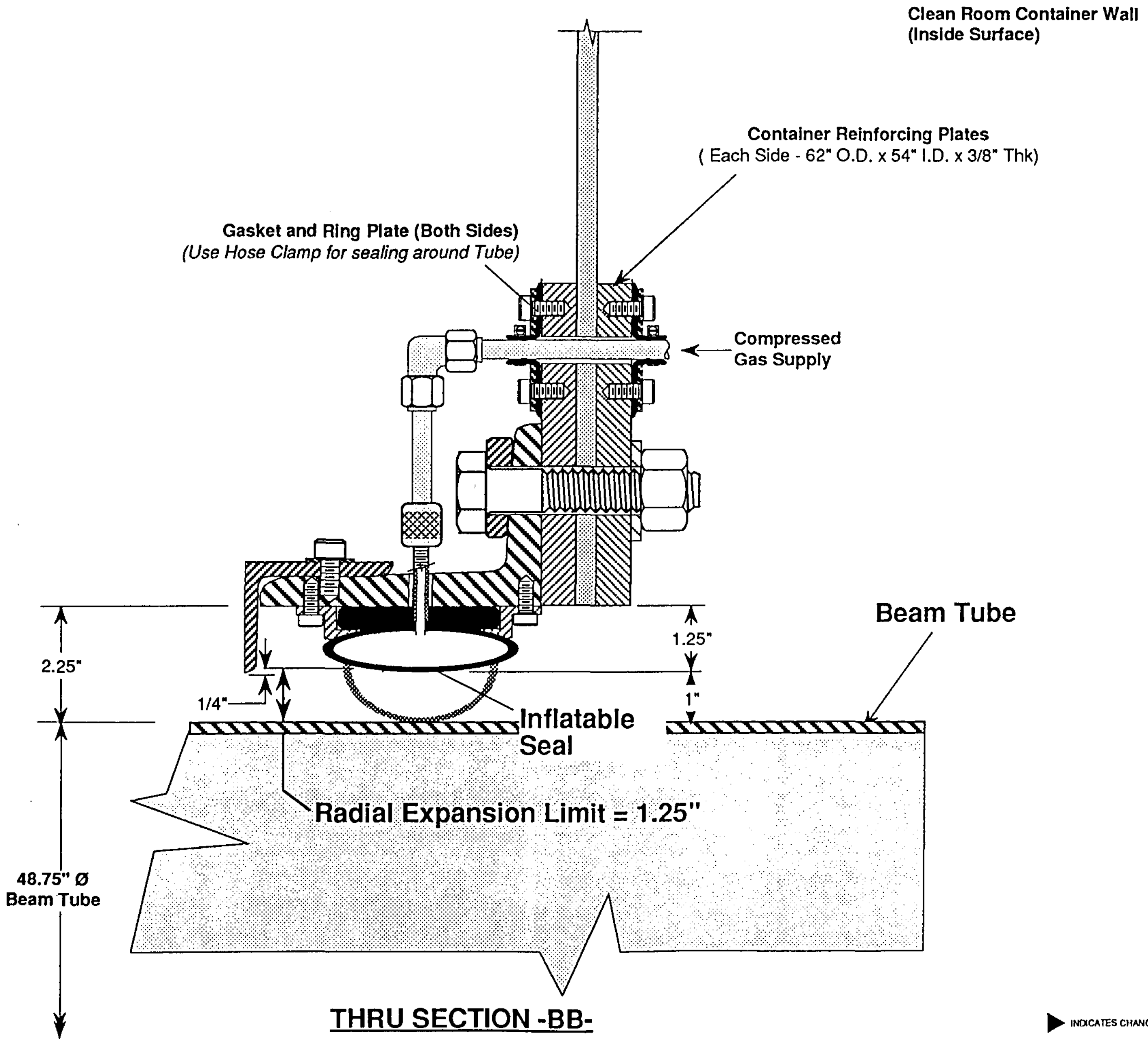
Supplier's/Purchaser's No.

CBI

LIGO

CLEAN ROOM
Inflatable Seal
Detail

CBS-5-ISS
Sht 1 of 2



THRU SECTION -BB-

INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ____

CBI

LIGO

CLEAN ROOM Inflatable Seal Detail

Customer's No.

By ____ Chkd ____ Date ____

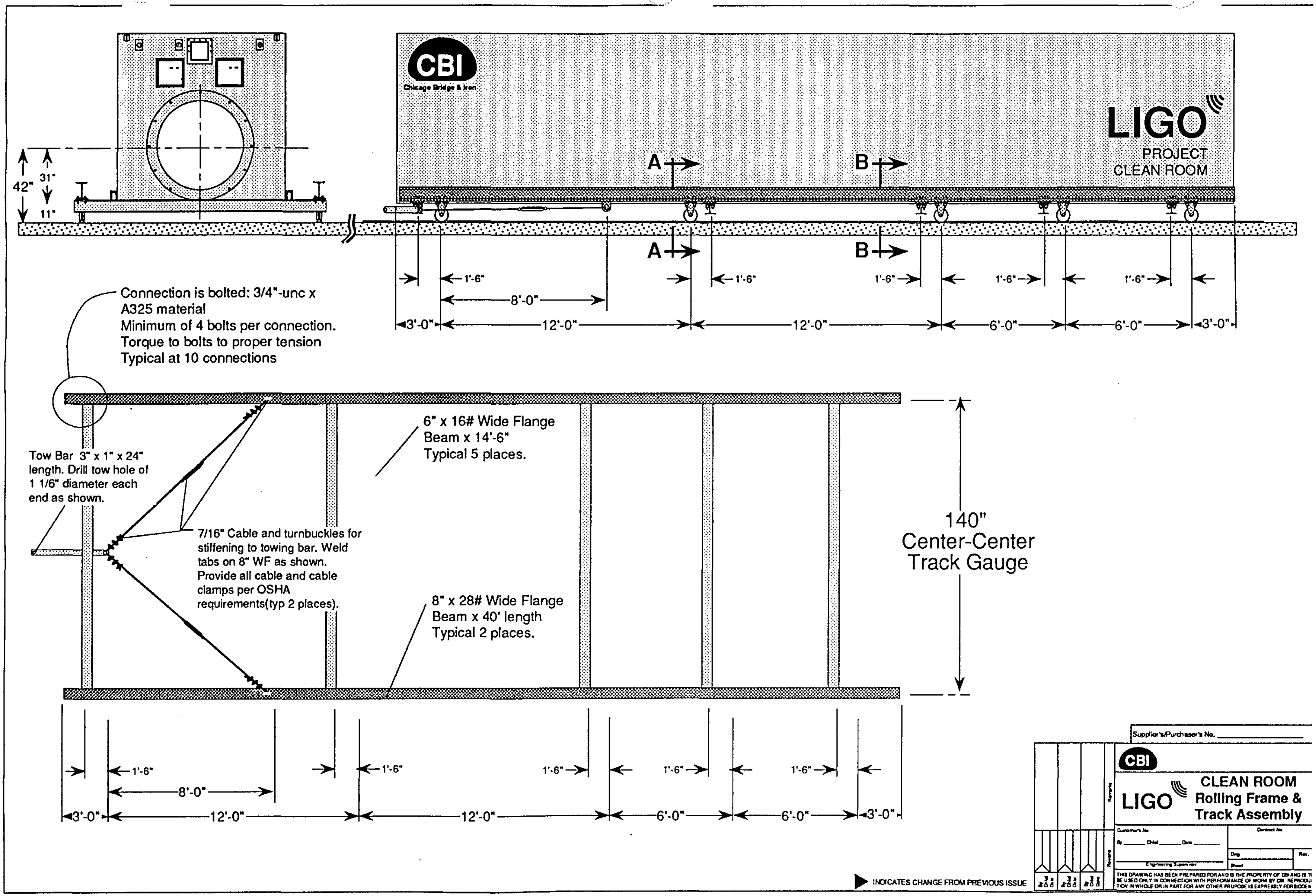
Engineering Supervisor

Contract No.

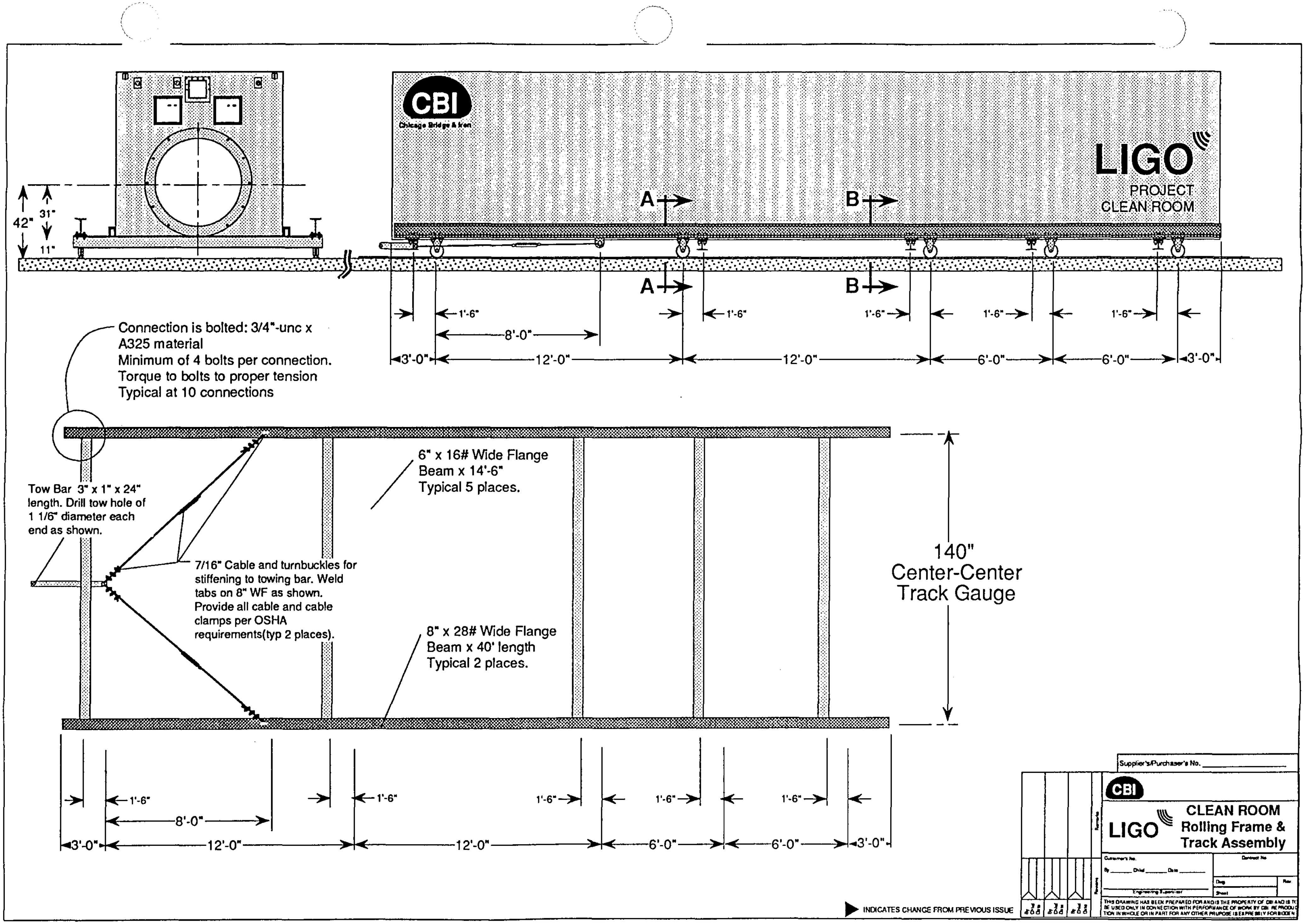
Dwg CRS-5-ISS

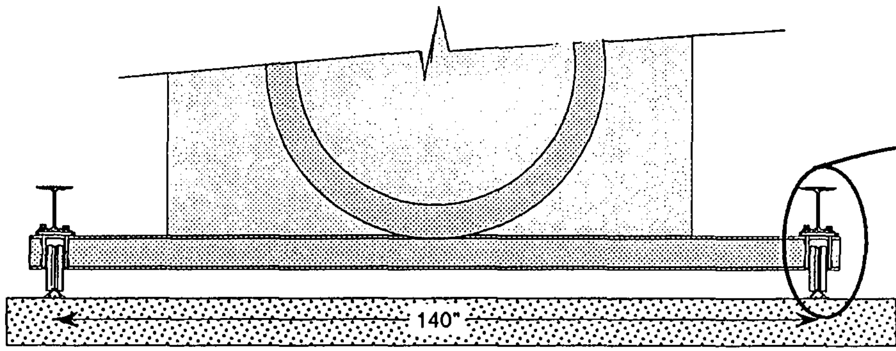
Sheet Sht 2 of 2

Rev

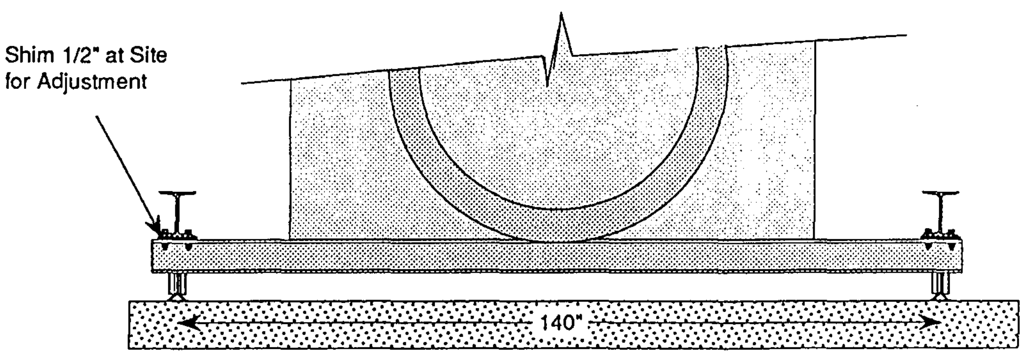


CBI
Chicago Bridge & Iron
LIGO
PROJECT
CLEAN ROOM
A
B
42"
31"
11"
1'-6"
8'-0"
3'-0"
12'-0"
6'-0"
Connection is bolted: 3/4"-unc x
A325 material
Minimum of 4 bolts per connection.
Torque to bolts to proper tension
Typical at 10 connections
6" x 16# Wide Flange
Beam x 14'-6"
Typical 5 places.
Tow Bar 3" x 1" x 24"
length. Drill tow hole of
1 1/6" diameter each
end as shown.
7/16" Cable and turnbuckles for
stiffening to towing bar. Weld
tabs on 8" WF as shown.
Provide all cable and cable
clamps per OSHA
requirements(typ 2 places).
8" x 28# Wide Flange
Beam x 40' length
Typical 2 places.
140"
Center-Center
Track Gauge
INDICATES CHANGE FROM PREVIOUS ISSUE
Supplier's/Purchaser's No.
CBI
LIGO
CLEAN ROOM
Rolling Frame &
Track Assembly

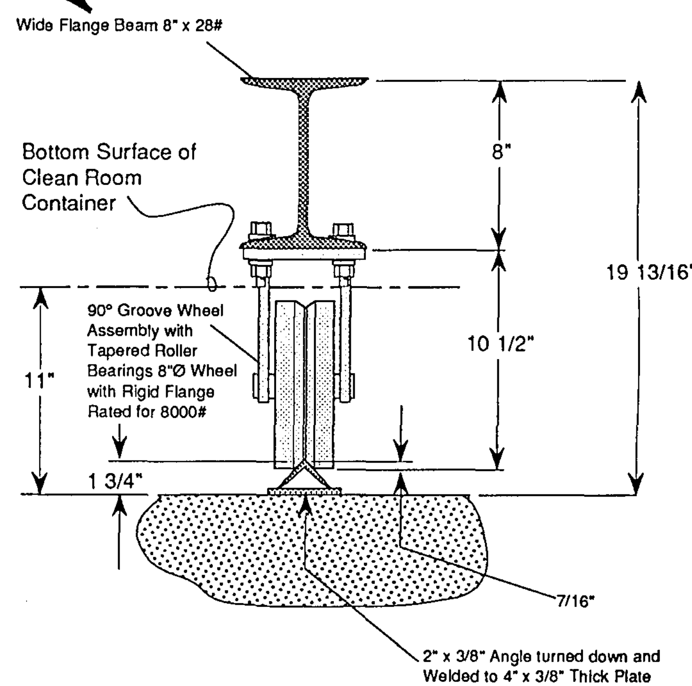

CBI
Chicago Bridge & Iron
LIGO
PROJECT
CLEAN ROOM
42"
31"
11"
A
B
1'-6"
8'-0"
3'-0"
12'-0"
6'-0"
Connection is bolted: 3/4"-unc x
A325 material
Minimum of 4 bolts per connection.
Torque to bolts to proper tension
Typical at 10 connections
6" x 16# Wide Flange
Beam x 14'-6"
Typical 5 places.
Tow Bar 3" x 1" x 24"
length. Drill tow hole of
1 1/6" diameter each
end as shown.
7/16" Cable and turnbuckles for
stiffening to towing bar. Weld
tabs on 8" WF as shown.
Provide all cable and cable
clamps per OSHA
requirements(typ 2 places).
8" x 28# Wide Flange
Beam x 40' length
Typical 2 places.
140"
Center-Center
Track Gauge
Supplier's/Purchaser's No.
CBI
LIGO
CLEAN ROOM
Rolling Frame &
Track Assembly
INDICATES CHANGE FROM PREVIOUS ISSUE



Sectional View -AA-



Sectional View -BB-



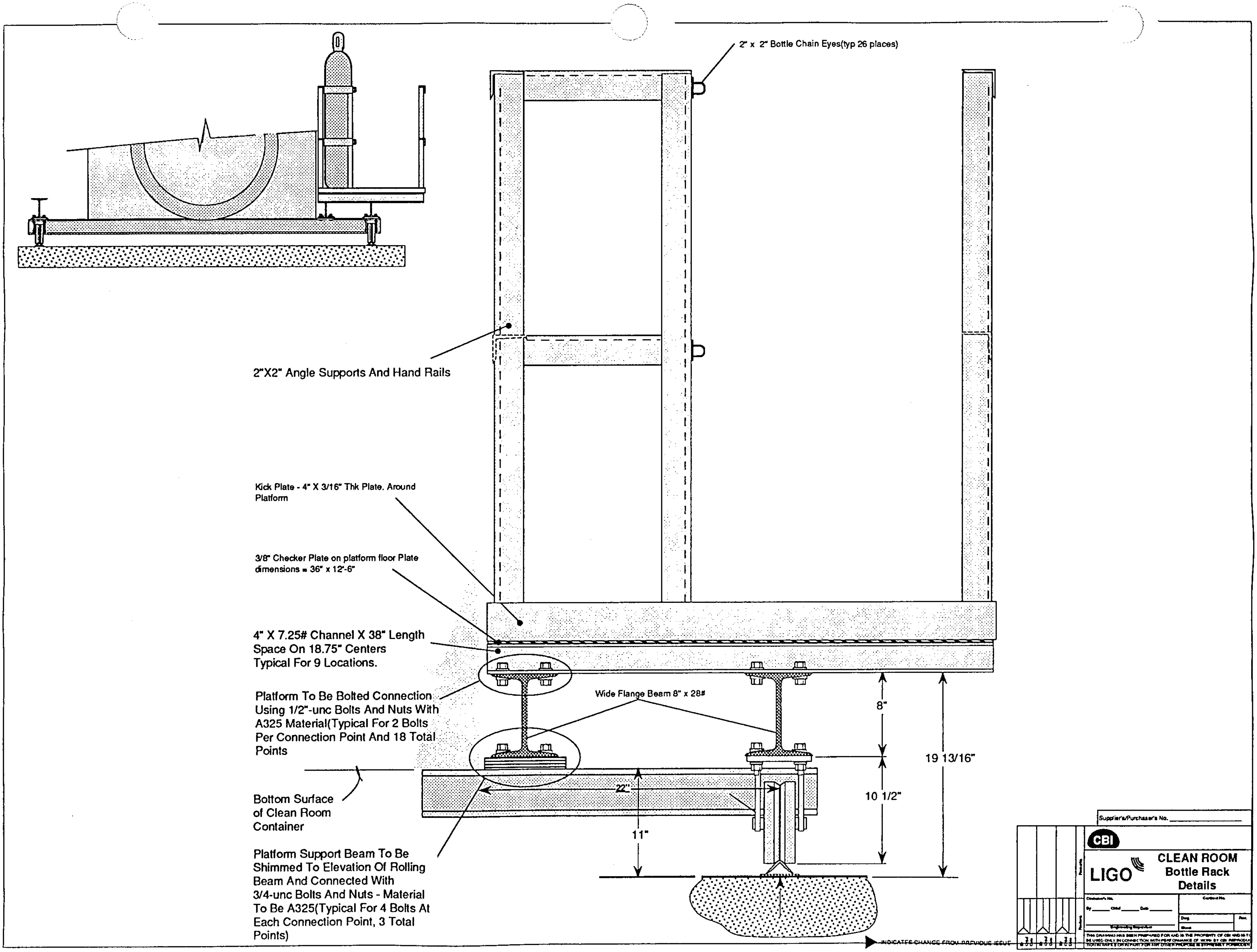
Supplier's/Purchaser's No.

CBI

LIGO

CLEAN ROOM
Rolling Frame &
Track Assembly

INDICATES CHANGE FROM PREVIOUS ISSUE



2" x 2" Bottle Chain Eyes(typ 26 places)
2"X2" Angle Supports And Hand Rails
Kick Plate - 4" X 3/16" Thk Plate. Around Platform
3/8" Checker Plate on platform floor Plate dimensions = 36" x 12'-6"
4" X 7.25# Channel X 38" Length Space On 18.75" Centers Typical For 9 Locations.
Platform To Be Bolted Connection Using 1/2"-unc Bolts And Nuts With A325 Material(Typical For 2 Bolts Per Connection Point And 18 Total Points)
Wide Flange Beam 8" x 28#
8"
19 13/16"
10 1/2"
22"
11"
Bottom Surface of Clean Room Container
Platform Support Beam To Be Shimmed To Elevation Of Rolling Beam And Connected With 3/4-unc Bolts And Nuts - Material To Be A325(Typical For 4 Bolts At Each Connection Point, 3 Total Points)
INDICATES CHANGE FROM PREVIOUS ISSUE
Supplier's/Purchaser's No.
CBI
LIGO
CLEAN ROOM
Bottle Rack
Details

DOC ID BDF-1
REV. NO. 1
CONTRACT 930212

TITLE:	BLOWER/DRYER/FILTRATION SYSTEM FOR BEAM TUBE POSITIVE AIR FLOW SPECIFICATION AND PROCEDURE - CALTECH	PAGE NO. 1 OF 5	

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	06-Nov-93
					REVISED	SDH	28-Mar-94
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO.

1.0 SCOPE:

This procedure covers the activities associated with the Blower/Dryer/Filtration System(BDF) located at the stationary beginning of the construction of the beam tube modules

The BDF System provides a positive air flow of clean, dry air through the tube during constructions activities.

Two(2) redundant units will be used. Controls shall be arranged to provide automatic start-up of one unit based on the condition or failure of the first. The second unit will provide back-up during servicing of the first and visa versa.

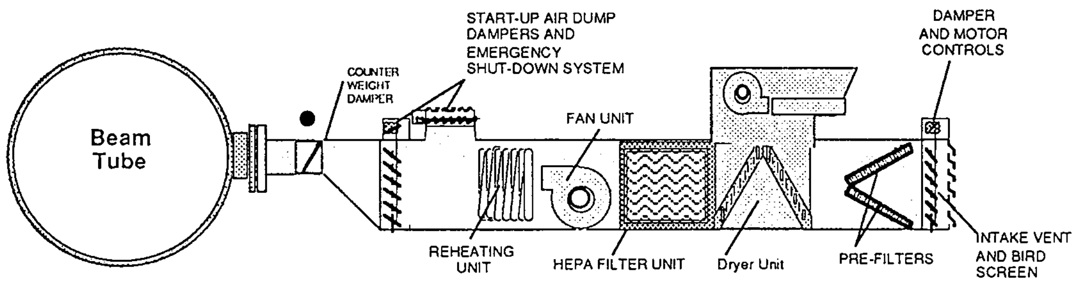
The following activities are described in this procedure:

1.1 General Arrangement and Specifications for the BDF Units.
1.2 Operating procedures for the BDF Units.
1.3 Maintenance Procedures for the BDF Units.
1.4 Storage and Shipping of BDF Units.

2.0 REFERENCES:

2.1 The procurement and operation of the BDF Units are based on the following references:

2.1.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.
2.1.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.
2.1.3 CBI Cleaning Procedure CL1N



BDF SYSTEM UNIT

3.0 EQUIPMENT:

Equipment referenced in other CBI procedures will be incorporated into this procedure. For specific items, see applicable references.

3.1 1500 CFM System Fan and Motor
3.2 DX Pre-Cooling Coil
3.3 DX After Cooling Coil
3.4 Air Cooled Condensing Units
3.5 30% Efficient Pre-Filters
3.6 Outside Air Motorized Damper
3.7 HEPA Filter Sized at 100, rated >0.3 Microns
3.8 Spare HEPA Filter for one change
3.9 Motorized start-up and by-pass dampers
3.10 Electric Re-Heat Coils, SCR controlled
3.11 Fire/Smoke detectors
3.12 Control for Redundant Operation
3.13 Weatherproof/Outdoor Construction

4.0 Operation of Units:

The BDF System shall produce the following output of air:

4.1.1 Air Flow volume of 1500 CFM to be divided equally in two directions. This provide a air flow velocity of 60 fpm.

4.1.2 Air quality shall maximum particle size of 0.3 microns using a HEPA 100 filter system.

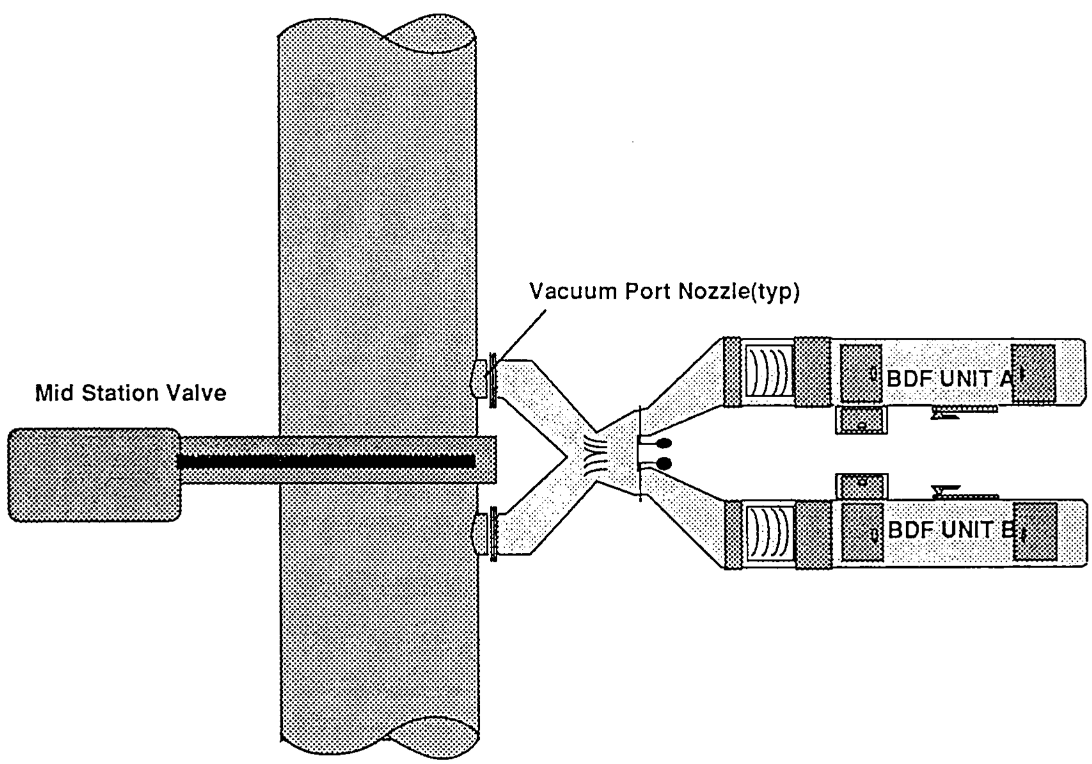
4.1.3 Moisture content shall equal 0° dew point at 75°F outlet temperature.

The BDF System shall be operated continuously during construction activities. The following event and response shall be controlled automatically.

4.2 Controls shall provide automatic unit start-up on the loss of the operating unit.

4.3 Controls shall shut down units and close all dampers upon detection of smoke or fire.

4.4 All dampers shall be provided with spring control to close upon loss of power to the unit.



BDF SYSTEM TUBE CONNECTION

4.4 Units shall be equipped with mercury filled, nitrogen purged contractors for motor and compressor operation.

5.0 Maintenance of Units:

The BDF System shall be maintained per the following schedule. A maintenance log shall be kept with the dates and initials of the technician performing the work. One unit shall be kept operating while the other unit is maintained. Each unit shall be alternated each day during operation.

5.1 Daily Maintenance:

5.1.1 Record all gauge and instrument readings for pressure and flow.

5.1.2 Inspect and replace as necessary pre-filters for each unit.

5.1.3 Based on pressure indicators, replace HEPA filters as necessary.

5.2 Weekly Maintenance:

5.2.1 All interior surfaces shall be wiped down with an approved cleaning agent.

5.2.2 Inspect all door and panel gaskets for air leaks and corrosion. Repair as required.

5.2.3 Inspect all intake screens, exhaust screens and condenser fans for dirt, debris, and corrosion. Clean and protect as required.

5.3 Monthly Maintenance:

5.3.1 Clean all coil finns and tubing with approved, commercial cleaning agent.

5.3.2 Inspect all electrical connections, contractors, and switches for proper operation.

5.3.3 Operate all dampers to assure proper operation and air leakage. Adjust as necessary.

6.0 Storage and Transportation:

6.1 Short term storage shall shall comply with all activities noted below.

6.1.1 All Doors and panels shall be locked during storage.

6.1.2 All inlet and outlet ducts shall be sealed.

6.1.3 All electrical cords and connections shall be covered from the weather and protected form outside abuse.

6.2 Long term storage and transportation shall shall comply with all activities noted below.

6.2.1 All activities noted in 6.1 shall be completed prior to long term storage or shipping.

6.2.2 Coat all inside surfaces with a rust inhibitor prior to locking doors and panels.

6.2.3 Cover the unit in a weather proofing sealer or a tarp to prevent direct contact with rain, snow and/or sunlight.

7.0 Transportation of BDF Units:

The BDF Units shall be transportable from one area or site to another. This is accomplished by equipment mounted skids and mounted on flatbed trailers.

CBI

TITLE RECEIVING INSPECTION	IDENTIFICATION IR			
	REFERENCE NO. 930212		SHT 1 OF 2	
	OFFICE		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES DESIGN & QUALIFICATION TEST	MADE BY PM	CHKD BY	MADE BY	CHKD BY
	DATE 04/04/94	DATE	DATE	DATE

1.0 SCOPE

This procedure describes the system followed to do receipt, inspection, and release of beam tube components.

2.0 REFERENCES

2.1 LIGO Specification 1100004, "Beam Tube Module Specification", dated May 11, 1993.

2.2 LIGO Specification 1100007, "Process Specification", dated May 11, 1993.

2.3 LIGO Quality Assurance Manual (QAM) to ANSI/ASQC Standard Q91.

2.4 LIGO Material Specifications and Purchasing Specifications.

2.5 Dimensional Control Procedure, DC.

2.6 Material Traceability, MI.

3.0 QAM REQUIREMENTS

The basic requirements for receipt inspection are stated in the LIGO QAM (reference 2.3). Additional requirements and clarification are specified in the following sections.

4.0 RECEIPT

4.1 Visually inspect beam tube components upon arrival at receiving area for shipment damage.

4.2 Check the identity of items received by comparing to shipping papers or packing list.

5.0 INSPECTION

5.1 Dimensional inspection shall be made per Section 5.3 of Dimension Control Procedure, DC8.

5.2 Vendor documentation shall be carefully reviewed for accuracy and completeness. This review shall be based upon the LIGO material and purchase specification requirements.

6.0 RELEASE

6.1 Items shall be released for use if the results of receiving inspection are acceptable and all necessary documentation is received and inspected.

CBI	IDENTIFICATION IR			
TITLE RECEIVING INSPECTION	REFERENCE NO. 930212		SHT 2 OF 2	
	OFFICE		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES DESIGN & QUALIFICATION TEST	MADE BY PM	CHKD BY	MADE BY	CHKD BY
	DATE 04/04/94	DATE	DATE	DATE

6.2 Section 4.0 of MI8 also requires that bake and outgas information be part of the CMTRs. Those items requiring material with bake and specific outgas characteristics can only be released if this documentation is received and checked for accuracy and completeness.

CBI	IDENTIFICATION DC			
TITLE DIMENSIONAL CONTROL PROCEDURE FOR LIGO	REFERENCE NO. 930212		SHT 1 OF 10	
	OFFICE		REVISION 0	
PRODUCT	MADE BY WRL	CHKD BY	MADE BY	CHKD BY
	DATE 03/30/94	DATE	DATE	DATE

1.0 SCOPE

1.1 This procedure describes the dimensional measurements that are required to be performed and recorded to meet the requirements of ASME Code, Section VIII, Division 1, Vacuum Service, the requirements of fabrication and construction, and the requirements of Caltech Specification No. 1100004.

2.0 DIMENSIONAL CONTROL EQUIPMENT

2.1 Calibration of specific types of equipment used for final acceptance of Code items shall meet the requirements of CBI's QAM. A list of equipment with reference to a Calibration Certificate (CC) with traceability to the National Institute of Science and Technology (NIST), the applicable internal calibration procedure(s) or policy statement, as applicable shall be maintained by the Project Manager.

3.0 DEFINITIONS

3.1 Clear Aperture -- The diameter of the cross section of a right circular cylinder between beam tube termination's, whose volume is unobstructed.

3.2 Reference Monument -- A mark in a fixed monument system.

3.3 Axis for the Clear Aperture -- The axis for the clear aperture is defined by X & Y coordinates furnished by Caltech for each reference monument location.

3.4 Beam Tube Module -- A beam tube that is approximately 2 kilometers (km) in length and terminated with a weld joint end preparation at the following locations.

1. The ends may be at a corner station and a mid station.
2. The ends may be at a corner station and a mid point joint.
3. The ends may be at a mid point joint and an end station.
4. The ends may be at a mid station and an end station.

3.5 Beam Tube Section -- Approximately 20 m length of fabricated beam tube with expansion joint, pumping port, baffle(s), and related equipment as applicable that are field assembled without intruding into the clear aperture.

3.6 Beam Tube Section Dimensional Test -- A test demonstrating acceptable geometry before each beam tube section gets installed. The contractor shall provide documentation that records actual measurements and provides calculations that demonstrate acceptable geometry and traceability to each beam tube section (See Caltech Specification No. 1100004, Section 4.3.3.).

3.7 Alignment Acceptance Test -- A task the contractor performs to verify and document that the tube alignment complies with the clear aperture requirement (See Caltech Specification No. 1100004, Section 4.4.).

4.0 MEASUREMENT METHODS

4.1 Accuracy -- The methods used to obtain and record the dimensions should be at least two times more accurate than the specified tolerance.

4.2 Temperature Correction -- The temperature of the environment surrounding the beam tube component shall be recorded and if necessary used to correct "as-measured" dimensions. The temperature of the steel shall be recorded and if necessary used with its Coefficient of Thermal Expansion to correct "as-measured" dimensions. Standard 68° Fahrenheit shall be used, when dimensions are corrected for temperature.

5.0 COMPONENT INSPECTION

5.1 Option Components -- The following list describes the beam tube component. The brief outline of the dimensional measurement method including the applicable measurement record is the same as for the Qualification Test Components.

A. Beam Tube Coils -- Supplier documentation review for width and thickness per material specification.
B. Welded Expansion Joints -- Inspection by supplier, documentation review, assembly fabrication, and final installation per procurement specification with measurement record (see Attachment 1 for typical Measurement Record & Check List Form **DC.1**) for design outside diameter, length, thickness, deviation from the true circular form, cylindrical straightness, and end parallelism.
C. Welded Beam Tubes -- Inspection by supplier, documentation review, receiving inspection with measurement record for design outside diameter, thickness, and nominal length.
D. Welded Beam Tube Assemblies -- Assembly fabrication and final installation with measurement record for design outside diameter, length, thickness, deviation from the true circular form, cylindrical straightness and end parallelism.
E. Beam Tube Baffle/Support Rings -- Inspection by supplier, documentation review, receiving inspection, assembly fabrication, and final installation with measurement record for design inside diameter, width, thickness, and deviation from the true circular form.
F. Support Welded Attachment Members -- Inspection by supplier, documentation review, receiving inspection with random checks for general dimensions shown on vendor shop drawings.
G. Beam Tube Stiffener Rings -- Inspection by supplier, documentation review, receiving inspection with random checks for general dimensions shown on vendor shop drawings.
H. Welded Baffles -- Inspection by supplier, documentation review, and final receiving inspection at installation. A performance test shall be performed by the supplier that demonstrates acceptable geometry and traceability to each baffle.
I. Beam Tube Supports including related items -- Inspection by supplier, documentation review, receiving inspection with random checks for general dimensions shown on vendor shop drawings, including horizontal & vertical adjustment, and final installation. Documentation for conformance verification uses records that describe reference points located on beam tube support rings (see alignment performance test procedure).

5.2 Inspection by Supplier -- The CBI Material Specification and Product Procurement Specification specify the dimensional measurements, inspections, and records provided by the vendor. Surface finish of items inside beam tube shall be measured for RMS (No smoother than 2.5 microns rms roughness).

5.3 Receiving Inspection

5.3.1 Beam Tube Coil receiving inspection performed by vendors.

5.3.2 Welded Expansion Joints have no measurements taken during receiving inspection. Review documentation provided.

5.3.3 Welded Beam Tubes as delivered from the vendor, have insufficient stability for completing final acceptance measurements. The beam tube shall be supported by equally (15 feet or less) spaced & leveled turning rolls. Temporary round out fixtures shall be installed at each end and at each support/baffle ring location. The measurements taken at receiving inspection verify procurement requirements and provide data for fabrication and installation. The circumference at each baffle location is used to establish beam tube baffle/support ring final machining dimensional specifications. The following measurements shall be recorded on a measurement record.

A. Measure and record circumference using a precision diameter tape accurate to ± 0.001" to obtain Outside Diameter (*Do*) within ½" to 2" from each end and at baffle locations.
   1. End Outside Diameter (*Do*) -- *Do max.* = 49.004"& *Do min.* = 48.890"
   2. Baffle/Support Outside Diameter (*Do*) -- *Do max.* = 49.004"& *Do min.* = 48.776"

B. Measure and record thickness using a 0.000" - 1.000" micrometer within ½" to 2" from each end, ½" to 2" from each side of weld joint and 180° from weld joint.
   1. Thickness (*t*) -- *t max.* = 0.130" & *t min.* = 0.120"

C. Measure and record ordered length using a 6" standoff block (with clamp), a tension clamp, and a 1/32" graduated steel tape. Measure and record temperature of the beam tube, steel tape and air. Stretch the tape to remove sag at the outside top centerline of the beam tube and take measurements. Establish reference points (2" offset inside the cut line at weld joint center line one end and repeat for each 90° at each end) for monitoring fabrication, installation, etc., and calculate the nominal length with steel tape sagg and tension factors taken into condideration.
   1. Tolerance: Ordered Length -- ± ½"

D Measure and record reference deviation (*eR*, see attachment 1) from the true circular form using an outside segmental circular template and go & no-go gauge within ½" to 2" of end cut lines and support & baffle ring locations. Measure the distance from template to surface of beam tube. Measure at each 90° point of the cross section relative to the weld joint centerline. Check gap using a go & no-go gauge and record gauge size as applicable. This measurement provides weld joint peaking and alignment data for monitoring fabrication shrinkage, etc., and establishes reference points that describe clear aperture at the specific cross section.
   1. Go gauge size -- *eR* max. = 0.114"

5.0 COMPONENT INSPECTION (Continued)

E. Measure and record straightness using a standoff block (2") with string line and 1/32" graduated scale. Attach standoff block with string line at reference points established along length. Measure the distance from string line to side of beam tube. Take measurements at center line, ¼ points, and baffle locations.
   1. Tolerance -- ± 1/16"

F. Measure and record squareness and flatness of ends using a level fixture with sensitivity = 0.001"/10", 20 sec., a 1/32" graduated scale and a go & no-go gauge. Measure the distance from level fixture to end of beam tube. Take measurements at reference points established along length (and at middle points for flatness). Check gap using a go & no-go gauge and record gauge size as applicable. Measure the cut line and reference points using a scale.
   1. Tolerance: Cut Line, Reference Points & Machined End -- ± 0.005"
   2. Tolerance: Rough Cut End -- ± ¼"

5.3.4 Beam Tube Baffle/Support Rings have random measurements verified during receiving inspection. Review documentation provided within the applicable measurement record. The following measurements shall be recorded.

A. Measure and record circumference using a precision diameter tape accurate to ± 0.001" to obtain Outside Diameter (*Do*).
   1. Outside Diameter Tolerance -- ± 0.005"

B. Measure and record reference width before welding using a 0" to 6" Vernier Caliper accurate to ± 0.001" to obtain reference width and Inside Diameter (*DI*). Establish reference points on the outside of the ring at each 90° location. Take measurements at reference points and calculate the inside diameter.
   1. Width Tolerance -- ± 0.005"

C. Measure and record reference deviation (*eR*, see attachment 1) from the true circular form using an inside segmental circular template and go & no-go gauge. Measure the distance from template to inside surface of ring. Measure at each 90° point of the cross section relative the reference point established on the outside of the ring. Check gap using a go & no-go gauge and record gauge size as applicable. This measurement provides alignment data for monitoring fabrication shrinkage, etc., and establishes reference points that describe clear aperture at the specific cross section.
   1. Go gauge size -- *eR* max. = 0.114"

D. Measure and record thickness using a 0" to 6" Vernier Caliper accurate to ± 0.001". Take verification measurements at the outside edge of 0° & 180° centerlines.
   1. Thickness = 0.375" ± 0.005"

5.3.5 Beam Tube Stiffener Rings have random measurements verified during receiving inspection. The measurements taken at receiving inspection are used for verification of procurement requirements. Review documentation provided by the supplier.

5.0 COMPONENT INSPECTION (Continued)

5.3.6 Welded Baffles have no measurements verified during initial receiving inspection. Review documentation provided by the supplier. Final receiving inspection is performed at installation. A performance test shall be performed by the supplier that demonstrates acceptable geometry and traceability to each baffle.

5.3.7 Support Welded Attachment Members have random measurements verified during receiving inspection with random checks for general dimensions shown on vendor shop drawings.

5.3.8 Beam Tube Supports including related items have random measurements verified during receiving inspection with random checks for general dimensions shown on vendor shop drawings.

5.4 Assemblies Fabrication

5.4.1 Welded Beam Tube Assemblies shall be supported by equally (15 feet or less) spaced & level turning rolls and shall have temporary round out fixtures installed at each end. An Alignment acceptance test for a typical baffle installation shall be performed at each baffle location for all assemblies with baffles. The following measurements shall be recorded on a measurement record.

A. Measure and record circumference using a precision diameter tape accurate to ± 0.001" to obtain Outside Diameter (*Do*) within ½" to 2" from each end and at baffle and support ring locations.
   1. End -- *Do max.* = 49.004" & *Do min.* = 48.890"
   2. Baffle & Support -- *Do max.* = 49.004" & *Do min.* = 48.776"

B. Measure and record finished length using a 6" standoff block (with clamp), a tension clamp, and a 1/32" graduated steel tape. Measure and record temperature of the beam tube, steel tape and air. Stretch the tape to remove sag along the outside top centerline of the beam tube assembly and take measurements at reference points established for monitoring fabrication shrinkage, etc., and calculate the shrinkage and average finished length.
   1. Tolerance: finished Length -- ± 1/8"

C. Measure and record deviation (*eR*) from the true circular form using an outside segmental circular template and go & no-go gauge within ½" to 2" of ends and at support & baffle ring cross sections. Measure the distance from template to surface of beam tube. Measure at each 90° point of the cross section relative to the weld joint centerline. Check gap using a go & no-go gauge and record gauge size as applicable. This measurement provides alignment data for monitoring installation shrinkage, etc., and establishes reference points that describe clear aperture at the specific cross section.
   1. Go gauge size -- *eR* max. = 0.114"

D. Measure and record cylindrical straightness using a standoff block (6") with string line and 1/32" graduated scale. Attach standoff block with string line at reference points established for length. Measure the distance from string line to side of beam tube. Take measurements at center line, ¼ points, and support & baffle ring locations.
   1. Tolerance -- ± 1/16"

CBI	IDENTIFICATION DC			
TITLE DIMENSIONAL CONTROL PROCEDURE FOR LIGO	REFERENCE NO. 930212		SHT 6 OF 10	
	OFFICE		REVISION 0	
PRODUCT	MADE BY WRL	CHKD BY	MADE BY	CHKD BY
	DATE 03/30/94	DATE	DATE	DATE

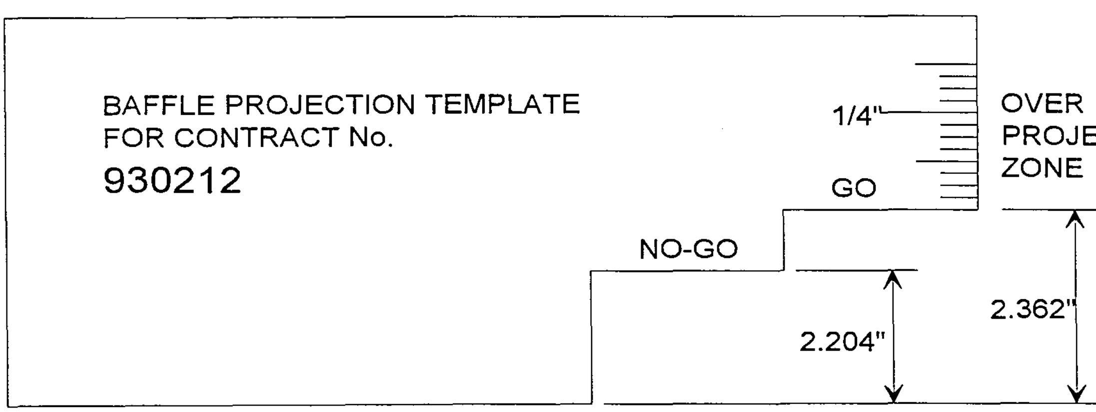
5.0 COMPONENT INSPECTION (Continued)

E. Measure and record squareness and flatness of ends using a level fixture with sensitivity = 0.001"/10", 20 sec., a 1/32" graduated scale and a go & no-go gauge. Measure the distance from level fixture to end of beam tube. Take measurements at reference points established along length (and at middle points for flatness). Check gap using a go & no-go gauge and record gauge size as applicable. Measure the cut line and reference points using a scale.
   1. Tolerance: Machined End -- ± 0.005"

F. Measure and record final baffle locations after welding using a 1/32" graduated steel tape. Stretch the tape to remove sag along the outside top centerline of the beam tube assembly. Recording the baffle locations is verification of all related dimensions shown in shop drawings. Take measurements along the top reference points.
   1. Tolerance -- + 0" & - ¼"

G. Measure and record baffle projection using a typical baffle and a go & no-go template (See fig. 5.5.1.H). Measure the distance from the baffle protruding edge to the beam tube inside surface. The measurements shall be taken at the following places.
   1. At each end within ½" to 2"
   2. At each side of weld joint within ½" to 2"
   3. At section mid points

   Check over projection between template and baffle protruding edge using 1/32" graduated scale on template. When applicable this measurement is used to correct an alignment acceptance test.
   1. Tolerance: Template -- ± 0.001" for go & no-go step heights
   2. Tolerance: over projection -- +0"



362
204
.ϕ58
Δh = 4 mm

Figure 5.5.1.H

5.0 COMPONENT INSPECTION (Continued)

H. Measure and record expansion joint nominal length using a 1/32" graduated steel tape. Stretch the tape to remove sag along the outside top centerline of the beam tube assembly. Recording the expansion joint nominal length is verification of all related dimensions shown in shop drawings. Take measurements along the top reference points.
   1. Tolerance -- ± ¼"

I. Measure and record pumping port centerline locations along length of beam tube assembly using a 1/32" graduated steel tape. Stretch the tape to remove sag along the outside top centerline of the beam tube assembly. Establish a reference point at the top centerline of the beam tube assembly relative to the pumping port centerline. Recording the pumping port location is verification of all related dimensions shown in shop drawings. Take measurements along the top reference points.
   1. Tolerance -- ± ½"

5.4.2 Beam Tube Baffle/Support Rings have measurements verified during assembly fabrication. Continue documentation within the applicable measurement record. The following measurements shall be recorded.

A. Measure and record circumference using a precision diameter tape accurate to ± 0.001" to obtain Outside Diameter (*Do*).
   1. Outside Diameter Tolerance -- ± 0.005"

B. Measure and record width (including gap) after welding using a 0" to 6" depth gauge accurate to ± 0.001" to obtain finished width and Inside Diameter (*DI*). Take measurements at reference points and calculate the inside diameter.
   1. Inside Diameter (*DI*) Tolerance -- ± 0.005"

C. Measure and record deviation (*eR*, see attachment 1) from the true circular form using an outside segmental circular template and go & no-go gauge. Measure the distance from template to outside surface of ring. Measure at each 90° point of the cross section relative to the reference point established on the outside of the ring. Check gap using a go & no-go gauge and record gauge size as applicable. This measurement provides alignment data for monitoring installation shrinkage, etc., and establishes reference points that describe clear aperture at the specific cross section.
   1. Go gauge size -- *eR* max. = 0.010"

5.4.3 Beam Tube Stiffener Rings have measurements verified during assembly fabrication.

5.5 Construction Installation

5.5.1 Welded Beam Tube Assemblies shall be installed in accordance with the contract drawings. The alignment procedure is used to measure and record final installation dimensions. The following measurements shall be recorded.

5.0 COMPONENT INSPECTION (Continued)

A. Measure installed baffle projection using a go & no-go template (see fig.5.5.1.H). Measure the distance from the baffle protruding edge to the beam tube inside surface. The measurements shall be taken at the following places.
   1. At each end within ½" to 2"
   2. At each side of weld joint within ½" to 2"
   3. At section mid points

1. Tolerance: Template -- ± 0.001" for go & no-go step heights

6.0 CALTECH SPECIFICATION DIMENSIONAL TOLERANCES

6.1 Clear Aperture -- Each beam tube module shall have a minimum clear aperture of **1.07** m (See Caltech Specification No. 1100004, Figure 4.).

6.2 Beam Tube Height -- The beam tube axis nominal height is approximately 1.1 m above the slab plane. The X & Y coordinates furnished by Caltech for each reference monument location at 250 m intervals (See Caltech Specification No. 1100004, Section 3.1.5.c & Figure 4.).

6.3 Baffle Spacing -- No baffles shall be installed within 100 m of any corner station, mid station, and end station. A 6 m baffles spacing is required within 250 m of any corner station, mid station, and end station starting at 100 m. A 20 m baffles spacing is required for the balance (See Caltech Specification No. 1100004, Figure 2.).

6.4 Pumping Port Spacing -- Starting at 250 m from any corner station, mid station, mid point joint, and end station a 250 m ports spacing is required for each beam tube module (See Caltech Specification No. 1100004, Figure 2.).

6.5 Beam Tube Section Support Alignment Adjustment Range -- An adjustment range of ± 7.5 centimeters (cm) in both the vertical and horizontal is required (See Caltech Specification No. 1100004, Section 3.1.5.c.).

7.0 ASME CODE, SECTION VIII DIV. 1 DIMENSIONAL TOLERANCES

7.1 See attachment 1 for dimensional tolerances.

8.0 RECORDS

8.1 Measurement Record & Check List shall be initiated and completed by the Welding & QC Supervisor or a designated inspector. The forms shall show necessary calculations, theoretical dimensions, verifications, and blanks to record actual dimensions measured. The number of measurements to be taken shall be indicated on the form. The equipment identification including serial number shall be recorded on the form as necessary.

CBI	IDENTIFICATION DC			
TITLE DIMENSIONAL CONTROL PROCEDURE FOR LIGO	REFERENCE NO. 930212		SHT 9 OF 10	
	OFFICE		REVISION 0	
PRODUCT	MADE BY WRL	CHKD BY	MADE BY	CHKD BY
	DATE 03/30/94	DATE	DATE	DATE

8.0 RECORDS (Continued)

8.2 Taking and recording measurements is a continuous activity throughout fabrication and installation. Identify actual dimensions measured relative to the assembly fabrication and construction completion sequence. Complete verifications of location of beam tube components and establish reference marks at specified points before components become inaccessible. Minimize multiple generation reference points or temporary reference marks to avoid degradation of measurements.

8.3 Submit the completed measurement record & check list to the Project Manager for inclusion into the final record package.

9.0 ATTACHMENTS

9.1 Attachment 1 -- ASME requirements

9.2 Attachment 2 -- (Typical) Measurement Record & Check List Form **DC.1**

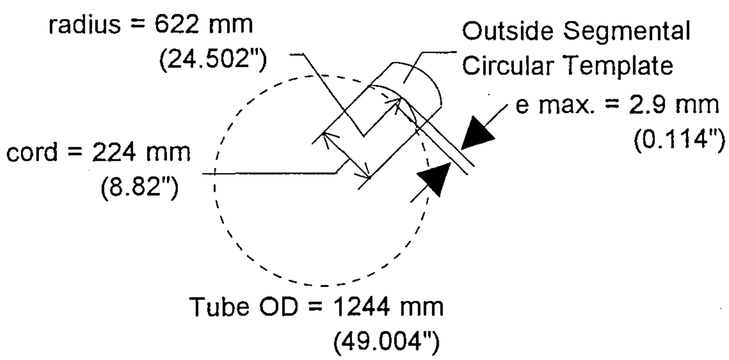
ATTACHMENT 1

A.1.1 **UG 80 -- Permissible Out-of-roundness of Cylindrical Shells**
"UG-80 (b) External Pressure. The shell of a completed vessel to operate under external pressure shall meet the following requirements at any cross section."

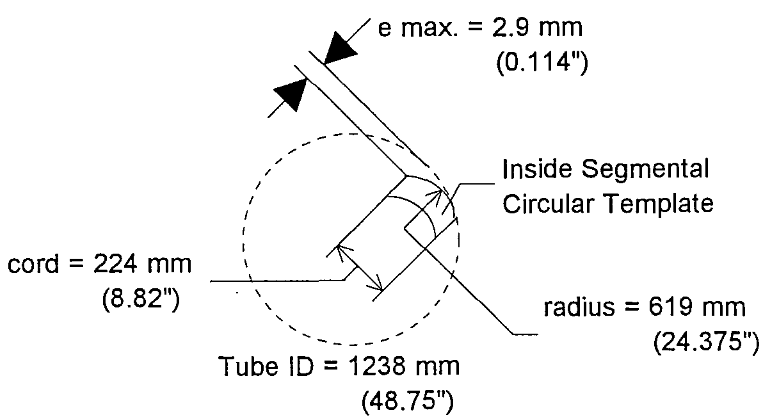
A.1.2 Paragraph UG-80 (b) (1) [Out-of- roundness limitations] -- At any cross section, D max. - D min. = 24.76 mm (0.975") within 1.238 m (48.75") from the center of an opening and 12.38 mm (0.487") at any other location.

A.1.3 Paragraph UG-80 (b) (2) -- [Deviation (*e*) from the true circular form]:

1. Outside segmental circular template dimensions, radius = 622 mm (24.502"), cord length = 224 mm (8.82") & *e* max. = 2.9 mm (0.114").



2. Inside segmental circular template dimensions, radius = 619 mm (24.375"), cord length = 224 mm (8.82") & *e* max. = 2.9 mm (0.114")



CB&I MEASUREMENT RECORD & CHECK LIST

Description		CBI				
Seq. No.	Operation, Inspection, or Examination to be completed	Applicable Procedure or Instruction	Init. Req'd "X"	Operation Insp. or Exam Accepted Initial	Date	REMARKS:

Made By	Chk'd By	Rev.	By				Contract Number 930212	No. ______
Date	Date		Chk'd					Sheet ___ of ___
			Date					

CBI

DOC. ID	MODSEQ
REV. NO.	1
CONTRACT	930212

TITLE FINAL ALIGNMENT AND MODULE TESTING SEQUENCE FOR LIGO.

Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	GLW	2/4/94
REVISED	KHF	3/14/94
AUTHORIZED		
REFERENCED STANDARD	REV. NO.	

1.0 Scope

This procedure outlines the final installation and testing sequences to be followed during the testing of the of the beam tube modules after all beam tube can sections have been installed.

Detail or supporting procedures for final alignment and testing are referenced as required. See paragraph 3.0 for listing.

The sequence is based upon the following conditions:

1.1 All beam tube can sections for the beam tube module to be tested have been successfully HMS tested at time of fabrication, final cleaned and installed. The installed beam tube can sections have also had the closing weld joints HMS tested and locally cleaned.

1.2 All isolation valves to pump ports, LN2 pumps, accessories, and RGA monitoring equipment have been installed and commissioned and flange seals to pump ports and have been successfully HMS tested and locally cleaned. (At present, LN2 pumps etc. are not in the workscope, only the installation of the valves and blind covers are included.)

****

Note

LN2 Pump Furnish and Installation
Is By Others.

****

1.3 The permanent vacuum pump sets for the applicable beam tube module havebeen installed at each end of the module, tested and are operational. (INSTALLATION BY OTHERS)

1.4 Preliminary alignment has been completed and all supports are grouted.

****
Reference

See
Final Alignment and Maintenance
of Beam Tube Modules
Doc ID "ALI-B"
****

1.5 Beam tube module precast concrete cover has been installed by others.

2.0 <u>Final Alignment and Testing Sequence</u>

2.1 Perform final alignment on each beam tube can section verifying alignment of the beam tube module.

****
Reference

See
Final Alignment and Maintenance
of Beam Tube Modules
Doc ID "ALM-B"
****

2.2 Complete alignment records and reports.

2.3 Perform helium mass spectrometer performance test of beam tube module. See Section 3.0 of procedure HMST4N

****
Reference

See
Helium Mass Spectrometer/Performance
Test of Beam Tube Module
Doc ID "HMST4N"
****

2.4 Complete HMS records and reports.

2.5 Skip step 2.6 if the results indicate no or acceptable inleakage.

2.6 Perform helium mass spectrometer hood test of beam tube module if step 2.3 was not acceptable.

****
Reference

See
Helium Mass Spectrometer Hood
Test of Beam Tube Module
Doc ID "HMST5N"
****

2.6 Install, Inspect & Accept insulation of modules (by Others).

2.7 Install, inspect and checkout I^2R Bakeout equipment and controls.

2.8 Perform bakeout of beam tube module under vacuum and testing per HMST4N.

****
Note

Bakeout of Beam Tube Module
Is By Others.
****

2.9 If during bakeout, unacceptable leakage rates are recorded, see "HMST5N" for decision tree and appropraite remedial operations.

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	RWK	6-20-88
REVISED		
AUTHORIZED	CNS	6-21-88
REFERENCED STANDARD		REV. NO.

1.0 SCOPE

This general visual inspection technique procedure is to be used with the procedure for the applicable referencing Code or Standard.

2.0 PERSONNEL:

Experienced personnel shall perform the inspections outlined in this procedure.

3.0 EQUIPMENT

3.1 Fillet weld gauges, weld reinforcement gauges and measuring tapes.

3.2 Two cell (C or D) flashlight or brighter light source.

3.3 Wire Brushes and/or Grinding Wheels - For stainless steel and nickel base alloy material, use wheels and 300 Series stainless brushes that have not been previously used on carbon or low alloy steels.

3.4 If necessary, cleaning agents such as iso-propyl alcohol, Tri-sodium phosphate, Dubl-Chek DR-60 or equal.

NOTE: When examining nickel base alloys or austenitic stainless steels, cleaning agents shall be analyzed individually for residual total sulfur, chlorine and fluorine content in accordance with Section V, Article 6, paragraph T-625. For nickel base alloys, the residual total sulfur content shall not exceed one (1) percent by weight. For austenitic stainless steels, the residual total chlorine and fluorine content shall not exceed one (1) percent by weight. CBI shall obtain certification of test results for each material, including batch number, if applicable. Cleaning agents purchased with known chemical composition do not require analysis.

3.5 If necessary, visual aids, such as mirrors, magnifying lenses, etc.

4.0 PROCEDURE

4.1 Prepare and clean the weld surface to be inspected.

4.1.1 Remove weld spatter, slag and flux with descaling tools, wire brushes, grinding wheels or other suitable means. Use stainless wire brushes when brushing austenitic or nickel base alloy material.

4.1.2 As necessary, clean welds of dirt, oil, grease or other substances that might interfere with the examination using a cleaning agent as listed in paragraph 3.4.

4.2 While performing the inspection, natural or artificial lighting shall be adequate to illuminate the surface being examined to a minimum of fifty (50) footcandles. Illumination from any one of the following light sources or a brighter light source is adequate:

Light Source	2D Cell Flashlight	60 Watt Bulb	75 Watt Bulb	100 Watt Bulb
Maximum Source to Object Distance in inches (mm)	10(254)	10(254)	15(381)	18(457)

4.3 If possible, the surface being inspected shall be viewed without visual aids. However, visual aids such as mirrors, magnifying lenses, etc. may be used if access to the surface being examined is not easily achieved.

4.4 Personnel performing direct visual inspections shall have access sufficient to place the eye within 24 inches (610mm) of the surface to be inspected and at an angle not less than 30 degrees to the surface to be inspected. If the use of visual aids is required, the resolution capability shall be at least equivalent to that obtainable by direct visual observation.

4.4 (continued)

This may be demonstrated by the inspector being able to see a fine line, 1/32 inch (1.0mm) wide or less, or other artificial flaw on the surface (or a surface similar to that being examined) in the least discernible (viewable) location of the area being examined.

4.5 If required by the applicable Code or Standard, inspect joints after fit-up, but before welding, for correct weld edge prep, gap and alignment.

4.6 After welding, inspect welds for surface indications and appearance and measure at representative locations for adequacy of size, concavity, convexity (if applicable), reinforcement and length using gauges and measuring tapes.

4.7 Where readily accessible for viewing without visual aids, inspect the root surface of single sided welds to determine the amount of penetration (protrusion) or concavity (suck up).

CBI

DOC. ID	VI8
REV. NO.	2
CONTRACT	STANDARD

TITLE VISUAL INSPECTION REQUIREMENTS FOR ASME SECTION VIII CODE - DIVISION 1 & 2 PRESSURE VESSELS

APPROVED

Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	RWK	9-1-89
REVISED	HKH	5-10-91
AUTHORIZED	CNS	5-10-91
REFERENCED STANDARD---	REV. NO. -	
u Code Update	HKH	9-3-93

1.0 SCOPE:

This procedure contains the ASME Section VIII Code visual inspection acceptance criteria requirements for completed welds and is to be used with the applicable standard or contract "X" or "N" general Visual Inspection Technique Procedure VI5.

2.0 REFERENCE

2.1 1989 ASME Section VIII Code or with any of the following Addenda: '89, '90, '91

u 2.2 1992 ASME Section VIII Code or with any of the following Addenda: '92

3.0 ACCEPTANCE CRITERIA:

3.1 As-welded surfaces are permitted, provided the surface of welds are sufficiently free from coarse ripples, grooves, overlaps, and abrupt ridges and valleys.

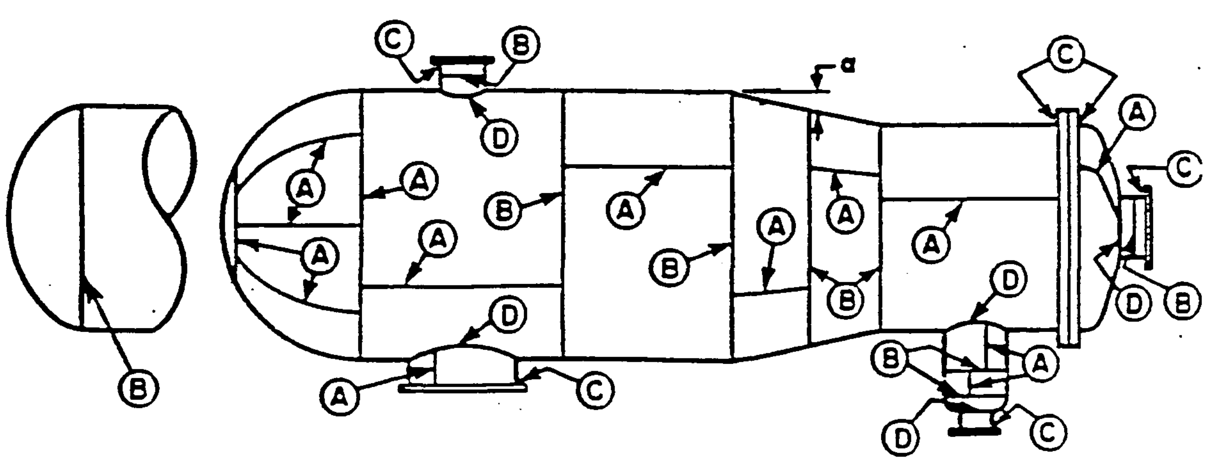
3.2 The surface condition of the finished weld shall be suitable for proper interpretation of radiographic and other required nondestructive examinations when these examinations are required by contract drawings.

3.3 Undercut shall not exceed 1/32 inch (0.8mm) or 10% of the nominal thickness of the adjoining surface, whichever is less.

3.4 The surface of butt welded joints may be flush with the base material or may have uniform crowns. The height of reinforcement for each weld surface shall not exceed the following:

Nominal Wall Thickness(T), in. (mm)	Maximum Reinforcement, in. (mm) — Circumferential Joints in Pipe and Tubing — Division 1	Division 2	Other Welds Div. 1 & 2
Less than 3/32 (2.4)	3/32 (2.4)	3/32 (2.4)	1/32 (0.8)
3/32 to 3/16 (2.4 to 4.8), incl.	1/8 (3.2)	3/32 (2.4)	1/16 (1.6)
Over 3/16 to 1/2 (4.8 to 12.7), incl.	5/32 (4.0)	1/8 (3.2)	3/32 (2.4)
Over 1/2 to 1 (12.7 to 25.4), incl.	3/16 (4.8)	5/32 (4.0)	3/32 (2.4)
Over 1 to 2 (25.4 to 51), incl.	1/4 (6.4)	5/32 (4.0)	1/8 (3.2)
Over 2 to 3 (51 to 76), incl.	1/4 (6.4)	5/32 (4.0)	5/32 (4.0)
Over 3 to 4 (76 to 102), incl.	1/4 (6.4)	7/32 (4.0)	7/32 (5.6)
Over 4 to 5 (102 to 127, incl.	1/4 (6.4)	1/4 (6.4)	1/4 (6.4)
Over 5 (127)	5/16 (7.9)	5/16 (7.9)	5/16 (7.9)

3.5 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.



3.6 Offset of final butt welded joints shall not be greater than that shown in Table 1.

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

TABLE 1

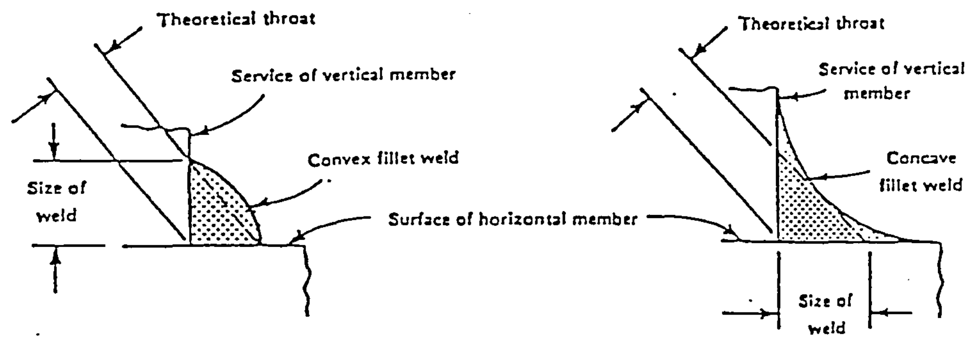
	Joint Categories	
Section Thickness, in. (mm)	A	B, C, & D
Up to 1/2 (12.7), incl.	1/4t	1/4t
Over 1/2 to 3/4 (12.7 to 19), incl.	1/8 in. (3.2)	1/4t
Over 3/4 to 1-1/2 (19 to 38), incl.	1/8 in. (3.2)	3/16 in. (4.8)
Over 1-1/2 to 2 (38 to 51), incl.	1/8 in. (3.2)	1/8t
Over 2 (51)	Lesser of 1/16t or 3/8 in. (9.5)	Lesser of 1/8t or 3/4 in. (19)

3.7 Any offset within the allowable tolerance of Table 1 shall be faired 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.

3.8 Fillet Welds

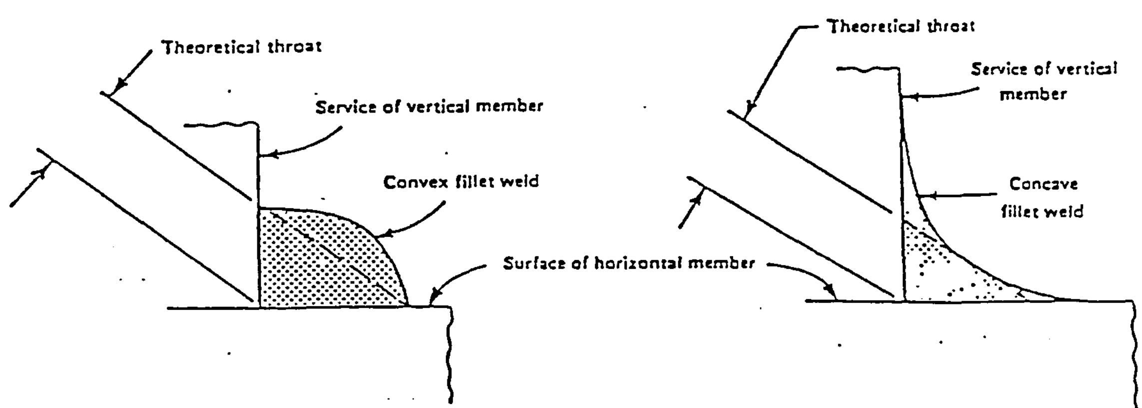
3.8.1 Fillet welds may vary from convex to concave.

3.8.2 The size of the fillet weld shall be determined as follows:



NOTE: The size of an equal leg fillet weld is the leg length of the largest inscribed right isosceles triangle. Theoretical throat = 0.7 X size of weld.

(a) Equal Leg Fillet Weld



NOTE: The size of an unequal leg fillet weld is the shorter leg length of the largest right triangle which can be inscribed within the fillet weld cross section.

(b) Unequal Leg Fillet Weld

3.9 Cracks or other linear indications in welds are unacceptable.

CBI	IDENTIFICATION CLCOUP			
TITLE STEAM CLEANING OF COUPONS FOR OUTGASSING TEST	REFERENCE NO. 930212		SHT 1 OF 5	
	OFFICE		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES DESIGN & QUALIFICATION TEST	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 03/30/94	DATE	DATE	DATE

1.0 SCOPE:

This procedure covers the steam cleaning of coupons cut from plate material.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning performed in accordance with this alternate procedure.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 For those coupons being shipped to Caltech, package and ship per Caltech instructions (see step 5.18 of this procedure).

4.0 EQUIPMENT AND MATERIALS:

4.1 Lint free cloths or paper towels.

4.2 100 Watt blacklight with 3650 Angstrom unit wavelength.

4.3 Blacklight meter capable of measuring at least 800 μ/cm^2.

4.4 Electric hot air dryer.

4.5 Steam cleaner (Jenny) with a heater coil and a dead man type hand held sprayer.

4.6 Two (2) vinyl polyester recovery containment pallet systems for catching and retaining the used cleaning and rinse solutions.

4.7 Clean Nitrilite chemical resistant gloves and neoprene or other chemical resistant apron or coveralls, face shields or goggles with side shields and foot coverings as needed.

4.8 Caltech supplied Ameristat packaging plastic.

4.9 Electrical tie wraps.

4.10 Clean metal channel locks.

4.11 Stainless steel 304L heat treated material for the qualification test beam tube and other components.

4.12 J Type thermocouple.

4.13 Digital thermocouple readout unit.

5.0 PROCEDURE:

5.1 Shear the coupons from the heat treated stainless steel material.

5.2 Adjacent to the steam jenny, place two (2) vinyl polyester recovery containment pallet systems. One to catch and retain the used condensed steam liquid and the other to serve as a draining and drying rack for the coupons. The use of the second recovery system will prevent the draining and drying rack pallet grids from becoming contaminated with the condensed steam run-off and, in turn, possibly contaminating the cleaned coupons. This is in a protected area.

5.3 Turn on the steam cleaner heating coils.

5.4 Spray water from the steam cleaner spray nozzle into the sanitary sewer drain until it reaches the boiling point (turns to steam).

5.5 Remove the pallet grids from both vinyl polyester recovery containment systems. With the steam cleaner sprayer held only a few inches away, thoroughly spray the four pallet grids of the two vinyl polyester recovery containment systems to remove any dirt or other contaminants from their surface. After the pallet grids are steam cleaned, replace them on the interstices of the recovery systems.

5.6 Attach a thermocouple to the surface of one of the 1" x 18" hydrogen outgassing coupons approximately in the middle of the 18" length on the side opposite from the center punch mark.

5.7 Steam clean the channel locks to be used in the next step.

5.8 To steam clean the coupons, hold each coupon by the uncontaminated end with the set of channel locks cleaned in the previous step. For the coupon that is to be cut for surface analysis coupons, hold it by the end away from the center punch mark. When spraying with the steam cleaner, let the coupon hang down from the channel locks over the one recovery containment system. With the steam cleaner sprayer held only a few inches away, thoroughly spray all the surfaces of the coupon for a minimum of fifteen (15) seconds to a maximum of twenty (20) seconds. When spraying is partially complete, momentarily place the coupon in a groove between a pallet grid and the interstices of that recovery system. Lift the coupon again with the channel locks shifted a few inches on the coupon to expose the coupon area previously covered by the channel locks. Complete the steam spraying of that coupon. Also monitor the thermocouple reading during the steam cleaning of that coupon and record the maximum coupon surface temperature noted.

5.9 While still holding the steam cleaned coupon with the channel locks, stand it on end by placing one end of the coupon in one of the grooves between a vinyl polyester pallet grid and the interstices of the previously unused vinyl polyester recovery containment system.

5.10 Repeat steps 5.8 and 5.9 for each coupon. When standing them on end to dry, set them 2" to 3" inches apart.

5.11 Allow the coupons to air dry. Only use the electric hot air dryer if the humidity is so high as to prevent rapid drying.

5.12 After the coupons are thoroughly dry, place a dust/mist respirator over one's mouth and nose. Just before handling the coupons, put on clean Nitrilite chemical resistant gloves. Be careful not to touch the outside of the gloves with the hands. While wearing the respirator and the gloves, wrap all of the coupons in a piece of Ameristat plastic laid on a cart with the inside surface of the roll turned upward. Fold the plastic over the coupons for protection and carry them to a darkened lab room.

5.13 Dispose of the cleaning/rinse condensed steam liquid by flushing it into the sanitary sewer.

5.14 Excluding the coupon with the thermocouple attached, blacklight inspect all the other cleaned coupons for hydrocarbon contamination as follows:

5.14.1 Turn on and warm up the blacklight for a minimum of five (5) minutes.

5.14.2 The examiner shall be in the darkened area for at least five (5) minutes to allow time for eye adaptation to the darkness prior to viewing the coupon surfaces. If the examiner wears glasses or lenses, they shall not be photosensitive.

5.14.3 Confirm the maximum distance at which the blacklight produces 800 $\mu w/cm^2$ on the examination surface using the blacklight meter.

5.14.4 Put on new clean Nitrilite gloves before handling any coupons in the darkened area.

5.14.5 In the darkened area, blacklight inspect all surfaces of all coupons. During the inspection, hold the blacklight no further or no closer from the examination surface than the distance established in step 5.14.3. Use extra care when inspecting the previously contaminated center punched surface of each coupon.

5.14.6 If the blacklight inspection reveals no hydrocarbon contamination (no fluorescent glow at 800 μ w/cm^2) on the surfaces of the coupons, proceed to step 5.15. If the blacklight inspection reveals residual amounts of hydrocarbon contamination, void this cleaning method procedure as inadequate.

5.15 For those coupons to be outgas tested by CBI, place those coupons in the CBITS ougassing test chamber following the handling instructions in step
5.12. For those coupons to be shipped to Caltech, proceed to step 5.16.

5.16 Package and ship hydrogen outgassing coupons to Larry Jones at Casltech in accordance with the Caltech instructions given as follows:

5.16.1 Place a piece of Ameristat film on a bench with the inside surface of the roll turned upward to provide a clean work surface.

5.16.2 Handle all coupons and film only when wearing dust/mist respirators and clean Nitrilite chemical resistant gloves.
5.16.3 Wrap twelve (12) hydrogen outgassing coupons to a bundle.

5.16.3 Wrap twelve (12) outgassing coupons to a bundle.

5.16.4 Keep the inside surface of the film roll toward the inside surface of the package being wrapped. Limit film handling to outside edges only.

5.16.5 Wrap coupons with at least two (2) layers of film so that the outside edges do not come in direct contact with the coupons. Accomplish this by rolling the film around the short dimension of the coupons.

5.16.6 Secure the film around the bundle with two (2) or more electrical tie wraps.

5.16.7 Label each bundle with the date wrapped, the identification of the cleaning procedure used to clean the coupons and the maximum coupon surface temperature noted during cleaning.

CBI	IDENTIFICATION CLCOUP			
TITLE STEAM CLEANING OF COUPONS FOR OUTGASSING TEST	REFERENCE NO. 930212		SHT 5 OF 5	
	OFFICE		REVISION 0	
PRODUCT LIGO BEAM TUBE MODULES DESIGN & QUALIFICATION TEST	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 03/30/94	DATE	DATE	DATE

5.16.8 Pack the wrapped 0.115" x 1" x 18" outgassing coupon bundles in a corrugated box. Add filler packing material as necessary for protection against possible shipping damage.

5.16.9 Label the box and ship these outgassing coupons via Airborne, Fedex or UPS to:

California Institute of Technology
Attention: Larry K. Jones 102 - 33
Pasadena, CA 91125

CBI

TITLE	IDENTIFICATION CL1N			
CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE LEAK TESTING AND FINAL ASSEMBLY - CALTECH	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 04/05/94	DATE	DATE	DATE

1.0 SCOPE:

This procedure covers the on-site solvent spot cleaning followed by the on-site final steam cleaning for completed beam tube can sections after being helium mass spectrometer leak tested and before being installed and welded into final position. Use this procedure with procedure LIGOCP.

2.0 PERSONNEL CLOTHING REQUIREMENTS:

2.1 Personnel entering beam tube can sections prior to, during or following initial solvent spot or final steam cleaning, must be wearing white clean room style coveralls, white shoe covers over soft soled shoes or clean room type white boots, white caps and white gloves. Shoes with nails or other sharp projections must be removed.

2.2 Clean room clothing for use by anyone entering a beam tube can section must be cleaned on a regular weekly basis when in use or anytime it becomes obviously soiled with deposits of dirt, oil or grease.

3.0 EQUIPMENT AND MATERIALS TO BE USED WITH THIS PROCEDURE:

3.1 Materials listed in procedure LIGOCP.

3.2 White nylon coveralls, white shoe covers (booties), white head covers and white gloves.

3.3 Steam cleaner skid with circulation pumps, valves, hose, hose reels and jet cleaning head with adjustable tensioning legs for each can section cleaning station.

3.4 One variable speed power winch (tugger) with cable for each cleaning station for pulling the jet cleaning head through the can sections.

3.5 Propane gas or natural gas for firing the steam cleaner.

3.6 A minimum of two high volume air movers at each cleaning station.

3.7 No Smoking and Flammable Gas signs.

3.8 Plastic covers for sealing the ends of each can section after satisfactory final cleaning and drying.

3.9 Two inch (2") wide duct tape.

<table>
<tr><td rowspan="2">CBI</td><td colspan="4">IDENTIFICATION
CL1N</td></tr>
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<tr><td rowspan="2">TITLE
CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE LEAK TESTING AND FINAL ASSEMBLY - CALTECH</td><td colspan="2">REFERENCE NO.
930212</td><td colspan="2">SHT 2 OF 3</td></tr>
<tr><td colspan="2">OFFICE</td><td colspan="2">REVISION
1</td></tr>
<tr><td rowspan="2">PRODUCT</td><td>MADE BY
CNS</td><td>CHKD BY</td><td>MADE BY</td><td>CHKD BY</td></tr>
<tr><td>DATE
04/05/94</td><td>DATE</td><td>DATE</td><td>DATE</td></tr>
</table>

4.0 PROCEDURE:

See the cleaning set-up at the end of the procedure for a conceptual sketch of the following.

4.1 Post "No Smoking" and "Flammable Gas" signs around the entire cleaning area while cleaning operations are being performed.

4.2 Install high flow volume input and output fans at the opposite ends of each of the can section cleaning stations.

4.3 Install vent hoods above each cleaning station to rapidly remove steam cleaning vapor from the cleaning area.

4.4 Place a beam tube can section in the center of the cleaning station area with the output fan end of the can section elevated approximately two foot (2') (or more as necessary) above the input fan end.

4.5 Initially spot clean each can section as follows:

4.5.1 Wipe the blacklight and blacklight power lead cables with acetone and/or alcohol solvent to remove deposits of dirt, grease and oil before taking this equipment into the can section to be cleaned.

4.5.2 Put on white nylon coveralls, white shoe covers, white head cover and white gloves before entering the can section to be cleaned.

4.5.3 Starting at the end of the can section with the input fan, inspect the interior surface of the entire length of the can with the blacklight. Remove all deposits of hydrocarbons indicated by the blacklight using acetone and/or alcohol soaked lint free clean rags and/or paper towels.

4.5.4 Document completion of the initial spot cleaning of each can section by entry in the cleaning log book.

4.6 Final clean each can section as follows:

4.6.1 Connect the CBI cleaning skid to a source of potable tap water (soften as necessary) (see 4.1 of procedure LIGOCP).

4.6.2 At the low end of the can section to be final cleaned, install a receiving tank with a valved connection.

4.6.3 To the valve on the receiving tank, install a drain hose to the sanitary sewer.

CBI

TITLE	IDENTIFICATION: CL1N			
CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE LEAK TESTING AND FINAL ASSEMBLY - CALTECH	REFERENCE NO. 930212		SHT 3 OF 3	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 04/05/94	DATE	DATE	DATE

4.6.4 Turn on the steam cleaner. When the steam cleaner reaches operating temperature, proceed to step 4.6 5.

4.6.5 Connect a clean steam hose from the steam cleaner to the jet cleaning head.

4.6.6 Place the jet cleaning head at the high end of the can section to be cleaned. Adjust the jet cleaning head tensioning legs so that it is centered in the can.

4.6.7 Connect the cable from a power winch (tugger) to the end of the jet cleaning head. Connect the energy supply to the power winch.

4.6.8 When the jet cleaning head starts to rotate, energize the power winch (tugger) to start the jet cleaning head moving through the can section toward the low end at a rate of approximately two (2) feet per minute. Open the valve to the receiving tank to carry the condensed steam (used water) to the sanitary sewer. Reel up the excess steam hose as the jet cleaning head proceeds through the can section toward the low end.

4.6.9 When the jet cleaning head reaches the low end of the can section, turn off the power to the winch pulling the cleaning head and disconnect the jet cleaning head from the winch cable.

4.6.10 Vacuum all standing condensed steam from the bellows convolution of the can section expansion joint. Wipe the convolution dry using lint free rags or paper towels. The personnel doing this work must be wearing white nylon coveralls, white booties, white head covers and white gloves.

4.6.11 If an internal visual inspection of the can section indicates the cleaning is not adequate, repeat steps 4.6.8 through 4.6.10 as necessary until the internal visual inspection indicates the cleaning is adequate.

4.6.12 When the internal visual inspection of the can section indicates that the cleaning is adequate, proceed to step

4.6.16 As soon as the can section has air dried, install plastic covers over the ends and seal the covers to the outside of the can with duct tape to keep out all dirt and other contaminates. Move the sealed can section to the storage area to await installation in the beam tube module.

5.0 DOCUMENTATION:

Document as outlined in 5.0 of procedure LIGOCP the satisfactory completion of both the preliminary solvent cleaning and the final steam cleaning operations .

CBI	IDENTIFICATION CL2N			
TITLE MAINTENANCE OF PARTIALLY COMPLETED BEAM TUBE MODULES AFTER FINAL ASSEMBLY DURING CONSTRUCTION	REFERENCE NO. 930212		SHT 1 OF 4	
	OFFICE		REVISION 0	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 11/03/93	DATE	DATE	DATE

1.0 SCOPE:

This procedure covers the maintenance required to maintain the cleanliness integrity of partially completed beam tube modules during construction. Included is the spot cleaning requirements of the closing weld joint between can sections after welding of those joints is complete. Use this procedure with procedure LIGOCP.

2.0 PERSONNEL CLOTHING REQUIREMENTS:

Personnel entering the beam tube module and/or performing local internal cleaning of closing joints after local HMS hood testing of those joints is complete shall wear clean room type clothing consisting of lint free white overalls, head covers, shoe covers and gloves. No objects shall be carried in the pockets of individuals.

3.0 EQUIPMENT TO BE USED WITH THIS PROCEDURE:

3.1 A blower/drier/filtration system to be used at the starting end of the initially placed beam tube module. This system shall be capable of continually maintaining a positive flow of clean dry air through the partially completed beam tube module to ensure that no contaminants enter the beam tube module during construction.

3.2 A portable clean room to be used during the construction of each beam tube can section. This clean room will have an inflatable seal for sealing around the can section on the beam tube side of the clean room. This clean room will always be over/around the exposed open end of the last can section put in place for the beam tube module. The portable clean room will have a space between the work area and the outer exit that will act as a change room. The change room shall contain:

3.2.1 A storage area for unissued clean room clothing consisting of lint free white overalls, head covers, shoe covers and gloves.

3.2.2 Lockers or hooks for storing worn still clean clothing.

3.2.3 Materials for cleaning and bagging any construction equipment to be taken into the beam tube module.

3.2.4 An area for storing the cleaned internal baffles for later installation in applicable can sections after the closing weld joint between those can sections are completed and leak tested.

3.2.5 Rack containing purge gas for welding and purge gas for HMS leak testing with associated hoses and valves.

3.2.6 Rolls of polyethylene and duct tape for wrapping any cleaned equipment to be taken into the beam tube module.

3.2.7 Items 4.2 and 4.3 of procedure LIGOCP.

3.3 All-weather portable welding enclosure containing the fit-up and welding equipment for use on the exterior of all closing weld joints being fit-up and welded between can sections.

3.4 All-weather portable testing enclosure containing the helium mass spectrometer and associated leak testing equipment for use on the exterior of all completed closing weld joints between can sections.

3.5 Internal doughnut shaped inflatable purge dam/test hood enclosure for use for purging during welding of closing joints between can sections and for use as a helium hood during the helium mass spectrometer leak testing of closing joints between can sections.

3.6 Clean room clothing.

4.0 PROCEDURE:

See the conceptual cleaning maintenance set-up sketch at the end of this procedure.

4.1 Set up the blower/drier/filtration system at the start end of the beam tube module. As soon as the blower/drier/filtration system is ready to be energized, remove the plastic cleaning cover from the start end of the first beam tube can section and place it in position at the joint to the interconnecting station which will be housing the blower/drier/filtration system.

4.2 Install the portable clean room over the leading end of that beam tube can section. Pressurize the inflatable seals that seal the can side of the clean room around the can section. Remove the plastic cleaning cover from the leading end of that beam tube can section. Also immediately energize the blower/drier/filtration system so that dry filtered air is now passing through the first beam tube can section and escaping at the leading end through the check valve like flaps in the doors of the portable clean room.

4.3 Post a security guard inside the change room portion of the clean room with a sign-in and sign-out log for all personnel and a list of each item of equipment entering and leaving the beam tube module. Maintain the security guard 24 hours a day unless there is a physical barrier that can be locked to prevent personnel from entering the beam tube module. All personnel entering the beam tube module must have empty pockets. The posted security guard shall move with the portable clean room as it is moved from can section to can section.

4.4 Transport to the site the next beam tube can section to be installed.

4.5 Install a plastic cleaning cover on the leading end of the beam tube can section. If this cover will totally block the flow of clean dry air through the beam tube, make a slit in the plastic cleaning cover and tape a piece of polyethylene over the slit with the tape on only one edge so the polyethylene so that it can flutter to leave the air pass through. Deflate the inflatable seal around the can section. Then roll the portable clean room about 70' down the line away from the leading end of the can section.

4.6 Set the next can section within about 6" to 8" of the end of the beam tube can section to which it is going to be fit. Move the all-weather portable welding enclosure into place around the closing weld joint between these two can sections. After this welding enclosure is in place, remove the end cap on the trailing end of the new beam tube can section and then move it against the other can section in preparation for weld fit-up.

4.5 Roll the portable clean room back over the end of the leading can section and pressurize the circular inflatable seal around that can section.

4.6 Once the portable clean room is in place at the leading end of that next can section, remove the plastic cleaning cover from the leading end of that can section.

4.7 Once the plastic cover is removed from the leading end of the new beam tube can section, fit-up the weld joint between those two can sections. Then install the internal purge dam/test enclosure doughnut with inflatable seals. Inflate the purge dam seals and purge and weld the joint.

4.8 After the weld joint is welded complete, move the all-weather welding enclosure containing the fit-up and welding equipment part of the way down the leading can section to await the placement of the next can section.

4.9 Move the all-weather testing enclosure containing the helium mass spectrometer and associated leak test equipment into position over the completed weld joint. Perform the helium mass spectrometer final test of that weld.

4.10 After completion of the local helium mass spectrometer of the closing weld joint between the can sections, deflate the seals and remove the internal purge dam/ test enclosure from that joint. Move the purge dam/test enclosure with hoses toward the leading end of the tube module to the next weld joint. Locally clean the inside of the completed and leak tested weld joint area to remove all contaminates that may have resulted from these operations.

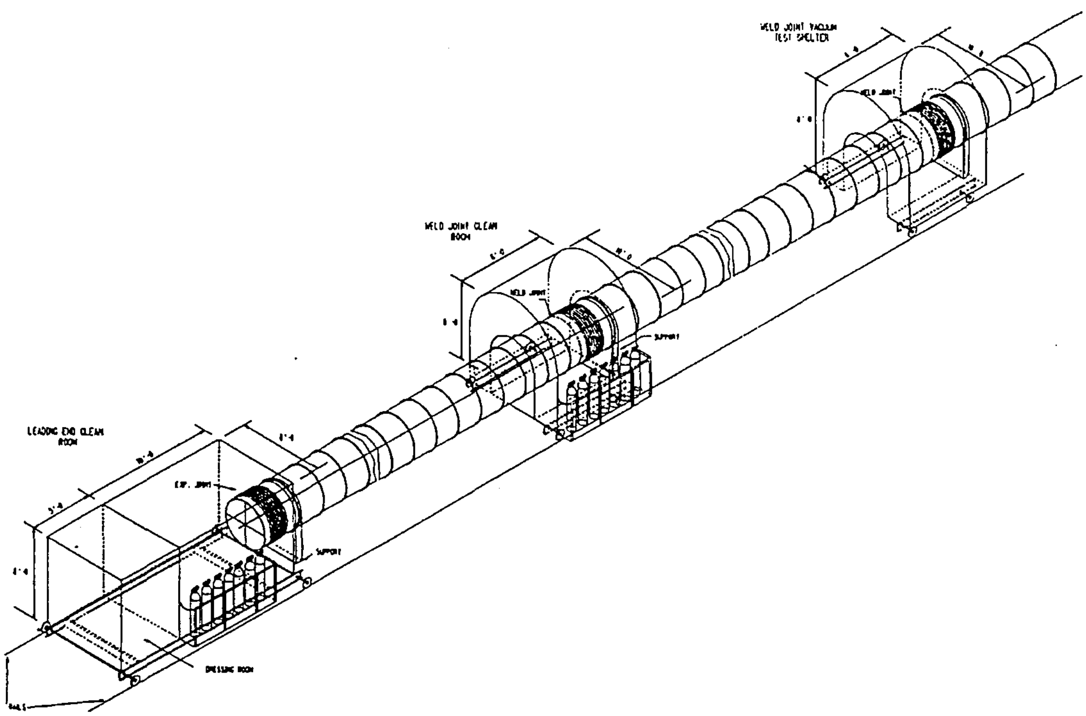
4.11 While the HMS test in steps 4.9 and 4.10 is being performed, transport to the site the next can section to be installed.

4.12 Repeat steps 4.5 through 4.11 for each of the can sections as they are installed.

	IDENTIFICATION CL2N			
TITLE MAINTENANCE OF PARTIALLY COMPLETED BEAM TUBE MODULES AFTER FINAL ASSEMBLY DURING CONSTRUCTION	REFERENCE NO. 930212		SHT 4 OF 4	
	OFFICE		REVISION 0	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY	CHKD BY
	DATE 11/03/93	DATE	DATE	DATE

5.0 DOCUMENTATION:

Document the completion of all events associated with this procedure in accordance with 5.0 of procedure LIGOCP.



CLEANING MAINTENANCE SET-UP SKETCH

CBI	IDENTIFICATION CL3N			
TITLE FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES - CLATECH PRODUCT	REFERENCE NO. 930212		SHT 1 OF 3	
	OFFICE		REVISION 1	
	MADE BY SDH	CHKD BY	MADE BY SDH	CHKD BY
	DATE 11/09/93	DATE	DATE 03/21/94	DATE

1.0 SCOPE:

This procedure details the requirements for final cleaning of the LIGO tube section from the weld area back to the end open to the clean room.

2.0 PERSONNEL:

2.1 Experienced personnel shall perform and supervise all cleaning in accordance with this planned approach and the cleaning referenced in this plan.

2.2 Personnel entering the inspection and cleaning room and/or the controlled area of the beam tube access penetration during final assembly operations shall meet the conditions and clothing requirements of CBI Wearing Apparel Procedure CRWA-1.

2.3 Personnel shall participate in a training course in which this procedure and any referenced procedure is presented by an authorized instructor. The course shall be documented by means of a written examination.

3.0 REFERENCES:

The following documents detail operations in conjunction to this activity. All references should be followed during the execution of this procedure.

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard practice for Cleaning and De-scaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 CBI Procedure:LIGOCP; "PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO PROJECT FOR CALTECH."

3.4 CBI Cleaning Procedure CL1N; "CLEANING OF COMPLETED BEAM TUBE SECTIONS AFTER LEAK TESTING AND BEFORE FINAL ASSEMBLY - CALTECH."

3.5 CBI Cleaning Procedure CL2N; "LOCAL CLEANING OF PARTIALLY COMPLETED BEAM TUBE MODULES AFTER CLOSING WELD AREA OF FINAL ASSEMBLY AND DURING CONSTRUCTION - CALTECH."

3.6 CBI Procedure LIGOVT1; "BLACKLIGHT INSPECTION PROCEDURE."

3.7 CBI Procedure LIGOCR1; "CLEAN ROOM TRANSPORTING, STORAGE AND MAINTENANCE."

3.8 CBI Procedure CRWA-1; "CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS DURING CONSTRUCTION AND INSPECTION ACTIVITIES."

4.0 EQUIPMENT:

4.1 See CBI Procedure CRWA-1 for complete listing or wearing apparel for Beam Tube and Clean Room Access.

4.2 The following is a listing of materials used for final cleaning of LIGO beam tube inner surfaces.

4.2.1 De-ionized water with a chlorine content in the range of 0.02 to 200 ppm.

4.2.2 Technical grade solvents as listed on an approved materials listing.

4.2.3 Lint free wiping cloths and/or paper towels.

5.0 PROCEDURE:

WARNING **ALL FACTORS GOVERNING "CONFINED SPACE" ENTRY INCLUDING DOCUMENTATION SHALL BE STRICTLY ENFORCED.**

5.1 After welding and testing activities are complete all inflatable purge dams shall be removed from the tube. All hoses shall be coiled in their respective bins and equipment stored inside the controlled area of the clean room..

5.2 All cleaning and inspection equipment entering the tube shall be inventoried and logged for accountability.

5.3 During final cleaning activities, the beam tube baffles shall be installed. work this procedure for all surfaces of the tube and baffles.

5.4 One cleaning person shall be allowed in the tube. Materials shall be mounted onto a dolly and moved down the tube to the weld joint with a black light.Inspect the tube surfaces per the approved procedure

5.5 Using a blacklight in the darkened tube area, the cleaner shall inspect the inner tube wall area directly in front of his location for dirt, debris and any deposits of hydrocarbons and chemicals. Areas found shall be contaminated shall be locally wiped with an approved solvent and allowed to dry. After inspection, the areas shall not be disturbed without re-inspection.

5.6 Document the tube designation and the final acceptance of the cleaning before moving from the tube location. Inventory all wiping cloths, solvent containers and equipment removed from the tube and compare with the initial inventory to assure all articles are removed from the tube. Document this inventory.

5.7 Close the tube end using a sealed cap equipped with a one direction vent flap to allow pressure to escape the tube.

6.0 DOCUMENTATION:

6.1 Documentation of the confined entry activities are required per OSHA and CBI safety procedures. Report forms shall be available from the site safety department.

6.2 Checklists shall be used for personnel entering the clean room areas, inventories of the equipment entering these areas, and inventories of equipment and materials entering the beam tube. See attached inventory form CR-01.

6.3 A Cleaning Inspection Report shall be completed with results of the final cleanliness inspection. This report shall document personnel performing cleaning, results of inspection and signed by the authorized inspector. See attached inspection form CR-02.

6.4 These records shall be turned into the QC Manager at the end of each shift. The final inspection turnover documents shall include these reports.

CBI

DOC ID CL3N
REV. NO. 1
CONTRACT 930212

TITLE: FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES - CALTECH

CBI LIGO

INVENTORY FORM
CLEAN ROOM

	DESCRIPTION OF EQUIPMENT/MATERIAL	BY	TIME	DATE
Line 01				
Line 02				
Line 03				
Line 04				
Line 05				
Line 06				
Line 07				
Line 08				
Line 09				
Line 10				
Line 11				
Line 12				
Line 13				
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Line 32				
Line 33				
Line 34				
Line 35				
Line 36				
Line 37				
Line 38				

Inspection/Date ______ Location: ______ Auditor ______

SUBJECT

CLEAN ROOM INVENTORY

CBI

SHT ______ OF ______

CBI

DOC ID CL3N
REV. NO. 1
CONTRACT 930212

TITLE: FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES - CALTECH

CBI
CHICAGO BRIDGE & IRON
LIGO PROJECT
CONTRACT No. 930212

Specification : CL3N
Date: ______
Time: ______ Beginning
______ Ending

TEST REPORT

TUBE LOCATION/POSITION ______
TUBE IDENTIFICATION ______

TEST EQUIPMENT:

BLACK LIGHT METER CALIBRATION:
INSTRUMENT IDENTIFICATION: ______ CALIBRATION DATE: ______

BLACK LIGHT CALIBRATION:
LIGHT SERIAL/REFERENCE No. ______ CALIBRATION DATE: ______

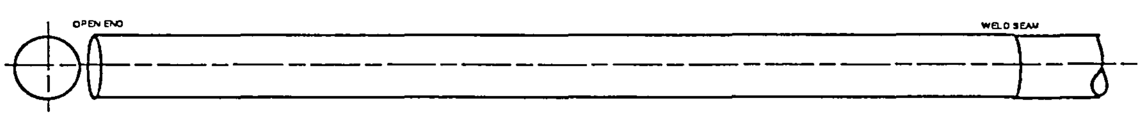
INSPECTION OF BEAM TUBE AS NOTED ABOVE HAS BEEN FOUND TO BE CLEAN AND ALL EQUIPMENT AND MATERIALS REMOVED. ______ INITIALS

TUBE END HAS BEEN SEALED AND POSITIVE AIR FLOW IS OBSERVED THRU THE ONE WAY VENT FLAP. ______ INITIALS

NAME ______
DATE: ______
SIGNATURE ______

REMARKS: ______

MAP ANY ANOMALIES BELOW



BEAM TUBE

DOC ID	CRWA-1
REV. NO.	0
CONTRACT	930212

TITLE: CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS DURING CONSTURCTION & INSPECTION ACTIVITIES- CALTECH

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	03-Mar-94
					REVISED	0	
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO.

1.0 SCOPE:

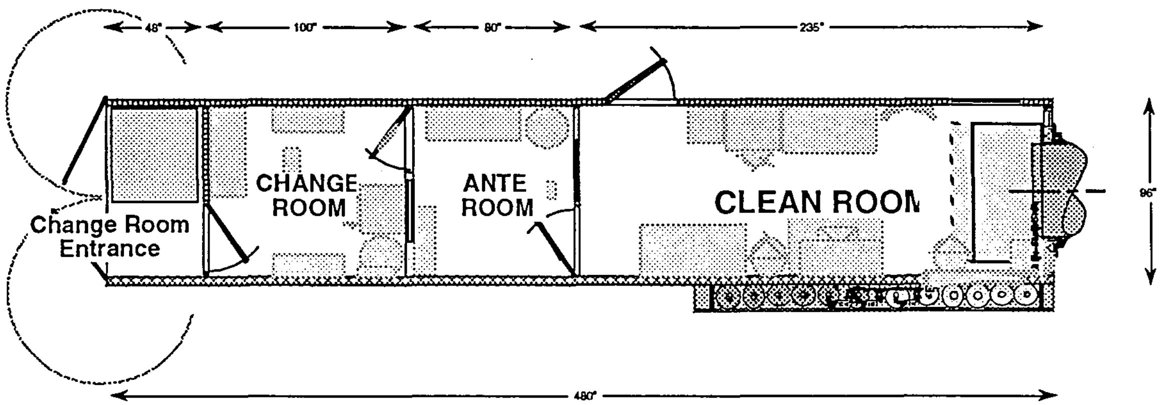
This procedure covers protective wearing apperal for Beam Tube Access through the Clean Room. All personnel entering beyond the Change Room[1] into the Ante and Clean Room shall be properly clothed and protected as noted in the following instructions.

2.0 PURPOSE:

The foremost importance of CBI's work is the personal safety of its employees. Standard safety precautions including eye protection, head & foot protection, and limited access procedures will be followed during these activities. In addition, proper personnel protection is requied when handling solvents during the cleaning process affiliated with the LIGO final spot cleaning activity.

The LIGO project's success is based on the ability to meet ultra high vacuum requirements inside the beam tube. This requirement would be compromised with a finger print or scuff mark left on a beam tube inner surface.

[1] The Clean Room Container has three rooms: Change Room, Ante Room and Clean Room. These rooms are detailed in Figure 1.1.



FIRGURE 1.1

It is critical for the personnel entering the beam tubes to take every precaution in avoiding contamination. These instructions are provided to assure all body surfaces be covered, with the possible exception of clean shaven faces, in order to prevent contact with the inner beam tube surfaces.

3.0 REFERENCES:

The alignment maintenance procedures for the Beam Tube Module are based on the following references:

3.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.

3.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.

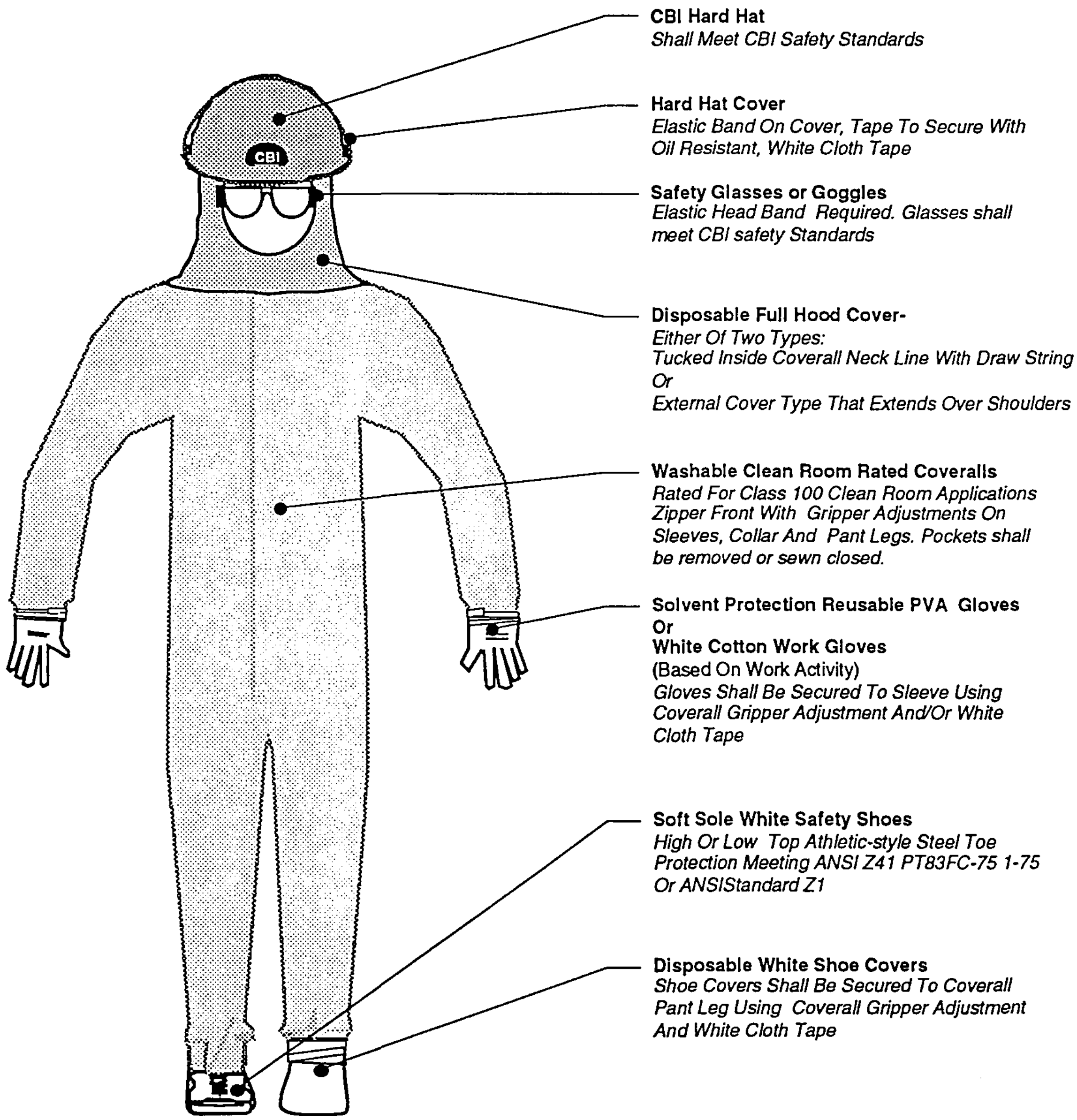
3.3 CBI Cleaning and Clean Room Procedures.

4.0 EQUIPMENT & MATERIALS:

The following is a listing of Safety Equipment and Wearing Apparel required for access into the Clean Room and final access into the Beam Tube.

4.1 CBI Hard Hat Meeting CBI Safety Standards.
4.2 Disposable Hard Hat Protective Cover.
4.3 CBI supplied Safety Glasses with side Shields meeting CBI Safety Standards.
4.4 Elastic Head Band for securing Safety Glasses to the technician.
4.5 Disposable White Hood for hair capture.
4.6 Washable white Coverall meeting Clean Room Class 100 specifications. All pockets shall be removed or permanetly sewn closed. Zipper front and elastic, chinch, or Velcro® closures on sleeves, neck and pant legs.
4.7 Solvent Protection, Re-usable PVA Gloves.
4.8 Cloth, Lint-free white gloves.
4.9 Soft Sole, White, Steel Toe Shoes rated for ANSI Z41, PT83FC-71 1-75 and CBI Safety Standards. Shoes shall be high or low top athletic style.
4.10 Disposable White Boot length Shoe Covers.
4.11 3/4" or 1" width Lint-free, White Cloth Tape.

See the following detail(Figure 4.1) for information. Substitution of the above equipment and/or materials shall be approved by site QA Manager.


CBI
CBI Hard Hat
Shall Meet CBI Safety Standards
Hard Hat Cover
Elastic Band On Cover, Tape To Secure With Oil Resistant, White Cloth Tape
Safety Glasses or Goggles
Elastic Head Band Required. Glasses shall meet CBI safety Standards
Disposable Full Hood Cover-
Either Of Two Types:
Tucked Inside Coverall Neck Line With Draw String
Or
External Cover Type That Extends Over Shoulders
Washable Clean Room Rated Coveralls
Rated For Class 100 Clean Room Applications Zipper Front With Gripper Adjustments On Sleeves, Collar And Pant Legs. Pockets shall be removed or sewn closed.
Solvent Protection Reusable PVA Gloves
Or
White Cotton Work Gloves
(Based On Work Activity)
Gloves Shall Be Secured To Sleeve Using Coverall Gripper Adjustment And/Or White Cloth Tape
Soft Sole White Safety Shoes
High Or Low Top Athletic-style Steel Toe Protection Meeting ANSI Z41 PT83FC-75 1-75 Or ANSIStandard Z1
Disposable White Shoe Covers
Shoe Covers Shall Be Secured To Coverall Pant Leg Using Coverall Gripper Adjustment And White Cloth Tape

<u>FIGURE 4.1</u>

5.0 APPAREL INSTRUCTIONS REQUIRED FOR CLEAN ROOM ENTRY

Clean Room access instructions are described in procedure CL3N. The following is a detailed set of instruction for wearing clean room compatable clothing.

5.1 Personnel shall remove street shoes when inside the Change Room and put on disposable shoe coverings over their sock feet. A lockable compartment(locker) is available for storing personal affects.

5.2 Personnel shall remove street cloths in the Change Room and suit up with CBI provided coveralls. Coveralls shall be clean and in good repair. All soiled garments shall be stored in a designated soiled storage bin and forwarded to the cleaning service for cleaning. Damaged garments shall be tagged with a description of the location and extent of tears, wear or if necessary removal from service.

5.3 Put on safety glasses and head band. Check that head band is secure to glasses and that all screws and shields are tight each time the glasses are removed.

5.4 Personnel shall install hood. If hood type is tucked into coverall collar, do so, and tighten gripper or draw string on coverall. If hood type is shoulder canopy type assure coverall collar is drawn before installing hood. Do not allow hair to extend outside face opening.

5.5 When the above steps are complete, personnel shall move into Ante Room for final dress-out. Assure outer door is closed when inside the Ante room.

5.6 Remove disposable shoe covers and if un-soiled, store in designated location. If soiled, place in designated waste Put on CBI supplied soft sole work shoes. Install NEW shoe covers and tuck covers into coverall pant legs. Tighten legs using coverall gripper and install a few wraps of white cloth tape over each pant leg and shoe cover.

5.7 Preclean all hard hats with solvent and install a new liner for each clean room technician. These hats shall be designated for clean room use only and stored in the Ante Room. Each entry requires that the hard hat and cover be inspected for rips, scuffs, dirt, etc. When necessary, remove cover and install new disposable cover and secure with white cloth tape. Install the Hard Hat before entering the Clean Room.

5.8 The disposable, white, lint-free cloth gloves for clean room access shall be installed inside the coverall sleeve cuff, cinched tight using the sleeve gripper or Velcro® strap and a apply a few wraps of white cloth tape to secure.

5.9 Store solvent Protection Gloves in the Flamable Materials Cabinet inside the Clean Room. Put on these gloves in the Clean Room over the white cloth gloves with the glove cuff over the coverall sleeve, or remove the white cloth gloves provided the solvent gloves are tucked into the sleeve of the coverall in a similar manner as the cloth gloves and secured by cinching the sleeve gripper or Velcro® and securing with white cloth tape.

5.10 Store respirators in the Clean Room as required. Care and cleaning shall conform the the CBI Safety requirements.

6.0 INSTRUCTIONS REQUIRED FOR CLEAN ROOM EXIT

Clean Room exit instructions are described in procedure CL3N. The following is a detailed set of instruction for the removing, storing and cleaning of clean room compatable clothing and equipment.

6.1 When exiting the Clean Room, remove Solvent Protection Gloves before entering the Ante Room. The gloves shall be inspected, cleaned and dried. If gloves are soiled or torn and cannot be re-used, then dispose of gloves in the flamable waste container. Clean and dry gloves shall be stored in the Flamable Materials Cabinet for re-use.

6.2 Enter Ante Room and remove white cloth gloves, hard hat and shoes. Inspect each item of disposable apparel and determine if it can be re-used again. If not, dispose in waste container. If re-usable, place the item in the designated "Used" container.

6.3 Personnel are to leave hard hats, soft sole shoes and disposable items in the Ante Room. Install "Used"(if any) shoe covers on stockened feet and proceed into the Change Room.

6.4 Personnel shall remove the disposable hood and discard it into the designated waste container.

6.5 Personnel shall remove the shoe covers and coveralls and dress into street clothes.

6.6 Personnel shall inspect the coveralls for rips, soiled areas and general cleanliness. If coveralls are acceptable, install in personal locker for reuse the following day. If there is to be more than a one day delay in returning to the clean room duty(weekend, holiday, etc.), dispose of the coverall into the soiled storage bin.

7.0 LAUNDRY SERVICE

Laundry service for clean room coveralls and shoes shall follow the routine noted below:

7.1 CBI shall purchase independently or through the Laundry Service, a quantity of specified coveralls estimated based on CBI/Laundry Service agreed delivery and pick-up schedules. This quantity will be estimated based on a six(6) technician crew size.

7.2 The Laundry service shall stitch closed all pockets and close any "thru the suit" openings to assure no objects may be stored inside the coveralls.

7.3 Repairs required during this service shall be made by the Laundry Service. CBI will inspect and tag areas requiring repair. If damage is caused by the Laundry service, they shall repair or replace coveralls at their expense.

7.4 Laundry service shall deliver and pick-up coveralls at a designated location on the construction site. Access schedules will be limited and an escort will be required for on-site travel.

7.5 Cleaning shall be performed using minimum amounts of detergent to avoid contamination of clean room and beam tube surfaces. An inspection of the laundry facilities by CBI will be required before contract award.

7.6 Periodic testing of coverall materials including detergents and bleach concentrations shall be performed by CBI. Any deviations form agreed upon amounts shall be corrected by the Laundry Service.

7.7 The Laundry Service shall notify CBI of any changes in detergents or cleaning processes. CBI will have the right to review and accept or reject changes.

7.8 At the end of the job, all coveralls found to be in satisfactory condition shall be delivered to CBI at the site, cleaned, packaged, and boxed for shipment.

7.9 CBI and the Laundry Service will determine the best method of cleaning soft soled shoes. At periods not exceeding 6 months, the shoes shall be cleaned over a CBI "down" period (weekend, holiday, work stoppage, etc,).

DOC. ID CLCOUP
REV. NO. 3
CONTRACT 930212

TITLE CLEANING OF WELDED AND PLAIN COUPONS FOR OUTGASSING TESTS CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	12-7-93
REVISED	CNS	12-28-93
AUTHORIZED		
REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

This procedure covers both the initial solvent cleaning of the plate material after it is ready for welding and the final Oakite 33 cleaning of the 0.115" x 1" x 18" coupons for the outgassing tests.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning performed in accordance with this procedure.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 Packaging per Caltech instructions.

4.0 EQUIPMENT AND MATERIALS:

4.1 Stainless steel power brushes used only for stainless steel.

4.2 Industrial grade 99% mol isopropyl alcohol.

4.3 Lint free cloths or paper towels.

4.4 100 Watt blacklight with 3650 Angstrom unit wavelength.

4.5 Blacklight meter capable of measuring at least 800 $\mu w/cm^2$.

4.6 Electric hot air dryer.

4.7 Litmus paper or ph meter.

4.8 One (1) five (5) gallon container of de-ionized water.

4.9 Oakite 33 mixed with the de-ionized water in a proportion of 2% by volume.

4.10 Oakite Enprox 714 for neutralizing the used Oakite 33 cleaning solution.

4.11 One (1) metal drum and one (1) heater for heating the de-ionized water and the Oakite 33 cleaning solution.

4.12 Metal or glass tube thermometer with a range in excess of 160°F.

4.13 Recovery system for catching and retaining the used cleaning and rinse solutions.

4.14 Neoprene or other chemical resistant gloves and apron or coveralls, face shields or goggles with side shields and foot coverings as needed.

4.15 Two (2) chemical resistant plastic 1 1/2 to 3 gallon pump type sprayers and one five (5) or ten (10) gallon chemical resistant plastic bucket.

5.0 PROCEDURE:

Steps 5.1 through 5.5 is to be used only for test coupons. This is due to the possible hydrocarbon contamination that may be present as a result of the coupon shearing operation.

5.1 Turn on and warm up the blacklight for a minimum of five (5) minutes.

5.2 The examiner shall be in the darkened area for at least five (5) minutes to allow time for eye adaptation to the darkness prior to viewing the surface . If the examiner wears glasses or lenses, they shall not be photosensitive.

5.3 Confirm the maximum distance at which the blacklight produces 800 $\mu w/cm^2$ on the examination surface using the blacklight meter.

5.4 In a darkened area, blacklight inspect the plate material that has been power brushed for welding back one inch (1") from each weld preparation edge. During the inspection, hold the blacklight no further from the examination surface than the distance established in step 5.3.

5.5 While being viewed under the blacklight, remove as much hydrocarbon contamination as possible from the power brushed plate material by flushing with isopropyl alcohol and wiping with lint free clothes or paper towels.

5.6 After all welding and shearing of coupons is complete, view all coupons, both welded and plain, in a darkened area with the blacklight. Repeat step 5.5 as necessary.

5.7 Arrange the coupons together in a chemically inert rack with a catch basin where the used Oakite 33 cleaning solution can be retained. If done outdoors, the cleaning area shall be covered and be protected from the wind so as to prevent contamination during and after cleaning.

5.8 Nearly fill both pump type sprayers with de-ionized water.

5.9 Mix a 2% by volume solution of Oakite 33 with the de-ionized water in one (1) of the pump type sprayers.

5.10 Place each pump type sprayer in a metal drum partially filled with tap water.

5.11 Heat the de-ionized water and the Oakite 33 cleaning solution in each of the pump type sprayers to a temperature of approximately 160°F by heating the tap water in the metal drum. Check the temperature of the de-ionized water and Oakite 33 cleaning solution with the thermometer.

5.12 With the pump type garden sprayer containing the 140°F to 160°F de-ionized water, thoroughly spray rinse the exposed surfaces of all coupons. While wearing clean neoprene rubber or chemical resistant gloves, turn over the coupons so that the opposite surface of the coupons is exposed. Then thoroughly spray those surfaces. Allow the used de-ionized water to run off into the catch basin.

5.13 With the pump type sprayer containing the 140° to 160°F Oakite 33 cleaning solution, thoroughly spray the exposed surfaces of all coupons. While wearing clean neoprene rubber or chemical resistant gloves, turn over the coupons so that the opposite surface of the coupons is exposed. Then thoroughly spray those surfaces. Allow the used cleaning solution to run off into the catch basin.

5.14 Wait for five (5) minutes and repeat step 5.13. Any time the catch basin becomes nearly full of used Oakite 33 solution, pump the used cleaning solution from the catch basin into an empty plastic container.

5.15 After five (5) minutes have elapsed, repeat step 5.12.

5.16 While wearing clean neoprene rubber or chemical resistant gloves, turn the coupons while directing the heat from an electric hot air dryer on the coupons to ensure that all surfaces are dry.

5.17 When the coupons are thoroughly dry, package the coupons in accordance with the Caltech packaging instructions.

5.18 Add Oakite Enprox 714 to the catch basin or plastic container of used Oakite 33 cleaning solution until the solution is neutralized to a ph of 7 as indicated by the litmus paper remaining at its neutral color when dipped in the solution or by a ph meter.

5.19 When the used Oakite 33 cleaning solution is neutralized, drain it into the sanitary sewer. **DO NOT** drain it into the storm sewer.

CBI

DOC. ID	CLCOUPA
REV. NO.	0
CONTRACT	930212

TITLE FOR SURFACE ANALYSIS AND OUTGASSING TEST CLEANING OF PLAIN COUPONS CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
						PREPARED	CNS	02-22-94
						REVISED		
						AUTHORIZED		
						REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

This coupon cleaning procedure covers both the initial hydrocarbon contamination of the plate material and the Oakite 33 cleaning of forty nine (49) coupons cut from that plate material in areas that contain no old or new marker dye marks. One (1) 0.115" x 1" x 18" coupon will be used for post clean cutting by others into ten (10) or more 0.115" x 1 cm x 1 cm coupons for surface analysis by the XPS, SIMS and Auger methods. Eight (8) of these will be hydrocarbon contaminated and two (2) will be uncontaminated. Forty eight (48) 0.115" x 1" x 18" coupons will be used for the hydrogen outgassing test.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning performed in accordance with this procedure.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 Package and ship per Caltech instructions (see step 5.23 of this procedure).

4.0 EQUIPMENT AND MATERIALS:

4.1 Lint free cloths or paper towels.

4.2 100 Watt blacklight with 3650 Angstrom unit wavelength.

4.3 Blacklight meter capable of measuring at least 800 $\mu w/cm^2$.

4.4 Litmus paper or pH meter.

4.5 One (1) five (5) gallon container of de-ionized or distilled water.

4.6 Oakite 33.

4.7 Oakite Enprox 714.

4.8 One (1) metal drum and one (1) heater for heating the de-ionized (distilled) water/Oakite 33 cleaning solution and de-ionized (distilled) rinse water.

4.9 Metal or glass tube thermometer with a range in excess of 160°F.

4.10 Two (2) vinyl polyester recovery containment pallet systems for catching and retaining the used cleaning and rinse solutions.

4.11 Clean Nitrilite chemical resistant gloves and neoprene or other chemical resistant apron or coveralls, face shields or goggles with side shields and foot coverings as needed.

4.12 Dust/mist respirators with exhalation valve that are NIOSH/MSHA approved such as Zee #2304.

4.13 Two (2) chemical resistant plastic two (2) gallon containers for the pump type sprayers. One (1) for mixing and holding the Oakite 33 cleaning mixture and one (1) for holding the de-ionized (distilled) rinse water.

4.14 Caltech supplied Ameristat packaging plastic.

4.15 Electrical tie wraps.

4.16 Supra Tech non-detergent SAE 30 motor oil.

4.17 Paint brush approximately one (1) inch wide.

4.18 Clean metal channel locks.

4.19 Stainless steel 304L heat treated material supplied by Caltech for the test coupons. Use material from an area or areas that contain no old or new marker dye marks.

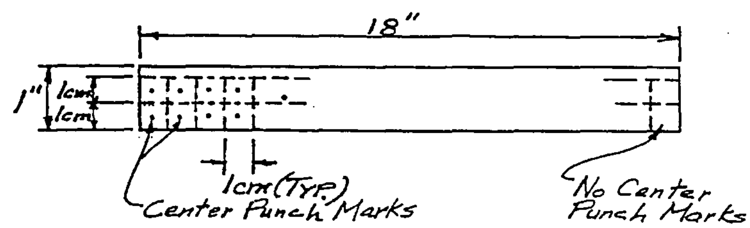
4.20 Clean blunt nose center punch.

4.21 One (1) 0.115" x 1" x 18" coupon with a J type thermocouple attached from previous alternate coupon cleaning procedures.

4.22 Digital thermocouple readout unit.

5.0 PROCEDURE:

5.1 Before shearing the coupons from the Caltech supplied sheets of heat treated 304L stainless steel, center punch mark the surface which is to be hydrocarbon contaminated at a minimum of forty nine (49) locations. For all forty nine (49) coupons, these locations shall be slightly off-center toward the end to be contaminated of the anticipated sheared position of each of these coupons. For the forty ninth (49th), also center punch mark the anticipated location of the eight (8) 1 cm x 1 cm contaminated surface analysis coupons in the 1" x 18" coupon being shipped to MIT. See the cutting sketch below.



5.2 Brush motor oil across the anticipated shear lines on the steel sheet surface in a pattern that will ultimately result in an oil residue coating of approximately one half of the surface on the center punched side of each of the forty eight (48) 1" x 18" hydrogen outgassing coupons. It should cover half of the surface of the forty ninth (49th) coupon on the end with the center punch marks from which eight (8) contaminated 0.115" x 1 cm x 1 cm surface analysis coupons will be cut. Two (2) 0.115" x 1 cm x 1 cm coupons will be cut from the other uncontaminated end.

5.3 Wipe the excess motor oil from the surface of the sheet steel with clean clothes or paper towels until it feels dry to the touch.

5.4 Shear the coupons from areas of the steel sheet having no old or new marker dye marks following the layout instructions.

5.5 In the cleaning area arrange two (2) vinyl polyester recovery containment systems. One to catch and retain the used Oakite 33 cleaning solution and the other to serve as a draining and drying rack for the coupons. The use of the second recovery system will prevent the draining and drying rack pallet grids from becoming contaminated with the Oakite 33 cleaning solution and, in turn, possibly contaminating the cleaned coupons. The cleaning area shall be in a protected area out of the weather.

5.6 Nearly fill both chemical resistant pump type plastic sprayers with de-ionized (distilled) water.

5.7 Mix a 2% by volume solution of Oakite 33 with the de-ionized (distilled) water in one (1) of the two (2) gallon chemical resistant pump type plastic sprayers.

5.8 Place each chemical resistant pump type plastic sprayer in a metal drum partially filled with tap water.

5.9 Heat the de-ionized (distilled) rinse water and the Oakite 33 cleaning solution in each of the pump type sprayers to a temperature of approximately 160°F by heating the tap water in the metal drum. Check the temperature of the de-ionized (distilled) rinse water and Oakite 33 cleaning solution with the metal or glass thermometer.

5.10 While heating the de-ionized (distilled) rinse water and Oakite 33 cleaning solution, remove the pallet grids from both vinyl polyester recovery containment systems. As soon as the Oakite cleaning solution and rinse water are at the required temperature, thoroughly spray the four pallets of the two recovery containment systems with the Oakite solution followed by the rinse water to remove any dirt or other contaminants from their surface. After the pallet grids have been cleaned, replace them on the interstices of the recovery systems.

5.11 Clean with Oakite 33 cleaning solution the channel locks to be used in the next step.

5.12 To clean the coupons, hold each coupon by the uncontaminated end with the set of channel locks cleaned in the previous step. For the coupon that is to be cut for surface analysis coupons, hold it by the end away from the multiple center punch marks. When spraying with the pump type sprayer, let the coupon hang down from the channel locks over the one recovery containment system.

5.13 With the pump type sprayer containing the 140°F to 160°F de-ionized (distilled) water held only a few inches away, thoroughly spray rinse all the surfaces of the coupon. Allow the de-ionized (distilled) water to run off into the recovery containment system.

5.14 While still holding the rinsed coupon, with the pump type sprayer containing the 140°F to 160°F Oakite 33 cleaning solution held only a few inches away, thoroughly spray all surfaces of the coupon with Oakite 33 cleaning solution for a minimum of fifteen (15) seconds to a maximum of twenty (20) seconds. Also monitor the thermocouple reading during the Oakite 33 spray cleaning of that temperature indicating coupon and record the maximum surface temperature noted.

5.15 While still holding the Oakite 33 cleaned coupon with the channel locks, stand it on end 2" to 3" apart from other coupons by placing one end of the coupon in one of the grooves between a vinyl polyester pallet grid and the interstices of the vinyl polyester recovery containment system over which the coupon was being sprayed with the Oakite 33 cleaner.

5.16 Wait for five (5) minutes and repeat step 5.14 for each coupon.

5.17 After another five (5) minutes have elapsed, repeat step 5.13. Thoroughly rinse the coupons to remove all traces of the Oakite 33 cleaning residue.

5.18 Allow the coupons to air dry. Only use the electric hot air dryer if the humidity is so high as to prevent rapid drying of the coupons.

5.19 Add Oakite Enprox 714 to the used Oakite 33 cleaning solution in the vinyl polyester recovery containment system until the solution is neutralized to a pH of 7 as indicated by the pH meter or the litmus paper remaining gray when dipped in the solution

5.20 When the used Oakite 33 cleaning solution is neutralized, drain it into the sewer.

5.21 After the coupons are thoroughly dry, place a dust/mist respirator over one's mouth and nose. Just before handling the coupons, put on clean Nitrilite gloves. Be careful not to touch the outside of the gloves with the hands. While wearing the respirator and the gloves, wrap all of the coupons in a piece of Ameristat plastic laid on a cart with the inside surface of the roll turned upward. Fold the plastic over the coupons for protection and carry them to a darkened lab room.

5.22 Excluding the coupon with the thermocouple attached, blacklight inspect all coupons for hydrocarbon contamination as follows:

5.22.1 Turn on and warm up the blacklight for a minimum of five (5) minutes.

5.22.2 The examiner shall be in the darkened area for at least five (5) minutes to allow time for eye adaptation to the darkness prior to viewing the surface. If the examiner wears glasses or lenses, they shall not be photosensitive.

5.22.3 Confirm the maximum distance at which the blacklight produces 800 $\mu w/cm^2$ on the examination surface using the blacklight meter.

5.22.4 Put on new clean Nitrilite gloves before handling coupons in the darkened area.

5.22.5 In the darkened area, blacklight inspect all surfaces of all coupons. During the inspection, hold the blacklight no further or no closer from the examination surface than the distance established in step 5.22.3. Use extra care when inspecting the previously contaminated center punched surface of each coupon.

5.22.6 Record observations of any significant residual hydrocarbon contamination (fluorescent glow at 800 $\mu w/cm^2$) revealed on the surfaces of the coupons by the blacklight inspection.

5.23 Package and ship the forty eight (48) hydrogen outgassing coupons to Larry Jones at Caltech and the forty ninth (49th) coupon with extra center punch marks to Rainer Weiss at MIT in accordance with the Caltech instructions given as follows:

5.23.1 Place a piece of Ameristat film on a bench with the inside surface of the roll turned upward to provide a clean work surface.

5.23.2 Handle all coupons and film only when wearing dust/mist respirators and clean Nitrilite chemical resistant gloves.

5.23.3 Wrap twelve (12) hydrogen outgassing coupons to a bundle. In a separate bundle wrap the single coupon from which the surface analysis coupons will be cut by MIT.

5.23.4 Keep the inside surface of the film roll toward the inside surface of the package being wrapped. Limit film handling to outside edges only.

5.23.5 Wrap coupons with at least two (2) layers of film so that the outside edges do not come in contact with the coupons. Accomplish this by rolling the film around the short dimension of the coupons or coupon. Then fold the outer edges of the film to the middle.

5.23.6 Secure the film around the bundle with two (2) or more electrical tie wraps.

5.23.7 Label each bundle with the date wrapped, the identification of the cleaning procedure used to clean the coupons and the maximum coupon surface temperature noted during either the cleaning or the rinsing phase.

5.23.8 Pack the wrapped 0.115" x 1" x 18" hydrogen outgassing coupon bundles in a corrugated box. Add filler material as necessary for protection against possible shipping damage.

5.23.9 Label this box and ship these hydrogen outgassing coupons via Airborne, Federal Express or UPS to:

California Institute of Technology
Attention: Larry K. Jones 102 - 33
Pasadena, CA 91125

5.23.10 In a second corrugated box pack the single coupon for cutting into surface analysis coupons. Add filler packing material as necessary for protection against possible shipping damage.

5.23.11 Label this box and ship these surface analysis coupons via Airborne, Federal Express or UPS to:

Attention: Rainer Weiss
Room 20B145
Massachusetts Institute of Technology
18 Vassar Street
Cambridge, MA 02139

CBI

DOC. ID	CLCOUPA0
REV. NO.	2
CONTRACT	930212

TITLE CLEANING OF PLAIN COUPONS BY ALTERNATE METHOD #0 FOR SURFACE ANALYSIS AND OUTGASSING TEST CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	02-16-94
REVISED	CNS	02-22-94
AUTHORIZED		
REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

This alternate coupon cleaning procedure covers both the initial hydrocarbon contamination of the plate material and the cleaning of fifty (50) coupons cut from that plate material in areas that contain no old or new marker dye marks. One (1) 0.115" x 1" x 18" coupon will be used for post clean cutting by others into ten (10) or more 0.115" x 1 cm x 1 cm coupons for surface analysis by the XPS, SIMS and Auger methods. Eight (8) of these will be hydrocarbon contaminated and two (2) will be uncontaminated. Forty eight (48) 0.115" x 1" x 18" coupons will be used for the hydrogen outgassing test. The extra one (1) 0.115" x 1" x 18" coupon will have a thermocouple attached for determining the typical maximum coupon temperature during steam cleaning. This same coupon with the thermocouple attached will be used in each of the alternate coupon cleaning procedures investigated.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning performed in accordance with this alternate procedure.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 Package and ship per Caltech instructions (see step 5.18 of this procedure).

4.0 EQUIPMENT AND MATERIALS:

4.1 Lint free cloths or paper towels.

4.2 100 Watt blacklight with 3650 Angstrom unit wavelength.

4.3 Blacklight meter capable of measuring at least 800 $\mu w/cm^2$.

4.4 Electric hot air dryer.

4.5 Steam cleaner (Jenny) with a heater coil and a dead man type hand held sprayer.

4.6 Two (2) vinyl polyester recovery containment pallet systems for catching and retaining the used cleaning and rinse solutions.

4.7 Clean Nitrilite chemical resistant gloves and neoprene or other chemical resistant apron or coveralls, face shields or goggles with side shields and foot coverings as needed.

4.8 Dust/mist respirators with exhalation valve that are NIOSH/MSHA approved such as Zee #2304.

4.9 Caltech supplied Ameristat packaging plastic.

4.10 Electrical tie wraps.

4.11 Supra Tech non-detergent SAE 30 motor oil .

4.12 Paint brush approximately one inch (1") wide.

4.13 Clean metal channel locks.

4.14 Stainless steel 304L heat treated material supplied by Caltech for the test coupons. Use material from an area or areas that contain no old or new marker dye marks.

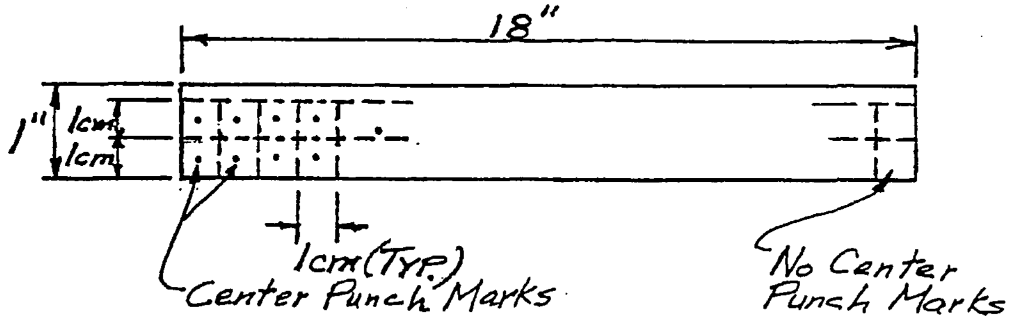
4.15 Clean blunt nose center punch.

4.16 J Type thermocouple.

4.17 Digital thermocouple readout unit.

5.0 PROCEDURE:

5.1 Before shearing the coupons from the Caltech supplied sheets of heat treated 304L stainless steel, center punch mark the surface which is to be hydrocarbon contaminated at a minimum of fifty (50) locations. For all fifty (50) coupons, these locations shall be slightly off-center toward the end to be contaminated of the anticipated sheared position of each of these coupons. For the fiftieth (50th) coupon, also center punch mark the anticipated location of the eight (8) 1cm x 1cm contaminated surface analysis coupons in the 1" x 18" coupon being shipped to MIT. See the cutting sketch below.



5.2 Brush motor oil across the anticipated shear lines on the steel sheet surface in a pattern that will ultimately result in an oil residue coating of approximately one half of the surface on the center punched side of each of the forty nine (49) 1" x 18" hydrogen outgassing coupons. It should cover half of the surface of the fiftieth (50th) coupon on the end with the center punch mark from which eight (8) contaminated 0.115" x 1 cm x 1 cm surface analysis coupons will be cut. Two (2) 0.115" x 1 cm x 1 cm coupons will be cut from the other uncontaminated end.

5.3 Wipe the excess motor oil from the surface of the sheet steel with clean clothes or paper towels until it feels dry to the touch.

,.4 Shear the coupons from areas of the steel sheet having no old or new marker dye marks following the layout instructions.

5.5 Adjacent to the steam jenny, place two (2) vinyl polyester recovery containment pallet systems. One to catch and retain the used condensed steam liquid and the other to serve as a draining and drying rack for the coupons. The use of the second recovery system will prevent the draining and drying rack pallet grids from becoming contaminated with the condensed steam run-off and, in turn, possibly contaminating the cleaned coupons. This is in a protected area.

5.6 Turn on the steam cleaner heating coils.

5.7 Spray water from the steam cleaner spray nozzle into the sanitary sewer drain until it reaches the boiling point (turns to steam).

5.8 Remove the pallet grids from both vinyl polyester recovery containment systems. With the steam cleaner sprayer held only a few inches away, thoroughly spray the four pallet grids of the two vinyl polyester recovery containment systems to remove any dirt or other contaminants from their surface. After the pallet grids are steam cleaned, replace them on the interstices of the recovery systems.

5.9 Attach a thermocouple to the surface of one of the 1" x 18" hydrogen outgassing coupons approximately in the middle of the 18" length on the side opposite from the center punch mark.

5.10 Steam clean the channel locks to be used in the next step.

5.11 To steam clean the coupons, hold each coupon by the uncontaminated end with the set of channel locks cleaned in the previous step. For the coupon that is to be cut for surface analysis coupons, hold it by the end away from the center punch mark. When spraying with the steam cleaner, let the coupon hang down from the channel locks over the one recovery containment system. With the steam cleaner sprayer held only a few inches away, thoroughly spray all the surfaces of the coupon for a minimum of fifteen (15) seconds to a maximum of twenty (20) seconds. When spraying is partially complete, momentarily place the coupon in a groove between a pallet grid and the interstices of that recovery system. Lift the coupon again with the channel locks shifted a few inches on the coupon to expose the coupon area

5.11 (cont'd)

previously covered by the channel locks. Complete the steam cleaning of that coupon. Also monitor the thermocouple reading during the steam cleaning of that coupon and record the maximum coupon surface temperature noted.

5.12 While still holding the steam cleaned coupon with the channel locks, stand it on end by placing one end of the coupon in one of the grooves between a vinyl polyester pallet grid and the interstices of the previously unused vinyl polyester recovery containment system.

5.13 Repeat steps 5.11 and 5.12 for each coupon. When standing them on end to dry, set them 2" to 3" inches apart.

5.14 Allow the coupons to air dry. Only use the electric hot air dryer if the humidity is so high as to prevent rapid drying.

5.15 After the coupons are thoroughly dry, place a dust/mist respirator over one's mouth and nose. Just before handling the coupons, put on clean Nitrilite chemical resistant gloves. Be careful not to touch the outside of the gloves with the hands. While wearing the respirator and the gloves, wrap all of the coupons in a piece of Ameristat plastic laid on a cart with the inside surface of the roll turned upward. Fold the plastic over the coupons for protection and carry them to a darkened lab room.

5.16 Dispose of the cleaning/rinse condensed steam liquid by flushing it into the sanitary sewer.

5.17 Excluding the coupon with the thermocouple attached, blacklight inspect all the other cleaned coupons for hydrocarbon contamination as follows:

5.17.1 Turn on and warm up the blacklight for a minimum of five (5) minutes.

5.17.2 The examiner shall be in the darkened area for at least five (5) minutes to allow time for eye adaptation to the darkness prior to viewing the coupon surfaces. If the examiner wears glasses or lenses, they shall not be photosensitive.

5.17.3 Confirm the maximum distance at which the blacklight produces 800 $\mu w/cm^2$ on the examination surface using the blacklight meter.

5.17.4 Put on new clean Nitrilite gloves before handling any coupons in the darkened area.

5.17.5 In the darkened area, blacklight inspect all surfaces of all coupons. During the inspection, hold the blacklight no further or no closer from the examination surface than the distance established in step 5.17.3. Use extra care when inspecting the previously contaminated center punched surface of each coupon.

5.17.6 If the blacklight inspection reveals no hydrocarbon contamination (no fluorescent glow at 800 $\mu w/cm^2$) on the surfaces of the coupons, proceed to step 5.18. If the blacklight inspection reveals residual amounts of hydrocarbon contamination, void this cleaning method procedure as inadequate.

5.18 Package and ship the forty eight (48) hydrogen outgassing coupons to Larry Jones at Caltech and the forty ninth coupon with extra center punch marks to Rainer Weiss at MIT in accordance with the Caltech instructions given as follows:

5.18.1 Place a piece of Ameristat film on a bench with the inside surface of the roll turned upward to provide a clean work surface.

5.18.2 Handle all coupons and film only when wearing dust/mist respirators and clean Nitrilite chemical resistant gloves.

5.18.3 Wrap twelve (12) hydrogen outgassing coupons to a bundle. In a separate bundle wrap the single coupon from which the surface analysis coupons will be cut by MIT.

5.18.4 Keep the inside surface of the film roll toward the inside surface of the package being wrapped. Limit film handling to outside edges only.

5.18.5 Wrap coupons with at least two (2) layers of film so outside edges do not come in direct contact with the coupons. Accomplish this by rolling the film around the short dimension of the coupon(s). Then fold the outer edges of the film to the middle.

5.18.6 Secure the film around the bundle with two (2) or more electrical tie wraps.

5.18.7 Label each bundle with the date wrapped, the identification of the cleaning procedure used to clean the coupons and the maximum coupon surface temperature noted during cleaning.

5.18.8 Pack the wrapped 0.115" x 1" x 18" hydrogen outgassing coupon bundles in a separate corrugated box. Add filler packing material as necessary for protection against possible shipping damage.

5.18.9 Label this box and ship these hydrogen outgassing coupons via Airborne, Federal Express or UPS to:

California Institute of Technology
Attention: Larry K. Jones 102 - 33
Pasadena, CA 91125

5.18.10 In a second corrugated box pack the single coupon for cutting into surface analysis coupons. Add filler packing material as necessary for protection against possible shipping damage.

5.18.11 Label this box and ship this coupon via Airborne, Federal Express or UPS to:

Attention: Rainer Weiss
Room 20B145
Massachusetts Institute of Technology
18 Vassar Street
Cambridge, MA 02139

CBI	IDENTIFICATION CLCOUPA1			
TITLE CLEANING OF PLAIN COUPONS BY ALTERNATE METHOD #1 FOR SURFACE ANALYSIS AND OUTGRASSING TEST CALTECH	REFERENCE NO. 930212		SHT 1 OF 8	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY CNS	CHKD BY
	DATE 02/18/94	DATE	DATE 02/22/94	DATE

1.0 SCOPE:

This alternate coupon cleaning procedure covers both the initial hydrocarbon contamination of the plate material and the Mirachem 500 cleaning of forty nine (49) coupons cut from that plate material in areas that contain no old or new marker dye marks. One (1) 0.115" x 1" x 18" coupon will be used for post clean cutting by others into ten (10) or more 0.115" x 1 cm x 1 cm coupons for surface analysis by the XPS, SIMS and Auger methods. Eight (8) of these will be hydrocarbon contaminated and two (2) will be uncontaminated. Forty eight (48) 0.115" x 1" x 18" coupons will be used for the hydrogen outgassing test.

2.0 PERSONNEL:

Experienced personnel shall perform and supervise all cleaning performed in accordance with this alternate procedure.

3.0 REFERENCES:

3.1 California Institute of Technology Technical Specification Number 1100004 for Beam Tube Modules and Number 1100007 for Type 304L Stainless Steel Vacuum Products.

3.2 ASTM Designation A 380 Standard Practice for Cleaning and Descaling Stainless Steel Parts, Equipment and Systems (as a guide).

3.3 Package and ship per Caltech instructions (see step 5.25 of this procedure).

4.0 EQUIPMENT AND MATERIALS:

4.1 Lint free cloths or paper towels.

4.2 100 Watt blacklight with 3650 Angstrom unit wavelength.

4.3 Blacklight meter capable of measuring at least 800 $\mu w/cm^2$.

4.4 Electric hot air dryer.

4.5 Mirachem 500 Cleaner/Degreaser.

4.6 Steam cleaner (Jenny) with a heater coil and a dead man type hand held sprayer.

4.7 Two (2) vinyl polyester recovery containment pallet systems for catching and retaining the used cleaning and rinse solutions.

4.8 Clean Nitrilite chemical resistant gloves and neoprene or other chemical resistant apron or coveralls, face shields or goggles with side shields and foot coverings as needed.

4.9 Dust/mist respirators with exhalation valve that are NIOSH/MSHA approved such as Zee #2304.

4.10 Two (2) chemical resistant plastic two (2) gallon containers for pump type sprayers.

4.11 Caltech supplied Ameristat packaging plastic.

4.12 Electrical tie wraps.

4.13 Supra Tech non-detergent SAE 30 motor oil.

4.14 Paint brush approximately one inch (1") wide.

4.15 Clean metal channel locks.

4.16 Stainless steel 304L heat treated material supplied by Caltech for the test coupons. Use material from an area or areas that contain no old or new marker dye marks.

4.17 Clean blunt nose center punch.

4.18 One (1) 0.115" x 1" x 18" coupon with a J type thermocouple attached from previous alternate coupon cleaning procedures.

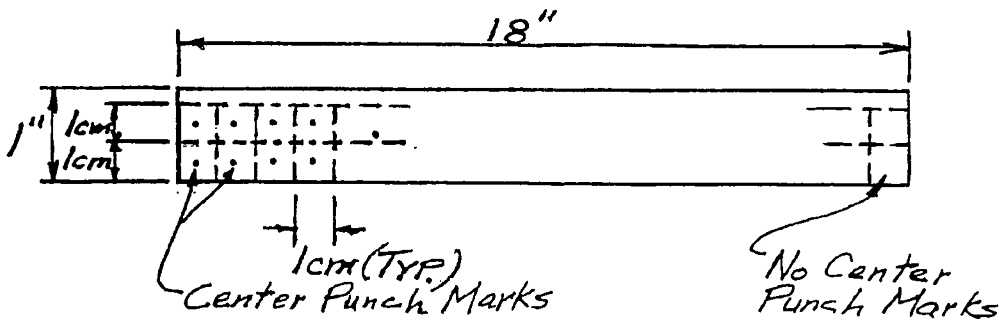
4.19 Digital thermocouple readout unit.

5.0 PROCEDURE:

5.1 Before shearing the coupons from the Caltech supplied sheets of heat treated 304L stainless steel, center punch mark the surface which is to be hydrocarbon contaminated at a minimum of forty nine locations. For all forty nine (49) coupons, these locations shall be slightly off-center toward the end to be contaminated of the anticipated sheared position of each of these coupons. For the forty ninth (49th) coupon, also center punch mark the anticipated location of the eight (8) 1 cm x 1 cm contaminated surface analysis coupons in the 1" x 18" coupon being shipped to MIT. See the cutting sketch below.

CBI

TITLE	IDENTIFICATION			
	CLCOUPA1			
CLEANING OF PLAIN COUPONS BY ALTERNATE METHOD #1 FOR SURFACE ANALYSIS AND OUTGRASSING TEST CALTECH	REFERENCE NO. 930212		SHT 3 OF 8	
	OFFICE		REVISION 1	
PRODUCT	MADE BY CNS	CHKD BY	MADE BY CNS	CHKD BY
	DATE 02/18/94	DATE	DATE 02/22/94	DATE



5.2 Brush motor oil across the anticipated shear lines on the steel sheet surface in a pattern that will ultimately result in an oil residue coating of approximately one half of the surface on the center punched side of each of the forty eight (48) 1" x 18" hydrogen outgassing coupons. It should cover half of the surface of the forty ninth (49th) coupon on the end with the center punch marks from which eight (8) contaminated 0.115" x 1 cm x 1 cm surface analysis coupons will be cut. Two (2) 0.115" x 1 cm x 1 cm coupons will be cut from the other uncontaminated end.

5.3 Wipe the excess motor oil from the surface of the sheet steel with clean clothes or paper towels until it feels dry to the touch.

5.4 Shear the coupons from areas of the steel sheet having no old or new marker dye marks following the layout instructions.

5.5 Adjacent to the steam jenny, place two (2) vinyl polyester recovery containment pallet systems. One to catch and retain the used Mirachem 500 cleaning solution and condensed steam rinse liquid and the other to serve as a draining and drying rack for the coupons. The use of the second recovery system will prevent the draining and drying rack pallet grids from becoming contaminated with the Mirachem 500 cleaning solution and condensed steam run-off and, in turn, possibly contaminating the cleaned coupons. This is in a protected area.

5.6 Turn on the steam cleaner heating coils.

5.7 Spray water from the steam cleaner spray nozzle into the sanitary sewer drain until it reaches the boiling point (turns to steam).

5.8 Remove the pallet grids from both vinyl polyester recovery containment systems. With the steam cleaner sprayer held only a few inches away, thoroughly spray the four pallet grids of the two vinyl polyester recovery containment systems to remove any dirt or other contaminants from their surface. After the pallet grids are steam cleaned, replace them on the interstices of the recovery systems.

5.9 Mix one (1) part by volume of Mirachem 500 cleaner/degreaser with three (3) parts of water in both of the plastic spray containers in a quantity sufficient to nearly fill both pump type sprayer plastic containers.

5.10 Insert the screened suction line of the steam cleaner into one of the plastic containers of Mirachem 500 cleaning solution. Spray the water (as steam) from the steam cleaner spray nozzle into the sanitary sewer until the Mirachem 500 cleaning solution starts coming through.

5.11 Spray the Mirachem 500 cleaning solution from the steam cleaner spray nozzle back into its plastic container until the Mirachem 500 cleaning solution reaches the boiling point (turns to steam). Do this for both containers of solution.

5.12 Steam clean with Mirachem 500 cleaning solution the channel locks to be used in the next step.

5.13 To steam clean the coupons with Mirachem 500 cleaning solution, hold each coupon by the uncontaminated end with the set of channel locks cleaned in the previous step. For the coupon that is to be cut for surface analysis coupons, hold it by the end away from the center punch mark. When spraying with the steam cleaner, let the coupon hang down from the channel locks over the one recovery containment system. With the steam cleaner sprayer held only a few inches away, thoroughly spray all the surfaces of the coupon with the Mirachem 500 cleaning solution for a minimum of fifteen (15) seconds to a maximum of twenty (20) seconds. Also monitor the thermocouple reading during the Mirachem 500 steam cleaning of that temperature indicating coupon and record the maximum coupon surface temperature noted.

5.14 While still holding the Mirachem 500 cleaned coupon with the channel locks, stand it on end by placing one end of the coupon in one of the grooves between a vinyl polyester pallet grid and the interstices of the vinyl polyester recovery containment system over which the coupon was being sprayed with the Mirachem 500 cleaner.

5.15 Repeat steps 5.13 and 5.14 for each coupon. When standing them on end to await the rinse phase, set them 2" to 3" inches apart.

CBI

IDENTIFICATION			
CLCOUPA1			
REFERENCE NO. 930212		SHT 5 OF 8	
OFFICE		REVISION 1	
MADE BY CNS	CHKD BY	MADE BY CNS	CHKD BY
DATE 02/18/94	DATE	DATE 02/22/94	DATE

TITLE
CLEANING OF PLAIN COUPONS BY ALTERNATE METHOD #1 FOR SURFACE ANALYSIS AND OUTGRASSING TEST CALTECH
PRODUCT

5.16 After completing step 5.15, remove the screened suction line of the steam cleaner from the Mirachem 500 cleaning solution container. Connect the suction line of the steam cleaner to the water supply. Spray the existing Mirachem 500 cleaning solution from the steam cleaner into the vinyl polyester recovery containment system used for the Mirachem 500 cleaning until all the Mirachem 500 cleaning solution has been pumped through. Then spray water from the steam cleaner spray nozzle into the sanitary drain until it reaches the boiling point (turns to steam).

5.17 Steam rinse the channel locks to be used in the next step.

5.18 To steam rinse the coupons, with the channel locks rinsed in step 5.17 remove each coupon by the uncontaminated end from the groove of the pallet grid of the vinyl polyester recovery containment system. For the coupon that is to be cut for surface analysis coupons, remove it by the end away from the center punch mark. When spraying with the steam cleaner, let the coupon hang down from the channel locks over the recovery containment system used for the Mirachem cleaning. With the steam cleaner sprayer held only a few inches away, thoroughly spray all the surfaces of the coupon for a minimum of fifteen (15) seconds to a maximum of twenty (20) seconds. When spraying is partially complete, momentarily place the coupon in a groove between a pallet grid and the interstice of that recovery system. Lift the coupon again with the channel locks shifted a few inches on the coupon to expose the coupon area previously covered by the channel locks. Complete the steam rinse spraying of that coupon. Also monitor the thermocouple reading during the steam rinsing of that coupon and record the maximum coupon surface temperature noted.

5.19 While still holding the steam rinsed coupon with the channel locks, stand it back on end in a groove between the vinyl polyester pallet grid and the interstices of the previously unused vinyl polyester recovery containment system.

5.20 Repeat steps 5.18 and 5.19 for each coupon. When standing them on end to dry, set them 2" to 3" apart.

5.21 Allow the coupons to air dry. Only use the electric hot air dryer if the humidity is so high as to prevent rapid drying of the coupons.

5.22 After the coupons are thoroughly dry, place a dust/mist respirator over one's mouth and nose. Just before handling the coupons, put on clean Nitrilite gloves. Be careful not to touch the outside of the gloves with the hands. While wearing the respirator and the gloves, wrap all of the coupons in a piece of Ameristat plastic laid on a cart with the inside surface of the roll turned upward. Fold the plastic over the coupons for protection and carry them to a darkened lab room.

5.23 Dispose of the Mirachem 500 cleaning/rinse condensed steam liquid by flushing it into the sanitary sewer as allowed by the MSDS for this product.

5.24 Excluding the coupon with the thermocouple attached, blacklight inspect all coupons for hydrocarbon contamination as follows:

5.24.1 Turn on and warm up the blacklight for a minimum of five (5) minutes.

5.24.2 The examiner shall be in the darkened area for at least five (5) minutes to allow time for eye adaptation to the darkness prior to viewing the coupon surfaces. If the examiner wears glasses or lenses, they shall not be photosensitive.

5.24.3 Confirm the maximum distance at which the blacklight produces 800 $\mu w/cm^2$ on the examination surface using the blacklight meter.

5.24.4 Put on new clean Nitrilite gloves before handling any coupons in the darkened area.

5.24.5 In the darkened area, blacklight inspect all surfaces of all coupons. During the inspection, hold the blacklight no further or no closer from the examination surface than the distance established in step 5.24.3. Use extra care when inspecting the previously contaminated center punched surface of each coupon.

5.24.6 If the blacklight inspection reveals no hydrocarbon contamination (no fluorescent glow at 800 $\mu w/cm^2$) on the surfaces of the coupons, proceed to step 5.25. If the blacklight inspection reveals residual amounts of hydrocarbon contamination, void this cleaning method procedure as inadequate.

5.25 Package and ship the forty eight (48) hydrogen outgassing coupons to Larry Jones at Caltech and the forty ninth (49th) coupon with extra center punch marks to Rainer Weiss at MIT in accordance with the Caltech instructions given as follows:

5.25.1 Place a piece of Ameristat film on a bench with the inside surface of the roll turned upward to provide a clean work surface.

5.25.2 Handle all coupons and film only when wearing dust/mist respirators and clean Nitrilite chemical resistant gloves.

5.25.3 Wrap twelve (12) hydrogen outgassing coupons to a bundle. In a separate bundle wrap the single coupon from which the surface analysis coupons will be cut by MIT.

5.25.4 Keep the inside surface of the film roll toward the inside surface of the package being wrapped. Limit film handling to outside edges only.

5.25.5 Wrap coupons with at least two (2) layers of film so that the outside edges do not come in direct contact with the coupons. Accomplish this by rolling the film around the short dimension of the coupons or coupon. Then fold the outer edges of the film to the middle.

5.25.6 Secure the film around the bundle with two (2) or more electrical tie wraps.

5.25.7 Label each bundle with the date wrapped, the identification of the cleaning procedure used to clean the coupons and the maximum coupon surface temperature noted during either the cleaning or the rinsing phase.

5.25.8 Pack the wrapped 0.115" x 1" x 18" hydrogen outgassing coupon bundles in a corrugated box. Add filler material as necessary for protection against possible shipping damage.

5.25.9 Label this box and ship these hydrogen outgassing coupons via Airborne, Fedex or UPS to:

California Institute of Technology
Attention: Larry K. Jones 102 - 33
Pasadena, CA 91125

5.25.10 In a second corrugated box pack the single coupon for cutting into surface analysis coupons. Add filler packing material as necessary for protection against possible shipping damage.

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CLCOUPA1</td></tr>
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CLEANING OF PLAIN COUPONS BY ALTERNATE METHOD #1 FOR SURFACE ANALYSIS AND OUTGRASSING TEST CALTECH
PRODUCT</td><td colspan="2">REFERENCE NO.
930212</td><td colspan="2">SHT 8 OF 8</td></tr>
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1</td></tr>
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<tr><td>DATE
02/18/94</td><td>DATE</td><td>DATE
02/22/94</td><td>DATE</td></tr>
</table>

5.25.11 Label this box and ship these surface analysis coupons via Airborne, Fedex or UPS to:

Attention: Rainer Weiss
Room 20B145
Massachusetts Institute of Technology
18 Vassar Street
Cambridge, MA 02139

CBI

DOC. ID CLALT
REV. NO. 0
CONTRACT 930212

TITLE METHOD FOR QUALIFYING ALTERNATE CLEANING APPROACHES FOR FINAL CLEANING BEFORE HELIUM MASS SPECTROMETER TESTING

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	11-3-93
REVISED		
AUTHORIZED		
REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

The purpose of this cleaning qualification procedure is to compare the outgassing properties of the 304L low hydrogen stainless steel after coupons of that material have been cleaned with different cleaning agents.

2.0 MATERIAL & EQUIPMENT TO BE USED WITH THIS PROCEDURE:

2.1 Based on the contents of the MSDS for each of the cleaning agents reviewed, select and test those optional cleaning agents such as:

2.1.1 Simple Green

2.1.2 Mirachem 500

2.1.3 Oakite ELL

2.1.4 Triton

2.1.5 Diversey Wyandotte Aerowash

2.1.6 Pierce BS-35

2.2 A two percent (2%) by volume mixture of Oakite 33 as the control against which all other cleaning agents are compared.

2.3 Seven (7) 304L stainless steel outgas coupons that are one inch (1") x eighteen inch (18") x one eighth (1/8") in size. With a steel stencil, mark each coupon with an ID that identifies it with the cleaning agent used on that coupon.

3.10 Individually conduct an outgassing test on each of the cleaned coupons including the coupon cleaned with the Oakite 33 cleaning mixture.

3.11 Compare the outgassing data for each of the cleaning agents.

3.12 Select the cleaning agent with the lowest outgassing rate and Caltech's concurrence.

4.0 DOCUMENTATION:

4.1 Complete an outgassing rate report for each cleaning agent tested and the conclusion reached based on a summary of that data.

SECTION 6

CBI

DOC. ID	HMST1N
REV. NO.	0
CONTRACT	930212

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS LIGO PROJECT - CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	3-15-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

1.1 This procedure covers the helium mass spectrometer hood leak test of each completed beam tube can section. Perform this procedure in conjunction with the current revision of procedure LIGOTP.

1.2 Perform the leak testing outlined in this procedure after the:

1.2.1 Stiffeners, bellows assembly and, when applicable, the pump port nozzle have been welded to the beam tube can section.

1.2.2 Beam tube can section has been visually inspected and any weld repairs have been made to correct excess undercut, lack of penetration and pinholes in either the can spiral welds or the stiffeners to can welds.

1.2.3 Preliminary solvent cleaning has been satisfactorily completed.

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

All purchased equipment used in the performance of this procedure shall be specified to be helium mass spectrometer (HMS) leak tested to 2×10^{-10} atm. cc/sec. of helium. CBI will HMS leak test all purchased items during the initial leak test of the end seal assemblies. If a manufacturer only has the capability to HMS leak test to a lesser test sensitivity, then the manufacturer must accept the return of that item without charge if it should fail this initial leak test by CBI at this sensitivity level.

2.1 The helium mass spectrometers used to perform the leak testing outlined in this procedure shall be the Leybold Model UL400 with the optional high sensitivity of 2 x 10^{-12} atm. cc/sec. of helium (8 x 10^{-13} atm. cc/sec. of air) or instrument of comparable capability.

2.2 Hood test enclosure stands. Each enclosure as shown in the test set-up sketch shall consist of a gasketed support cradle and cover and shall be able to structurally withstand being fully evacuated. Each test enclosure stand shall contain the following:

2.2.1 A 40 KF (1 1/2"Ø) long flange installed in the middle on the top of the cover with a valve and piping to an exhaust hood for venting helium gas from the hood.

2.2.2 A 4 1/2" or 6"Ø vacuum dial gauge with a 1/4" NPT connection threaded into a 1/4"Ø NPT coupling welded into the test enclosure cover.

2.2.3 A 40 KF (1 1/2"Ø) long flange installed in the bottom portion of the test enclosure to which is connected a vacuum valve and a Leybold D65B rotary vane pump or unit of comparable or greater capacity. Use this pump for evacuating the test enclosure to about 10 torr (0.394" Hg absolute or 29.5" Hg negative gauge) before backfilling the enclosure with helium.

2.2.4 A 40 KF (1 1/2"Ø) long flange installed in the bottom portion of the test enclosure with a vacuum valve for backfilling with helium into that evacuated enclosure.

2.3 In order to be able to reasonably isolate the location of an indicated leak or leaks by time of flight measurement, at least one test enclosure stand at each jobsite shall contain additional equipment. The test cover of this stand shall contain the following:

2.3.1 Six (6) equally spaced 40 KF (1 1/2"Ø) long flanges along the top for connecting six (6) HPS or equivalent cold cathode gauge tubes.

2.3.2 Two HPS Model 937 or equivalent controllers for the six (6) cold cathode gauges in item 2.3.1.

2.3.3 High speed data acquisition programmed monitor for readout of the cold cathode gauge analog signals of item 2.3.1.

The underside portion of this test enclosure shall contain a:

2.3.4 Three inch (3"Ø) valved nozzle to which is connected a mechanical vacuum pump unit such as a Leybold WAU501 Roots booster backed by a D65B rotary vane pump or unit of comparable or greater capacity. The pump unit connection line shall contain a valved 40 mm (1 1/2"Ø) crossover line to a diffusion pump foreline.

2.3.5 200 K (8"Ø) flanged port to which is mounted a Balzer Model DIF 200 or equivalent diffusion pump. The 40 KF (1 1/2"Ø) foreline to this pump shall be connected through the valved crossover to the mechanical vacuum pump listed in item 2.3.4.

2.4 One end double seal assembly includes the following test equipment as shown on the test set-up sketch and described below.

2.4.1 A 160 K (6") Ø nozzle with a 6"Ø ASA flanged vacuum valve to which is connected a mechanical vacuum pump unit such as a Leybold WAU2001 Roots booster backed by a DK200 rotary piston pump or unit of comparable capacity with a 6"Ø cold trap at the inlet of the booster. The pump unit connection line shall contain a valved 100 mm (4"Ø) crossover line to a diffusion pump foreline. It shall also contain a tee with a 40 KF (1 1/2"Ø) long flange valved for connecting the helium mass spectrometer.

2.4.2 A 500 K (20"Ø) flanged port with a 20"Ø ASA flanged vacuum valve to which is mounted a flanged 20"Ø Balzer Model DIF 500A or equivalent diffusion pump. The 100 K (4"Ø) foreline to this pump shall be connected through the valved crossover line to the mechanical vacuum pump unit in item 2.4.1.

2.4.3 A 40 CF-F (1 1/2"Ø) long flange connection with a 40 CF-F blind for possible future use with a Residual Gas Analyzer (RGA).

2.4.4 A 40 KF (1 1/2"Ø) long flange connection for an ionization gauge tube connected to a control unit. Examples are a Varian Multi-Gauge, an HPS Model 937 or equivalent unit.

2.4.5 A 25 KF (1"Ø) UHV valve and a 25 KF (1"Ø) long flange connection with an adapter for a thermal conductivity gauge tube connected to the control unit listed in item 2.4.4. An example is a Varian Model 531.

2.4.6 A 16 KF (5/8"Ø) short flange valved connection leading from the interspace between the end assembly double seals to a mechanical vacuum pump.

2.4.7 Leybold Trivac D4B or equivalent mechanical vacuum pump for item 2.4.6.

2.5 Second end double seal assembly includes the following test equipment as shown on the test set-up sketch and described below.

2.5.1 A 500 K (20"Ø) flanged port with a 20"Ø ASA flanged vacuum valve to which is mounted a 20"Ø flanged housing containing an LN_2 cryogenic panel with an LN_2 inlet and a N_2 outlet.

2.5.2 A 25 KF (1"Ø) vacuum gate valve and a 25 KF (1" Ø) long flange connection for the mechanical vacuum pump inlet line.

2.5.3 Leybold Model D25B or equivalent mechanical vacuum pump connected to item 2.5.2 with a flexible metal hose with 25 KF (1"Ø) connectors for evacuating the LN_2 cryogenic panel housing.

2.5.4 16 KF (5/8"Ø) long flange connection for the system permeation helium standard leak.

2.5.5 16 KF (5/8"∅) short flange valved connection leading from the interspace between the end assembly double seals to a mechanical vacuum pump.

2.5.6 Leybold Trivac D4B or equivalent mechanical vacuum pump for item 2.5.5.

2.6 All vacuum valves 2" (50mm)∅ and smaller shall be bellows stem sealed and have KF style flange connections. Any such valves facing the evacuated space of the can section shall be stainless steel.

2.7 All valves larger than 2" (50mm)∅ shall be stainless steel UHV gate valves.

2.8 All "O" rings in test equipment shall be elastometers.

3.0 PROCEDURE:

3.1 Install the beam tube can section in the test enclosure stand. Do not close top cover of the enclosure at this time. See leak test arrangement sketch for details.

3.2 Engage the end double seal assemblies at each end of the beam tube can section. Energize the Leybold Trivac D4B or equivalent mechanical pump at each end double seal assembly. When the pump blank-off pressure reaches about 10 millitorr or less, open the valve to the space between the double seals.

3.3 Energize the Leybold WAU2001/DK200 or equivalent vacuum pump unit with the 6"∅ gate valve at the pump inlet closed. With that system operating and blanking at an adequate absolute pressure in the very low millitorr range, open the 6"∅ gate valve between the pump unit and the beam tube can section and start evacuating the can section. Also open the 4"∅ crossover line valve to the Balzer Model DIF 500A or equivalent diffusion pump. When the absolute pressure in the beam tube can section reaches about 1000 millitorr, begin cooling the 6"∅ cold trap in front of the inlet to the mechanical vacuum pump unit.

3.4 Evacuate the 20"Ø LN_2 cryogenic panel housing with its mechanical backing vacuum pump. As soon as it has been evacuated to the low millitorr absolute pressure level, begin cooling the panel with LN_2 in preparation for operation.

3.5 When the absolute pressure in the beam tube can section reaches approximately 500 millitorr, energize the diffusion pump.

3.6 When the absolute pressure reaches approximately 75 to 50 millitorr, close the 6"Ø roughing line gate valve at the 6"Ø flanged nozzle in the end seal assembly and then open the 20"Ø gate valve in front of the diffusion pump.

3.7 When the absolute pressure in the beam tube can section reaches about 5×10^{-4} torr and with the LN_2 cryogenic panel operating, open the 20"Ø gate valve to the LN_2 cryogenic panel mounted to the end seal assembly on the opposite end of the can section from the mechanical pump/diffusion pump systems.

3.8 Put the Leybold UL400 helium mass spectrometer or equivalent instrument into operation and calibrate (peak tune) the instrument to ensure that it meets the optimum leak testing sensitivity requirements.

3.9 When the absolute pressure in the can section reaches approximately 2×10^{-6} torr, open the valve to the helium mass spectrometer (HMS). While monitoring the HMS sensing element absolute pressure and the can section absolute pressure, slowly close the valve to the mechanical vacuum pump unit backing the 20"Ø diffusion pump. With the HMS solely backing the diffusion pump, monitor the can section absolute pressure to ensure that it continues to drop. Should the can section absolute pressure start to increase, indicating the throughput is too large for the HMS effective pump speed and diffusion pump foreline absolute pressure, reverse the valve arrangement and continue pumping the can section with the mechanical vacuum pump unit backing the diffusion pump. When the absolute pressure in the can section has reached a lower level, try again to solely back the diffusion pump with the HMS. When this is accomplished, proceed to step 3.11.

3.10 Should the can section absolute pressure fail to reach a level where the HMS can solely handle the diffusion pump throughout and leakage is suspected , helium tracer probe the end assembly seals for leaks.

3.10.1 If either one or both of these seals indicate inleakage, isolate and vent the test system and visually inspect the seal or seals to determine the cause of the leak or leaks. Replace, repair or modify the seal or seals as necessary and repeat steps 3.2 through 3.10 as necessary until the HMS is solely backing the diffusion pump.

3.10.2 If neither of the end seals indicate inleakage, close the top cover of the test enclosure. Evacuate the enclosure to approximately 10 torr. Monitor can section absolute pressure. A significant drop in can section absolute pressure during enclosure evacuation would indicate inleakage. To verify the existence of inleakage, vent the enclosure with helium to atmospheric pressure by closing the valve to the enclosure vacuum pump and opening the valve to the helium gas supply.

3.10.3 When unacceptable leakage in the can section has been verified, evacuate the helium from the test enclosure and backfill it with air. If the verified leakage is larger than 1×10^{-5} atm. cc/sec., open the test enclosure lid and attempt to pinpoint the location of the leak or leaks within a reasonable time by the conventional helium probe technique. If this is unsuccessful within a reasonable time or if the leakage is 1×10^{-5} atm. cc/sec. or smaller, then proceed to step 3.10.4.

3.10.4 Vent the evacuated leaking can section. Remove the leaking can section from that test enclosure, unless that test enclosure is the one equipped with the multiple cold cathode gauge heads, and place it in the test enclosure equipped with the multiple cold cathode gauge heads.

3.10.5 Engage the end seal assemblies at each end of the leaking beam tube can section and evacuate the leaking can section in accordance with steps 3.2 through 3.7.

3.10.6 Evacuate that test enclosure to an absolute pressure sufficiently low to enable the six (6) HPS or equivalent cold cathode gauge heads to become operational. Connect the gauge's control unit outputs to the high speed data acquisition system.

3.10.7 Vent the evacuated leaking can section in order to initiate the inleakage which will produce the time of flight data that will reveal the approximate lengthwise location of that inleakage. This should enable pinpointing the location of the source of that inleakage within about ±6" lengthwise on the can section.

3.11 After the can section absolute pressure has gone below about 2 x 10^{-6} torr and the HMS is solely backing the diffusion pump and the can section absolute pressure stabilizes or reaches a very slow rate of decrease, calibrate the test system as follows:

3.11.1 Record the HMS background signal in divisions. A division shall be based on the smallest increment on the most sensitive scale of the leak indicator meter.

3.11.2 While monitoring with a stop watch, open the valve to the helium permeation standard leak on the seal end assembly opposite from the pump end seal assembly. Record the elapsed time to first receive a signal if the elapsed time is long enough to record. Record the response time and the signal received in divisions. Close the standard leak valve and record the clean up time and the background signal after it has stabilized.

3.11.3 Subtract the post calibration background signal from the standard leak signal. Divide the helium leakage rate of the standard leak by the net leak indicator signal received in the test system from that system standard leak to obtain the test system sensitivity in atm. cc/sec/division of helium.

3.11.4 The goal is to attain a test system sensitivity that will enable an operator to detect a total helium leakage rate of 1×10^{-10} atm. cc/sec. or larger. If this desired test system sensitivity cannot be attained, then the test system sensitivity that must be attained is that which will enable an operator to detect a total helium leakage rate of 1×10^{-9} atm. cc/sec. or larger. If the test system sensitivity is inadequate, the can section must either be evacuated to a lower absolute pressure that will enable it to be achieved and/or be allowed to accumulate for a sufficient length of time to achieve this required test sensitivity. This system calibration shall be repeated as necessary to establish the required absolute pressure and/or the accumulation time needed to achieve this specified system sensitivity.

This has the new values

3.12 After successful completion of the system calibration in step 3.11, perform the hood test of that can section as follows.

3.12.1 Evacuate the test enclosure to approximately 10 torr.

3.12.2 Close the valve to the test enclosure vacuum pump.

3.12.3 Record the test system background leak indicator signal in divisions.

3.12.4 Vent the test enclosure to atmospheric pressure with helium gas by opening the valve to the helium gas supply.

3.12.5 Wait the elapsed time established during system calibration that would be necessary to detect a desired total helium leakage rate of 1×10^{-10} atm. cc/sec. or larger or required total helium leakage rate of 1×10^{-9} atm. cc/sec. or larger.

3.12.6 If the signal received indicates an unacceptable total leakage rate in a can section, then that leakage must be pinpointed either by repeating steps 3.10.3 and 3.10.4 or by using other more conventional HMS leak location techniques.

3.13 If the signal received in the established elapsed test time indicates a total helium leakage rate smaller than 1×10^{-9} atm. cc/sec. or if no signal is received in the established elapsed test time, then the can section is acceptable.

3.14 Vent with clean dry air (-20°F (+7°C) dew point) and seal both ends of the tube section.

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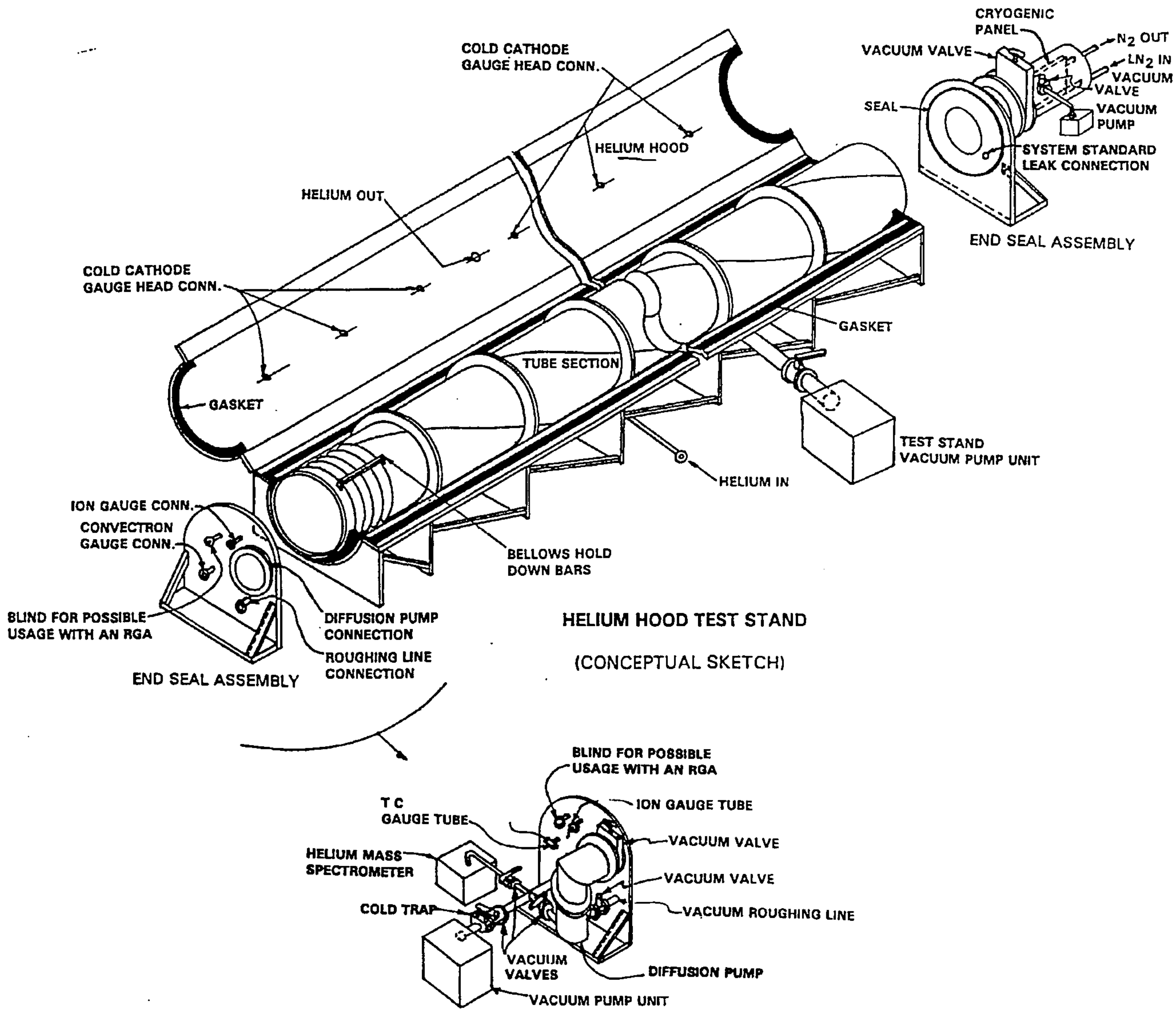
4.0 DOCUMENTATION

See procedure LIGOTP for documentation requirements.



TEST SETUP SKETCH

CBI

DOC. ID	HMST2N
REV. NO.	0
CONTRACT	930212

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS LIGO PROJECT - CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg		BY	DATE
						PREPARED	CNS	3-15-94
						REVISED		
						AUTHORIZED		
						REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

1.1 This procedure covers the helium mass spectrometer hood test of the closing weld joint between beam tube can sections. Perform this procedure in accordance with the current revision of procedure LIGOTP.

1.2 Perform the leak testing outlined in this procedure after the closing weld joint between two adjacent beam tube can sections has been visually inspected and any weld repairs have been made to correct excess undercut, lack of penetration and pinholes in that weld.

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

2.1 The helium mass spectrometers used to perform the leak testing outlined in this procedure shall be the Alcatel Model ASM 51, Leybold Model UL400, Varian Model 960, Veeco Model 18AB or equivalent with an optimum high sensitivity in the range of 10^{-11} atm. cc/sec. of helium.

2.2 A channel shaped curved metal box with an inflatable perimeter seal and a 40 KF (1 1/2"Ø) long flange for connection to the HMS. The box shall be sufficiently long to cover approximately 190^0 of the outside circumference of the closing weld joint between beam tube can sections. See the test set-up sketch at the end of this procedure.

2.3 Approximately ten (10) feet of flexible stainless steel hose with 40 KF (1-1/2"Ø) connectors on the ends for connecting the HMS to the metal vacuum box.

2.4 Combination weld purge dam/helium hood enclosure consisting of two (2) inflatable rubber seals containing two (2) 1/8"Ø connections 180° apart. The seals are interconnected with a fiber reinforced rubber ring also containing two (2) 1/8"Ø connections. The inflatable seal connections are for pressurizing and venting the

2.4 (cont'd)

seals. The one connection in the fiber reinforced rubber ring is for injecting both argon and helium gas and the second is for evacuating the enclosure. See the figure at the end of this procedure.

2.5 Two (2) hoses with 1/8"Ø connections for attaching to the fiber reinforced rubber ring and two (2) hoses with 1/8"Ø connections for attaching to the inflatable rubber seals.

2.5.1 The hose attached to one of the reinforced rubber ring connectors is for gas and the hose attached to the second reinforced rubber ring connector is for evacuation. The gas hose splits at a tee in the clean room and each of these hoses connects through a gas valve to an argon gas bottle and a helium gas bottle to be used respectively for welding purge gas and leak testing tracer gas.

2.5.2 A compressed air line is connected through a valve to one of the inflatable seal connections and a vent line is connected through a valve to the other inflatable seal connection.

2.6 Mechanical vacuum pump such as a Leybold Trivac D2B or equivalent.

2.7 Two (2) clamping rings for the two (2) 16 KF flanged connectors.

2.8 Sealing compound such as Apiezon Q or electrical putty.

3.0 PROCEDURE:

3.1 Visually inspect the outside of the closing weld joint between the beam tube can sections. Repair any excess undercut, lack of penetration or pinholes detected. Remove any rough areas adjacent to the weld in the vicinity of where the metal box seals will contact the outside surface of the tube in order to effect the best possible temporary seal.

3.2 Install the channel shaped curved metal box on a 190° segment over the outside of the closing weld joint between the beam tube can sections.

3.3 Pressurize the inflatable perimeter seal on the box.

3.4 Calibrate (peak tune) the HMS to obtain the optimum test sensitivity for the model instrument being used. Record the signal above the background signal in divisions. Since the volume of the metal vacuum box is insignificant, the test sensitivity for this system is the helium leakage rate of the standard leak divided by this net signal in divisions where a division is the smallest increment on the most sensitive scale of the leak indicator meter.

3.5 Vent the HMS manifold and connect the flexible metallic hose to the curved metal box and HMS.

3.6 Evacuate the curved metal box with the HMS auxiliary vacuum pump. After it has evacuated to approximately 100 millitorr, throttle open the HMS high vacuum system to the metal box. Should the vacuum in the metal box stabilize at a higher pressure indicating potential seal leakage, tracer probe the perimeter of the box seal to detect and pinpoint the area of leakage. If seal leakage is detected and pinpointed, temporarily seal it with sealing compound such as Apiezon Q or electrical putty.

3.7 Install the internal helium hood enclosure if it is not already in place as a purge dam for the prior welding.

3.8 When the HMS throttle valve is all the way open, the high vacuum absolute pressure meter indicator has stabilized (reached a plateau) and the leak rate meter indicator is on a scale that would enable the operator to detect 10^{-10} atm. cc/sec. range leakage, evacuate the helium hood enclosure to remove the argon present during welding.

3.9 Record the HMS background signal in divisions. A division shall be based on the smallest increment on the most sensitive scale of the leak rate indicator meter.

3.10 Backfill the hood enclosure with helium by opening the regulated helium gas supply.

3.11 Observe the HMS leak rate indicator meter for one (1) minute. If there is no increase in the leak indicator signal after one (1) minute, the leakage rate of this portion of the closing weld joint is less than 1×10^{-10} atm. cc/sec. and the leak test of this portion of the closing joint is acceptable and complete. If there is an increase in the leak indicator signal, proceed to step 3.12 to pinpoint the location of the unacceptable leakage in this portion of the closing weld joint.

3.12 Isolate the HMS from the test system and vent the 190° curved metal vacuum box. Replace the 190° curved metal vacuum box with a curved metal vacuum box approximately six inches (6") in length.

3.13 Visually inspect the 190° portion of the weld joint that contains the unacceptable leakage. If any area or areas are observed that appear to contain potential leaks, locally leak test that area or areas first.

3.14 Place the six inch (6") long box over the selected area of the closing weld joint. Connect the flexible metallic hose to the short metal box.

3.15 Evacuate the short metal box with the HMS auxiliary vacuum pump. After it has evacuated to approximately 100 millitorr, throttle open the high vacuum system to the metal box. Should the vacuum in the metal box stabilize at a higher pressure indicating potential seal leakage, tracer probe the perimeter of the seal to detect and pinpoint the area of leakage. If seal leakage is detected and pinpointed, temporarily seal it with sealing compound such as Apiezon Q or electrical putty.

3.16 Observe the HMS leak indicator signal in divisions as the high vacuum absolute pressure meter stabilizes (reaches a plateau). If the indicator signal shows an increase over the normal background, isolate the box. If the signal decreases, leakage is indicated in the area being tested. If the indicator signal shows no increase over normal background and/or does not change when the box is isolated, no leakage is indicated in that area.

3.17 When a leak(s) is pinpointed, vent the vacuum box and vent the helium hood enclosure.

3.18 Repair the pinpointed leak or leaks and retest the entire previously tested 190° segment of the closing weld joint.

3.19 When that 190° segment leak test shows no increase in the leak indicator signal after one (1) minute, the leakage rate of this portion of the closing joint is less than 1 x 10^{-10} atm. cc/sec. and the leak test of that portion of the closing weld joint is complete. If the leakage rate in this portion of the closing joint is still unacceptable, repeat steps 3.12 through 3.18.

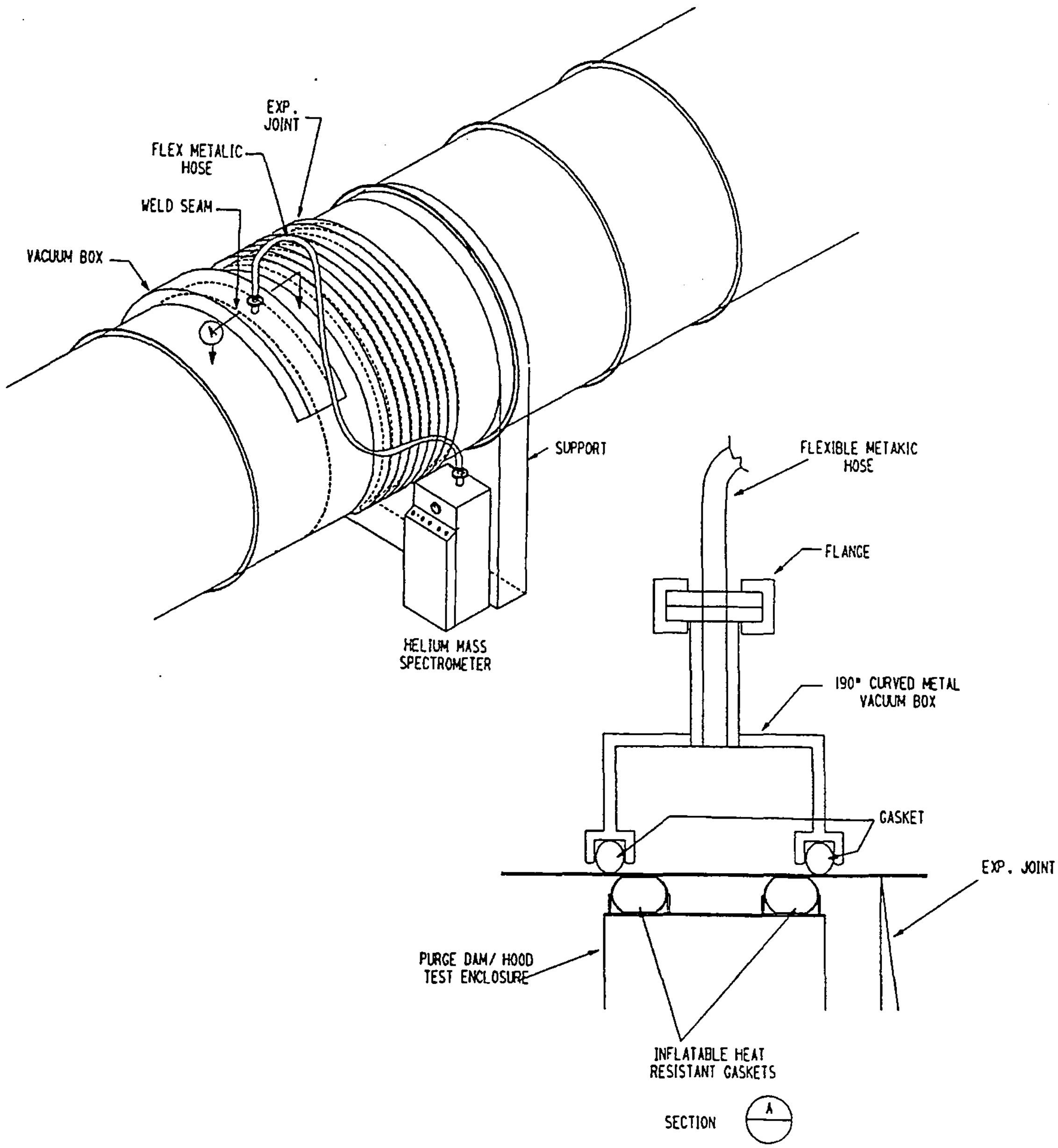
3.20 Vent the curved metallic vacuum box. Center and place this box over the outside of the 170° untested portion of the closing weld joint. Replace the helium hood enclosure on the inside of this weld joint.

3.21 Repeat steps 3.3 through 3.19 for the remaining 170° segment of the closing weld joint.

4.0 DOCUMENTATION:

See procedure LIGOTP for documentation requirements.

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS LIGO PROJECT - CALTECH



TEST SET-UP SKETCH

MISSING CAN AIR LEAK FOR LEAK ASSAY

DOC. ID	HMST3N
REV. NO.	0
CONTRACT	930212

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF PUMP PORTS WITH VALVE, LN_2 PUMP AND BLIND FLANGE WITH RGA ASSEMBLY LIGO PROJECT - CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	3-15-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD		REV. NO.

1.0 SCOPE:

1.1 This procedure covers the final helium mass spectrometer hood test of each pump port flange to 10"Ø valve flange seal, 10"Ø valve body and stem seal, 10"Ø valve flange to LN_2 pump flange seal, the LN_2 pump housing and internal cryogenic tubing, the LN2 pump flange seal to the blind flange, the blind flange to the 40 CF-F and 40 KF flange fittings and the RGA head and the cold cathode gauge head and the valve to which it is connected. Use this procedure in conjunction with the current revision of procedure LIGOTP.

1.2 Perform the leak testing outlined in this procedure on the beam tube can sections with pump ports after each of these applicable can sections has:

1.2.1 Been successfully HMS leak tested in accordance with procedure HMST1N

1.2.2 Been final cleaned in accordance with procedure CL1N.

1.2.3 Had the following installed on the 10"Ø pump port. A 10"Ø UHV gate valve, LN_2 pump, and a blind flange with 40 CF-F connections to an RGA head, a valved cold cathode gauge head and a valved potential HMS test connection.

1.2.4 Been installed in the partially erected beam tube module.

1.2.5 Been welded to the previous can section in the beam tube module being erected and that weld joint has been successfully HMS leak tested in accordance with procedure HMST2N and locally cleaned.

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

2.1 The helium mass spectrometers used to perform the leak testing outlined in this procedure shall be the Alcatel Model ASM 51, Leybold Model UL400, Varian Model 960, Veeco Model 18AB or equivalent with an optimum high sensitivity in the range of 10^{-11} atm. cc/sec. of helium.

2.2 A 16" x 42" x varying depth (30" minimum) rectangular shaped cylinder metal box with a metal cover containing a 40 KF (1 1/2"∅) short flange for connection to the helium mass spectrometer and a 16 KF (5/8"∅) short flange connection for the system permeation helium standard leak. Shape the open end of the box to fit the curvature of the beam tube. The box shall be of such a size as to fit over the outside of the pump port nozzle, the 10"∅ valve and the LN_2 pump with blind flange with an RGA head and a valved cold cathode gauge head. It shall be HMS leak tested and all leaks repaired and retested before being used in production. Use a double tip cross section 60 durameter gasket to make the seal of the box to the outside of the beam tube. See the test set-up sketch at the end of this procedure.

2.3 Approximately ten (10) feet of flexible stainless steel hose with 40 KF (1-1/2"∅) connectors on the ends for connecting the HMS to the metal vacuum box.

2.4 6 to 10 mil polyethylene for making local hoods (bags).

2.5 2" to 4" wide duct tape for sealing local hoods (bags).

2.6 Sealing compound such as Apiezon Q or electrical putty.

3.0 PROCEDURE:

3.1 After final cleaning of a can section with a pump port, install equipment on the pump port as follows:

3.1.1 Unbolt the blind flange from the pump port. Clean the pump port interior neck by wiping with lint free clothes or paper towels soaked with isopropyl alcohol. Visually inspect the pump port flange and the valve flanges and sealing surfaces to ensure that those surfaces are free of scratches. Then clean those surfaces by wiping with lint free clothes or paper towels soaked with isopropyl alcohol.

3.1.2 Install a metal "O" ring and bolt the valve to the pump port with the valve seating surface toward the pump port.

3.1.3 Close the 10"∅ isolation valve.

3.1.4 Visually inspect the LN_2 pump flanges and sealing surfaces to ensure that those surfaces are free of scratches. Then clean those surfaces by wiping with lint free clothes or paper towels soaked with isopropyl alcohol.

3.1.5 Install a metal "O" ring and bolt the LN2 pump to the valve.

3.1.6 Visually inspect for scratches on the blind flange containing one 40 CF-F (1 1/2"Ø) flange fitting and one 40 KF (1 1/2"Ø) short flange valved fitting. Check the already cleaned surface of the LN_2 pump flange and reclean if necessary. Clean the surface of the blind flange by wiping with lint free cloths or paper towels soaked with isopropyl alcohol.

3.1.7 Install a metal "O" ring and bolt the blind flange to the LN_2 pump.

3.1.8 Visually inspect the blind flange fitting sealing surfaces for scratches. Clean those surfaces with isopropyl alcohol. Then install the RGA head to the 40 CF-F fitting and install vacuum valves on the other two 40 CF-F fittings. Connect the flexible metal hose from the HMS to one of the valves. Open that valve. Connect a cold cathode gauge head to the other valve. Make sure that valve is open.

3.2 Start and calibrate (peak tune) the HMS to obtain the optimum test sensitivity for the model instrument being used. The instrument sensitivity, based on the smallest division on the most sensitive scale of the leak indicator, must be no less than 1×10^{-10} atm. cc/sec.

3.3 Connect the flexible metal hose to the HMS and evacuate the LN_2 pump with the HMS. When the HMS throttle valve is all the way open and the system absolute pressure has stabilized (reached a plateau) and the HMS leak indicator is on a scale that is sufficiently sensitive to enable the operator to detect 10^{-10} atm. cc/sec. range leakage, inject helium into the inlet side of the LN_2 pump cryogenic tubes for about 30 seconds.

3.4 If any leakage is indicated in the LN_2 pump tubes by a signal increase on the HMS leak indicator within one (1) minute, vent the LN_2 pump and replace that LN_2 pump with another unit and repeat steps 3.1.4 through 3.3 until no leakage is indicated in the tubes.

3.5 Disconnect the HMS flexible metal hose from the LN_2 pump blind flange valve. Leave that valve open.

3.6 Wipe the interior of the metal vacuum box with isopropyl alcohol. Install a permeation helium standard leak on the 16 KF (5/8"Ø) connection in the metal vacuum box. Then install the metal box over the pump port, valve, LN_2 pump and blind flange with RGA head and cold cathode gauge head. Pull the box tight to the can section with straps connected to turnbuckles as shown in the figure at the end of this procedure.

3.7 Connect the HMS flexible metal hose to the 40 KF (1 1/2" Ø) fitting on the metal vacuum box and then evacuate the metal box with the HMS auxiliary vacuum pump. After it has evacuated to approximately 50 to 100 millitorr, throttle open the HMS high vacuum system to the metal box. Should the vacuum in the metal box stabilize at a higher pressure indicating potential leakage, tracer probe the perimeter of the seal to detect and pinpoint the area of leakage. If seal leakage is detected and pinpointed, apply sealing compound such as electrical putty, around the perimeter of the seal as necessary until no seal leakage is indicated.

3.8 Cut a piece of polyethylene approximately 14" square and tape it over the inside of the pump port opening into the beam tube. Leave a small spot untaped along both the bottom and top of this hood (bag).

3.9 When the HMS high vacuum absolute pressure meter indicator has stabilized (reached a plateau) and the leak rate meter indicator is on a scale that will enable the operator to detect 10^{-10} atm. cc/sec. range leakage, calibrate the test system as follows:

3.9.1 Record the HMS background signal in divisions. A division shall be based on the smallest increment on the most sensitive scale of the leak rate indicator meter.

3.9.2 Open the valve to the system standard leak in the metal box. There will be a brief sudden surge in signal due to the small pressure burst from the unevacuated space in the end of the leak. As soon as the leak indicator signal stabilizes and peaks, record this signal in divisions. If the time to receive this peak signal was more than a few seconds, then also record this response time. Close the standard leak valve and record the clean up time and the background signal after it has stabilized.

3.9.3 Subtract the post calibration background signal from the standard leak signal. Divide the helium leakage rate of the standard leak by the net leak indicator signal received in the test system from that system standard leak to obtain the system sensitivity for helium in atm. cc/sec./division.

3.9.4 The goal is to attain a test system sensitivity that will enable an operator to detect a total helium leakage rate of 1×10^{-10} atm. cc/sec. or larger. If this desired test system sensitivity cannot be readily achieved, then the test system sensitivity that must be attained is that which will enable an operator to detect a total helium leakage rate of 1×10^{-9} atm. cc/sec. or larger. If the test system sensitivity is inadequate, the metal box must be evacuated to a lower absolute pressure that will enable it to be achieved.

3.10 After successful completion of the system calibration in step 3.9, record the HMS background signal in divisions.

3.11 With a pressure regulated helium probe, inject helium into the polyethylene hood through the bottom opening in the tape while allowing the air to vent from the top hole in the tape. After purging with helium for about 15 seconds, seal the top vent hole and inflate the hood (bag) with helium.

3.12 Leakage smaller than 1×10^{-10} atm. cc/sec. is desirable, but any leakage equal to or larger than 1×10^{-9} atm. cc/sec. of helium as indicated by a signal on the HMS leak indicator is unacceptable. Pinpoint and repair unacceptable leakage. If site repair is not possible, replace the unacceptable part or parts and retest the same pump port assembly in accordance with this procedure. Repeat this as necessary until no leakage equal to or larger than 1×10^{-9} atm. cc/sec. of helium is indicated.

3.13 After a successful HMS leak test with the pump port valve closed, vent the evacuated test system and remove the metal box and putty seal if any sealing compound was used.

3.14 Open the pump port isolation valve. Close LN_2 pump blind flange valve that remained in the open position in step 3.5.

3.15 HMS test the same pump port assembly again by repeating steps 3.6 through 3.12.

3.16 If no leakage equal to or larger than 1×10^{-9} atm. cc/sec. of helium is indicated during the repeat of steps 3.6 through 3.12, remove the helium hood (bag) from the pump port on the inside of the can section, vent the evacuated test system and remove the metal vacuum box and putty seal if any sealing compound was used.

3.17 Leave the pump port isolation valve in the open position when this HMS test of the pump port assembly is completed.

3.18 Repeat steps 3.1 through 3.17 for each 10"Ø pump port assembly on the beam tube can sections with a pump port.

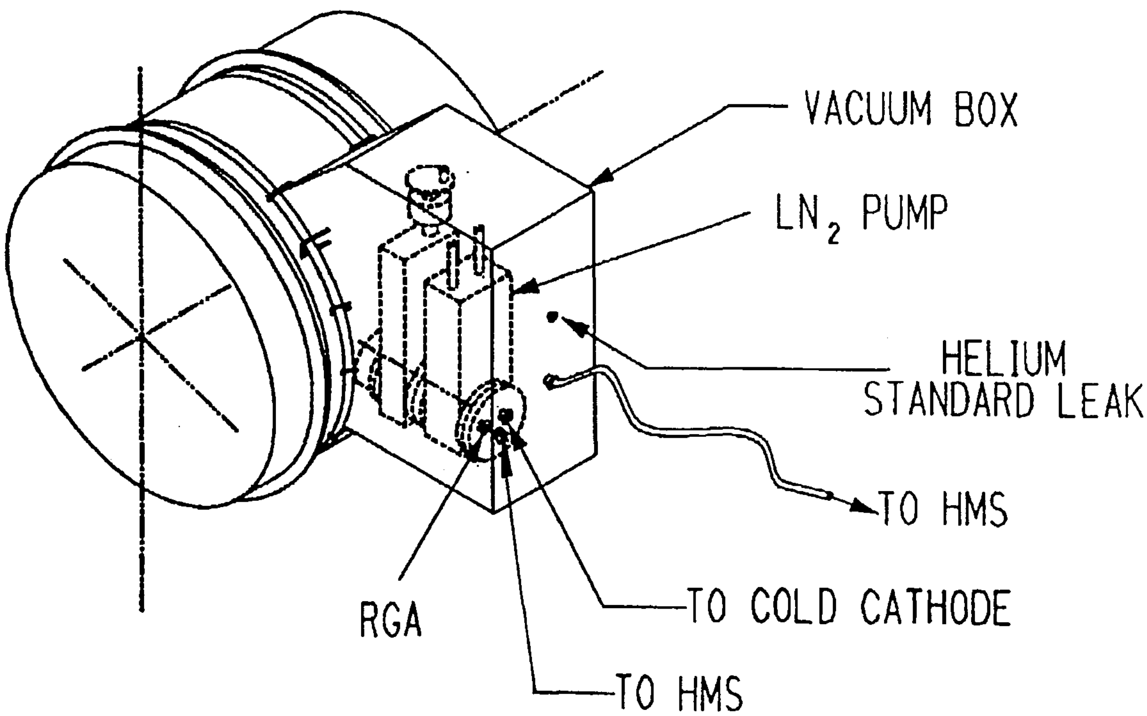
4.0 <u>DOCUMENTATION</u>:

Document in accordance with item 5.0 of procedure LIGOTP.

CBI

DOC. ID HMST3N
REV. NO. 0
CONTRACT 930212

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF PUMP PORTS WITH VALVE, LN_2 PUMP AND BLIND FLANGE WITH RGA ASSEMBLY LIGO PROJECT - CALTECH



TEST SETUP SKETCH

CBI	IDENTIFICATION HMST4N			
TITLE RGA/HMS/PERFORMANCE TEST OF BEAM TUBE MODULES LIGO PROJECT - CALTECH	REFERENCE NO. 930212		SHT 1 OF 5	
	OFFICE		REVISION 2	
PRODUCT	MADE BY CSN	CHKD BY	MADE BY	CHKD BY
	DATE 04/07/94	DATE	DATE	DATE

1.0 SCOPE:

1.1 This procedure covers the residual gas analyzer/helium mass spectrometer/performance test of each of the beam modules. Use this procedure in conjunction with the current revision of procedure LIGOTP.

1.2 Perform the sequence outlined in this procedure on the applicable beam tube module after :

1.2.1 All beam tube can sections in that module have been successfully HMS leak tested in accordance with procedure HMST1N, final cleaned and erected.

1.2.2 All closing weld joints in that module have been successfully HMS leak tested in accordance with procedure HMST2N and locally cleaned.

1.2.3 All pump port assemblies have been successfully HMS leak tested in accordance with procedure HMST3N and locally cleaned. A pump port asembly includes the pump port flange to 10"∅ valve flange seal, 10"∅ valve body and stem seal, 10"∅ valve flange to LN_2 pump flange seal, the LN_2 pump housing and internal cryogenic tubing, the LN_2 pump flange to the blind flange seal, the blind flange to the three 40 CF-F fittings and the RGA head and valved cold cathode gauge head and potential HMS test port attached to these fittings

1.2.4 The permanent vacuum pump set for the applicable beam tube module has been installed.

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

2.1 Leybold Model UL400 helium mass spectrometer leak detector with the optional high sensitivity of 2×10^{-12} atm. cc/sec. of helium (8×10^{-13} atm. cc/sec. of air) or instrument of comparable capability.

2.2 Flexible stainless steel hose with 40 KF (1 1/2"∅) fittings for connecting the helium mass spectrometer to the test system.

2.3 Caltech supplied LN_2 pump at each module pump port.

2.4 Caltechj supplied RGA instrument at each module pump port with a minimum amu mass range of 1-100.

2.5 Caltech supplied vacuum pump sets at both ends of each beam tube module. In a letter of 1/7/94 from Larry Jones, Caltech stated that each pump set shall consist of a 100 l/s mechanical pump backing a 2200 l/s turbomolecular pump. The pump sets shall be provided with valves to accomodate the helium mass spectrometer(s) for the beam tube module leak test.

2.6 Ultrasonic leak detector such as a model UF60 by Ultrasonics of Florida.

2.7 IBM compatable 486 PC with a DAS 1402 high speed board, STC-37 DAS 1400 terminal interface and Labtech Notebook 7.2 software data acquisition program with printer.

2.8 Seven (7) HPS or equivalent cold cathode gauge heads.

2.9 Three (3) HPS Model 937 or equivalent gauge tube controllers.

3.0 PROCEDURE:

3.1 All 10"∅ pump port isolation valves shall be in the open position.

3.2 Visually inspect the length of the beam tube module to be final tested.

3.3 Check-off each item on the checklist as it is inspected and found satisfactory during the walkdown.

3.4 Start and calibrate (peak tune) the helium mass spectrometer (HMS).

3.5 Conduct a blank-off and a HMS tracer probe test of the 100 l/s mechanical vacuum pump and 2200 l/s turbomolecular pump sets located at each end of each beam tube module. When both the blank-off and HMS tracer probe test results are satisfactory, begin evacuating the beam tube module.

3.6 Compare the system absolute pressure during pump down against a prepared theoretical pump down curve. Any time the actual pump down curve starts to vary significantly from the theoretical pump down curve, check all mechanical pump oil levels and condition of the oil for excess moisture and the blank-off pressures for the entire pump set systems. <u>Continue to plot absolute pressure versus time on semi-log paper during the entire pump down and test.</u>

Computer as in QT

3.7 When the absolute pressure in the beam tube module reaches approximately 100 millitorr, energize the beam tube module turbomolecular pumps.

3.8 Should the absolute pressure in the beam tube module stop decreasing before it reaches the level of 100 millitorr, indicating either gross leakage or overlooked internal contamination, repeat steps 3.2 and 3.3.

3.8.1 If any obvious problem item such as physical damage is discovered during the repeat walkdown checklist inspection of 3.2 and 3.3, scan the area with an ultrasonic leak detector. If leakage is indicated and pinpointed, isolate the vacuum pump sets, vent the system, repair and/or correct the problem and start over at step 3.5.

3.8.2 If no leakage is detected, review all can section final test reports/logs/PC entries and all closing weld joint test reports/logs and PC entries for statements or data that reveals potential leakage problem areas or internal contamination previously overlooked. LIst all potential problem areas revealed by these logs or reports.

3.8.3 Walk the beam tube module in all these potential problem areas with an ultrasonic leak detector to attempt to detect and pinpoint the location of the gross leak. If leakage is detected and pinpointed, record the location. When all areas are ultrasonically leak tested, isolate the vacuum pumps, vent the system, repair and/or correct the problem(s) and start over at step 3.5.

3.8.4 If gross leakage still exists, repeat all steps of item 3.8 using acetone while monitoring for rapid momentary pressure changes on the absolute pressure gauges.

3.8.5 Repeat these item 3.8 steps until gross leakage has been eliminated.

3.9 When the system absolute pressure reaches approximately 50 millitorr, open the valves between the turbomolecular pumps and the beam tube module. At the same time, close the valves in the roughing lines between the mechanical pump sets and the test system.

3.10 While continuing to evacuate the beam tube module, monitor with an RGA the following Caltech suggested system atomic mass numbers to obtain a signature analysis of the system gases. These amu values are 2, 12, 14, 15, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55 and 57.

3.11 If at this step of the procedure the system will not evacuate to a sufficiently low absolute pressure level and the RGA signature analysis indicates unacceptable leakage of 1×10^{-5} atm. cc/sec. or larger, proceed as follows:

3.11.1 In accordance with the figures attached to reference 3.4 in procedure LIGOTP, conduct a pressure assessment of the beam tube module using the RGA readouts at each of the pump ports to attempt to localize the area of the leakage.

3.11.2 Record the absolute pressure simultaneously readout at each RGA with both pump sets pumping on the beam tube module.

3.11.2 Isolate the pump set at the far end of the beam tube module. Record the absolute pressure simultaneously readout at each RGA.

3.11.3 Plot the ratio of the two pressure readings taken at each RGA against the distance in kilometers along the beam tube module from the leak. The highest ratio will be nearest the leak. The smaller the ratio, the further the distance from the leak.

CBI	IDENTIFICATION HMST4N			
TITLE RGA/HMS/PERFORMANCE TEST OF BEAM TUBE MODULES LIGO PROJECT - CALTECH	REFERENCE NO. 930212		SHT 4 OF 5	
	OFFICE		REVISION 2	
PRODUCT	MADE BY CSN	CHKD BY	MADE BY	CHKD BY
	DATE 04/07/94	DATE	DATE	DATE

3.11.4 With both pump sets again pumping on the system, record the absolute pressure simultaneously readout at each RGA every 1000 seconds and plot each of these readings in torr against distance in kilometers along the beam tube module. Continue recording and plotting until there is sufficient pressure change to reveal a meanful location pattern. Repeat this process with the pump set at the far end of the beam tube module isolated from the system..

3.11.5 Plot the pressure changes for the absolute pressure data in item 3.11.4 against the elapsed time in seconds during which those pressure changes occurred. Plot this for both conditions, i.e. first with both pump sets open to the system and second with one pump set open to the system and one pump set closed to the system.

3.11.6 If steps 3.11.2 through 3.11.5 reveals the approximate location of the leak, proceed to step 3.15.

3.12 If steps 3.11.2 through 3.11.5 do not reveal the approximate location of the leak, repeat the same steps using the readings of the cold cathode gauges located at each of the pump ports.

3.13 If step 3.12 also does not reveal the approximate location of the leak, connect the high speed data acquisition system to the cold cathode gauge controller units.

3.14 Isolate the pump sets at both ends of the beam tube module. At the same instant, energize the high speed data acquisition system. The timing of these three events must be closely co-ordinated due to the limited memory space of the PC. These high speed pressure change plots should reveal the location of the leak within a few meters. If that happens, proceed to step 3.15. Should this technique also fail to reveal the location of the leak, go to step 3.20.

3.15 Visually inspect the area of the approximate leak location to detect and pinpoint the exact source of the leakage.

3.15.1 If the leak is in a mechanical connection such as a flange seal which cannot be temporarily isolated from the system but may be repaired without entry into the beam tube module, vent the system with nitrogen gas, repair or replace the cause of the leak and re-evacuate the system.

jeopardizing

3.15.2 If the leak is a hole or crack in a weld which is not jeopradizing structural integrity, cover the leak area with a piece of plastic and apply seaing compound around the edge of the plastic to isolate the leak from the system.

3.15.3 If the leak is the result of a crack or damage which could be jeopradizing the structural integrity of the beam tube module and the beam tube would have to be entered to either make the repair or to locally

CBI	IDENTIFICATION HMST4N			
TITLE RGA/HMS/PERFORMANCE TEST OF BEAM TUBE MODULES LIGO PROJECT - CALTECH	REFERENCE NO. 930212		SHT 5 OF 5	
	OFFICE		REVISION 2	
PRODUCT	MADE BY CSN	CHKD BY	MADE BY	CHKD BY
	DATE 04/07/94	DATE	DATE	DATE

test the repair, vent the system with air. After the cause of the leak has been repaired, re-evacuate the system.

3.16 As long as the system absolute pressure continues to go down, continue to pump and monitor with the RGA to determine if the signature analysis still indicates no unacceptable inleakage.

3.17 Energize each of the LN_2 pumps with liquid nitrogen.

3.18 The leakage rate of the module shall be considered satisfactory and the module shall be considered ready for bake out:

3.18.1 When the beam tube module reaches an absolute pressure in the low end of the10^{-7} torr range, the RGA signature analysis continues to indicate no unacceptable inleakage and the absolute pressure continues to decrease, even if at a very slow rate,

3.18.2 Even if the beam tube module will not readily evacuate to a sufficiently low absolute pressure level, provided the RGA signature analysis indicates the gas load is attributable to outgassing and not unacceptable inleakage.

3.19 The system would now be ready for bake out by Caltech.

3.20 If unacceptable leakage developes in the beam tube module during bake out which jeopardizes continuing the bake-out, repeat the applicable steps of this procedure. If necessary, proceed to procedure HMST5N.

3.21 If all procedure steps have been performed and the system will not evacuate to a sufficiently low absolute pressure level and the RGA signature analysis still indicates unacceptable inleakage of 1×10^{-9} atm. cc/sec. or larger, perform a HMS hood test of the beam tube module in accordance with procedure HMST5N.

4.0 DOCUMENTATION:

Document in accordance with item 5.0 of procedure LIGOTP.

DOC. ID	HMST5N
REV. NO.	0
CONTRACT	930212

TITLE HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE MODULES
LIGO PROJECT - CALTECH

APPROVED	Engr	Corp Weld	Corp QA	Const	Mfg

	BY	DATE
PREPARED	CNS	3-15-94
REVISED		
AUTHORIZED		

REFERENCED STANDARD	REV. NO.

1.0 SCOPE:

1.1 This procedure covers the helium mass spectrometer hood test which will be performed on any beam module when the results at step 3.20 of procedure HMST4N for that beam tube module indicate it is necessary. Use this procedure in conjunction with the current revision of procedure LIGOTP.

1.2 Perform the leak testing outlined in this procedure on the applicable beam tube module after:

1.2.1 All beam tube can sections in that module have been successfully HMS leak tested in accordance with procedure HMST1N, final cleaned and erected.

1.2.2 All closing weld joints in that module have been successfully HMS leak tested in accordance with procedure HMST2N and locally cleaned.

1.2.3 All pump port assemblies with isolation valve, LN_2 pump and RGA head, cold cathode gauge head and potential HMS test connection have been successfully HMS leak tested in accordance with procedure HMST3N and locally cleaned. After this test is complete, the isolation valves are to remain in the open position.

1.2.4 The permanent mechanical and turbomolecular vacuum pump sets for the applicable beam tube module have been installed at each end of the module.

1.2.5 The helium mass spectrometer/performance test of the applicable beam tube module has been performed in accordance with procedure HMST4N and the results, either before and/or after the beam tube module bake out, indicate that this HMS hood test is necessary to meet the specification requirements of no inleakage equal to or larger than 1×10^{-9} atm. cc/sec.

2.0 <u>LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE</u>:

2.1 Leybold Model UL400 helium mass spectrometer leak detector with the optional high sensitivity of 2×10^{-12} atm. cc/sec. of helium (8×10^{-13} atm. cc/sec. of air) or instrument of comparable capability.

2.2 Adjustable helium standard leak that will span the leakage rate ranges from 10^{-5} to 10^{-7} atm. cc/sec.

2.3 Flexible stainless steel hose for connecting the helium mass spectrometer to the test system.

2.4 Caltech supplied LN_2 pump at each module pump port.

2.5 Caltech supplied RGA instrument at each module pump port with a minimum amu mass range of 1 - 100.

2.6 Caltech supplied pump sets at each end of the beam tube module. They shall consist of a 100 l/s mechanical pump backing a 2200 l/s turbomolecular pump. The pump sets shall be provided with valves at each end of the beam tube module to accommodate the helium mass spectrometer(s) for the beam tube module leak test.

2.7 IBM compatible 486 PC with a DAS 1402 high speed board, STC-37 DAS 1400 terminal interface and Labtech notebook 7.2 software data acquisition program with printer.

2.8 Seven (7) HPS or equivalent cold cathode gauge heads.

2.9 Three (3) HPS Model 937 or equivalent gauge tube controllers.

2.10 6 to 10 mil polyethylene for making local hoods (bags).

2.11 2" to 4" wide duct tape for sealing local hoods (bags).

3.0 <u>PROCEDURE</u>:

3.1 The beam tube module is already evacuated to some very low absolute pressure from procedure HMST4N.

3.2 Connect the high speed data acquisition system to the HPS model 937 or equivalent gauge tube controllers.

3.3 Close the isolation valves between the pump sets and the beam tube module. Conduct a blank-off of the 100 l/s mechanical vacuum pump and 2200 l/s turbomolecular pump set. When they are satisfactory, re-continue evacuating the beam tube module.

3.4 Should the absolute pressure in the beam tube module stop decreasing (plateau) in the 10^{-5} to 10^{-6} torr range:

3.4.1 Isolate the vacuum pump sets at both ends of the beam tube module. At the same instant, energize the high speed data acquisition system. The timing of these three events must be closely coordinated due to the limited memory space of the PC. These high speed pressure change plots should reveal the location of the leak within a few meters.

3.4.2 After sufficient data has been recorded (less than a minute), open the valve(s) to the beam tube module pump sets.

3.4.3 Analyze the high speed acquired pressure rise data for an indication of the approximate location(s) of the leakage problem(s) along the axis of the beam tube module.

3.4.4 Re-calibrate (peak tune) the helium mass spectrometer (HMS).

3.4.5 If this procedure is being performed after the module bake-out, remove the insulation in the area or areas indicated in step 3.4.3.

3.4.6 Throttle the HMS into the roughing line behind the turbomolecular pump nearest the indicated leak area or areas. Isolate the mechanical unit of that pump set from the system. Isolate the other pump set from the module.

3.4.7 Hood test the area or areas revealed in step 3.4.3. Continue to reduce the area of the hood until the leak(s) have been pinpointed. Mark all area or areas of pinpointed leakage.

3.4.8 Isolate the HMS and pump sets from the system, vent the system and repair all pinpointed leakage areas and re-evacuate the beam tube module.

3.4.9 Repeat all steps of item 3.4 until this problem is resolved.

3.5 While continuing to evacuate the beam tube module, monitor with the RGA the following Caltech suggested system atomic mass numbers to obtain a signature analysis of the system gases. These amu values are 2, 12, 14, 15, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55 and 57.

3.6 As long as the system absolute pressure continues to decrease, continue to pump and monitor with the RGA to determine if the signature analysis indicates any significant inleakage.

3.7 When the beam tube module absolute pressure reaches a plateau at a higher absolute pressure level than is desired either before or after the bake-out and the RGA signature analysis indicate unacceptable inleakage of 1×10^{-9} atm. cc/sec. or larger, continue with the remaining steps of this procedure.

3.8 Start a high volume fan blowing from one end of the beam tube module toward the other end inside the weather cover.

3.9 Begin HMS tracer probe testing at the end of the beam tube module at the end farthest downwind away from the fan. If this step is after bake-out, remove the insulation from this first 250 meter (820 foot) section to be HMS tracer probe tested.

3.10 Install a 10^{-8} atm. cc/sec. range permeation helium standard leak on the valved third connection on the pump port assembly in the 250 meter (820 foot) segment of beam tube module to be helium tracer probe tested.

3.11 Connect the HMS behind the pump set turbomolecular pump at the end of the beam tube module farthest from the high volume fan. With the HMS backing as much of the turbomolecular pump throughput as possible, calibrate the test system as follows:

3.11.1 Record the HMS background signal in divisions. Then open the valve to the standard leak. Record both the response time and HMS leak indicator signal in divisions.

3.11.2 Close the valve to the standard leak. Record the HMS clean-up time and background signal in divisions.

3.11.3 Divide the helium leakage rate of the standard leak by the standard leak indicator HMS signal minus the background signal after clean-up. This is the sensitivity of the test system in atm cc/sec. of helium per division with a division being a unit on the most sensitive scale of the HMS.

3.11.4 If a readable signal is not detected on the HMS leak indicator within a reasonable time, close the valve to the permeation standard leak. Replace that standard leak with the adjustable standard leak set to a leakage rate in the 10^{-6} to 10^{-7} atm. cc/sec. range and repeat steps 3.11.1 through 3.11.3.

3.12 With the weather cover fitting at the monument position open in the segment, tracer probe all welds and suspect areas with helium starting at the end of the 250 meter (820 foot) long section of beam tube module farthest from the fan.

3.13 Continuously monitor the oxygen level in the tunnel between the beam tube module and the weather cover to ensure safe levels of oxygen in this space.

3.14 Monitor the HMS leak indicator for a period of time equal to the response time unless that is extremely long. If that is the case, wait for a period of time equal to the time when the standard leak signal just started to increase steadily plus five (5) minutes.

3.15 If no leak indicator signal above the background signal is received within the time established in step 3.11.1, that 250 meter (820 foot) section of beam tube shall be considered satisfactory.

3.16 If a leak indicator signal above background is received, then unacceptable leakage has been detected. Purge the 250 meter (820 foot) long space in the weather cover with air until approximately three (3) volumes or more have passed through that space and the HMS leak indicator signal has started to clean-up. If the clean-up is going to take an excessively long time, partially vent the beam tube with nitrogen gas and re-evacuate that system. Repeat this process as necessary to reduce the HMS leak indicator background signal to a level on the most sensitive scale of the instrument.

3.17 If leakage is indicated, visually inspect all welds in that 250 meter (820 foot) section of beam tube. Revisit all testing and welding logs to try and find a clue as to the approximate location of the leak(s).

3.18 If any suspect area or areas are found in step 3.17, HMS tracer probe test those area or areas first. If none are found, methodically HMS tracer probe test all welds and suspicious areas detected visually in that section of beam tube. Start at the end farthest from the fan and work toward the opposite end of that segment.

3.19 Mark and record any leak (s) detected. Temporarily seal these leaks by covering them with a piece of polyethylene and sealing the polyethylene to the beam tube with sealing compound such as electrical putty.

3.20 If the RGA signature analysis still indicates unacceptable leakage in excess of 1×10^{-9} atm. cc/sec., remove the insulation from the next 250 meter (820 feet) segment of beam tube closer to the fan.

3.21 Then repeat steps 3.8 through 3.19.

3.22 Repeat this cycle until enough detected leaks have been temporarily sealed to reduce the leakage rate of the beam tube module to an acceptable level of less than 1×10^{-9} atm. cc/sec.

3.23 When sufficient leakage has been detected and pinpointed or the entire beam tube module has been HMS tracer probe tested per steps 3.8 through 3.19, vent the beam tube module and repair all detected leaks.

3.24 Re-evacuate the beam tube module and retest all repaired areas. If any unacceptable leaks still exist after being repaired, vent the system, repair those leaks and re-evacuate and retest those repairs. Repeat this process as necessary.

3.25 If steps 3.8 through 3.24 do not produce a total leakage rate of less than 1×10^{-9} atm. cc/sec. as indicated by the RGA signature analysis, in lieu of repeating the helium tracer probe test, enclose each 250 meter (82 foot) segment of the beam tube module in a polyethylene hood (bag) and repeat steps 3.8 through 3.24 using the helium hood technique.

4.0 DOCUMENTATION:

Document in accordance with item 5.0 of procedure LIGOTP.

CBI	IDENTIFICATION COUP-01			
TITLE COUPON OUTGASSING TEST PROCEDURE OPTION PHASE	REFERENCE NO. 930212		SHT 1 OF 7	
	OFFICE		REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES OPTION PHASE	MADE BY WAC	CHKD BY WAC	MADE BY	CHKD BY
	DATE 01/31/94	DATE 02/03/94	DATE	DATE

Multiple Chamber Configuration, Ambient Temperature Outgassing Test

RECORD KEEPING

All operating data taken, the time, the date, the coupon identification, all physical actions (such as opening or closing a valve) and all mental impressions, visual evidence or unusual occurances (such as how fast the system is pumping down or that this batch of coupons seems to be more oxidized than usual) shall be recorded in the lab notebook and the appropriate computer. Operating data shall include pressures, piping, vessel and coupon temperatures, bake-out durations etc. All RGA data will be automatically recorded on the RGA computer.

PREPARATION

It is assumed that the coupon test system has been conditioned to provide a low background outgassing rate. The system should be rebaked if a portion of the system (except the chamber as a normal occurrence) has been opened to atmosphere. The system should also be leak checked if it has been in any way disassembled. It is also assumed that the material samples have been cut into coupons which are 1" wide by 18" long.

The facility shall be inspected to ensure that the utilities are available. Breakers are turned on, water and air are available, nitrogen and helium bottles are available in sufficient quantities for the test.

Apparel

Test personnel shall wear, as a minimum, the following protective clothing:

1. Lab coat
2. Clean room gloves
3. Clean room hat
4. Clean room shoe covers (if in clean room)

Cleaning

The first step of the preparation is to clean the coupons. This shall be accomplished by following the cleaning procedure which has been developed for the coupon outgassing tests. During the option phase of the project, the project cleaning procedure shall be strictly followed.

Warnings:

1. **Failure to follow the cleaning procedure may result in significant changes in the outgassing rate which will invalidate the results of the test.**
2. **After cleaning; the coupons shall not be touched directly by the hands; laid on a non-clean surface; and shall not be wiped with anything but a clean, lint free, clean room quality cloth.**

The coupons shall then be loaded into the coupon chamber. The operator shall ensure that the permanent coupon (with the thermocouple) is located in the center of the chamber in order to represent a worst temperature location.

Chamber Sealing

Seal the coupon test chamber. Always use a new conflat gasket and remember to torque the bolts in a clockwise or counter clockwise sequence, <u>not in an across pattern</u> as wheel lug nuts would be installed. The bolts should be torqued approximately 1/4 turn per time and each bolt should be torqued at least four times.

SYSTEM PUMP-DOWN

Valve Alignment

This discussion is based on the assumption that at least one chamber is in operation and the following procedure is used to activate and test an additional chamber.

The system valving shall be aligned as follows:

• Chamber isolation valve to the dirty vacuum manifold	closed
• Chamber isolation valve to the clean vacuum manifold	closed
• Chamber re pressurization valve	closed
• Calibrated leak system isolation valve	closed
• Dirty turbomolecular pump isolation valve	open
• Dirty roughing pump isolation valve	open
• Hydrogen calibrated leak valve	closed
• RGA isolation valve	closed
• Cold trap vent valve	closed
• Clean turbomolecular pump isolation valve	closed
• Clean roughing pump isolation valve	closed

Roughing

The dirty pump system turbomolecular pump and roughing pump will be operating and the system will probably be at a high vacuum condition. If the system is at a high vacuum condition, shut off the cold cathode gage and place the turbomolecular pump controller in the stand-by mode of operation. Very slowly open the chamber isolation valve to the dirty pump system manifold. This will slowly evacuate the sample chamber.

High Vacuum Pumping

The roughing pump viscous inbleed valve will close as the pressure at the inlet to the roughing pump rises due to opening the chamber isolation valve. Wait until the viscous inbleed valve reopens and place the dirty pump system turbomolecular pump controller back into the run mode of operation. Allow the system to evacuate the chamber and system for a minimum of 10 minutes after the turbomolecular pump indicates it is at full speed and then activate the Cold Cathode Gage. Slowly open the chamber isolation valve to the clean pumping system, RGA Isolation valve and the calibrated leak system isolation valve. Allow the pump to evacuate the system to below 1×10^{-5} torr and activate the RGA in the faraday cup mode. Evaluate the system for an air leak using the RGA. Shut off the RGA and close the chamber isolation valve to the clean pumping system and the RGA isolation valve when confident that no leak exists.

BAKE-OUT

Activate the bake-out system for the piping manifolds and both of the pump systems. Open the RGA isolation valve. Ensure that the temperature does not increase by more than 60° C per hour. Allow the temperature to stabilize at 250° C. Approximately one hour after the start of the piping bake-out, activate the bake-out system for the chamber and set the chamber temperature controllers to 250° C. Initially, the pressure gage must be monitored to ensure that the system pressure does not rise above the operating range of the cold cathode gage and the turbomolecular pump (1 X 10^{-2} torr). If the pressure nears 1 X 10^{-2} torr, lower the setpoint of the chamber temperature controller to a point slightly below the current chamber temperature. Allow the chamber pressure to drop and then slowly increase the setpoint of the controller until it is set at 250° C. Continue the bake-out for 24 hours after the coupon temperature setpoint is achieved.

Chamber Cool Down

Turn the chamber and system bake-out heater temperature controllers to off. Close the chamber isolation valve to the dirty pumping manifold and open the isolation valve to the clean pumping manifold Activate the water cooling system on the chamber by opening the water supply valve. Monitor the chamber and system temperatures until the temperature of the chamber shell is at 25° C. Throttle the cooling water inlet valve to maintain approximately 25° C while the coupons cool down at a slower rate. The cooling water valve may be turned off after the chamber shell reaches 25° C if it is unrealistic to throttle the water temperature due to availability of personnel, etc.

OUTGASSING TEST

Outgassing Measurement

Close the chamber isolation valve to the clean pumping manifold and start an accurate timer. Allow the chamber to accumulate the outgassing for one hour. Open the RGA isolation valve and activate the RGA in the electron multiplier mode and fill the cold trap with LN2. Approximately five minutes prior to the end of the accumulation time, record the system pressure as indicated by the cold cathode gage and shut off the cold cathode gage. Close all other isolation valves from other chambers to the clean pumping manifold. Start recording the RGA measurements. Exactly at the end of the chamber accumulation time, shut the clean pumping system isolation valve and open the chamber isolation valve. Continue to monitor and record the RGA measurements until the pressure in the system has stabilized.

The RGA will be set in the table mode recording mass numbers 2, 18, 28, 32, 41 and 43 as a minimum every 15 seconds. More Mass numbers will be recorded if the software and scan time permit more masses.

Record P_{st}

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TITLE COUPON OUTGASSING TEST PROCEDURE OPTION PHASE	REFERENCE NO. 930212		SHT 5 OF 7
	OFFICE		REVISION 1
PRODUCT LIGO BEAM TUBE MODULES OPTION PHASE	MADE BY WAC	CHKD BY WAC	MADE BY	CHKD BY
	DATE 01/31/94	DATE 02/03/94	DATE	DATE

RGA Calibration

Shut all chamber isolation valves to the clean pumping manifold and the RGA isolation valve. Open the turbomolecular pump isolation valve. Open the calibration system isolation valve, open the hydrogen calibrated leak valve and start the cold cathode vacuum gage. Allow the system pressure to stabilize. Record the pressure and shut off the cold cathode gage. Shut the turbomolecular pump isolation valve and again start the accumulation timer for one hour. Prior the end of the accumulation time, activate the RGA and start recording the RGA measurements. Exactly at the end of the chamber accumulation time, open the RGA isolation valve and close the calibrated leak system valve. Continue to monitor and record the RGA measurements until the pressure in the system has stabilized. This procedure will provide a measurement of the sum of the calibrated leak and the piping system outgassing.

Record P_{px}

Shut off the RGA and close its isolation valve. Open the turbomolecular pump isolation valve, open the calibrated leak system isolation valve and start the cold cathode gage. Allow the pressure to stabilize. Record the system pressure and shut off the cold cathode gage. Close the turbomolecular pump isolation valve and start the accumulation timer for one hour. Prior the end of the accumulation time, activate the RGA and start recording the RGA measurements. Exactly at the end of the chamber accumulation time, open the RGA isolation valve and close the calibrated leak system valve. Continue to monitor and record the RGA measurements until the pressure in the system has stabilized. This procedure will measure the piping system outgassing only and by subtracting this value from the measured value above, a calibration factor can be determined.

Find P_p

Background Outgassing Measurement

If the system has not been operated enough to be sure of the total system background outgassing rate, the entire test procedure shall be repeated with an empty chamber.

Record P_{sb}

SYSTEM SHUTDOWN

Shut off the RGA . Close the chamber isolation valve to the clean manifold, close the hydrogen calibrated leak valve and open the calibrated leak system isolation valve. Open the turbomolecular pump isolation valve. Activate the system bake-out heaters and heat to a minimum temperature of 100° C. Shut off the cold cathode gage, close the calibrated leak system isolation valve, close the RGA isolation valve and open the cold trap purge gas valve and allow nitrogen to sweep the vaporized cold trap condensate out of the system. The vent valve should be opened sufficiently to allow the pressure increase to 0.3 torr. Set the turbomolecular pump controller to stand-by. Open the roughing pump ballast valve. Operate the system for a minimum of 3 hours with the bake-out and vent operating. Shut the Turbomolecular pump isolation valve, roughing system isolation valve and stop the roughing pump. Close the roughing pump ballast valve.

Sample Storage

The coupons shall be removed from the chamber and packaged in accordance with the sample packaging procedure. The sample bundle shall also be labeled to indicate the material heat and slab numbers, the test start date, the calculated outgassing rate and any other relevant information.

OUTGASSING RATE CALCULATION

Nomenclature:

- Background outgassing flow rate (without coupons) — Q_b (torr liters / sec)
- Total system outgassing flow rate (incl. coupons) — Q_t (torr liters / sec)
- Coupon outgassing flow rate — Q_c (torr liters / sec)
- Coupon outgassing rate(uncorrected) — k_{cu} (torr liters / sec cm^2)
- Coupon outgassing rate(corrected) — k_{cc} (torr liters / sec cm^2)
- System volume (including the chamber) — V_s (liters)
- System calibration volume (from the chamber isolation valve) — V_c (liters)
- Accumulation time — T_a (sec.)
- System partial pressure after accumulation (background) — P_{sb} (torr)
- System partial pressure after accumulation (total) — P_{st} (torr)
- Piping partial pressure after accumulation (w/ calibrated leak) — P_{px} (torr)
- Piping partial pressure after accumulation — P_p (torr)
- Coupon surface area — A_c
- Calibration factor — CF
- Calibrated Leak Rate — Q_x (torr liters / sec)

Note: the following procedure is used for the determination of hydrogen outgassing rate only

IDENTIFICATION COUP-01			
CBI			
TITLE COUPON OUTGASSING TEST PROCEDURE OPTION PHASE	REFERENCE NO. 930212	SHT 7 OF 7	
	OFFICE	REVISION 1	
PRODUCT LIGO BEAM TUBE MODULES OPTION PHASE	MADE BY WAC	CHKD BY WAC	MADE BY	CHKD BY
	DATE 01/31/94	DATE 02/03/94	DATE	DATE

Background Outgassing Rate

$Q_b=P_{sb}*V_s/T_a$

Total System Outgassing Flow Rate

$Q_t=P_{st}*V_s/T_a$

Coupon Outgassing Flow Rate

$Q_c=Q_t-Q_b$

Coupon Outgassing Rate (uncorrected)

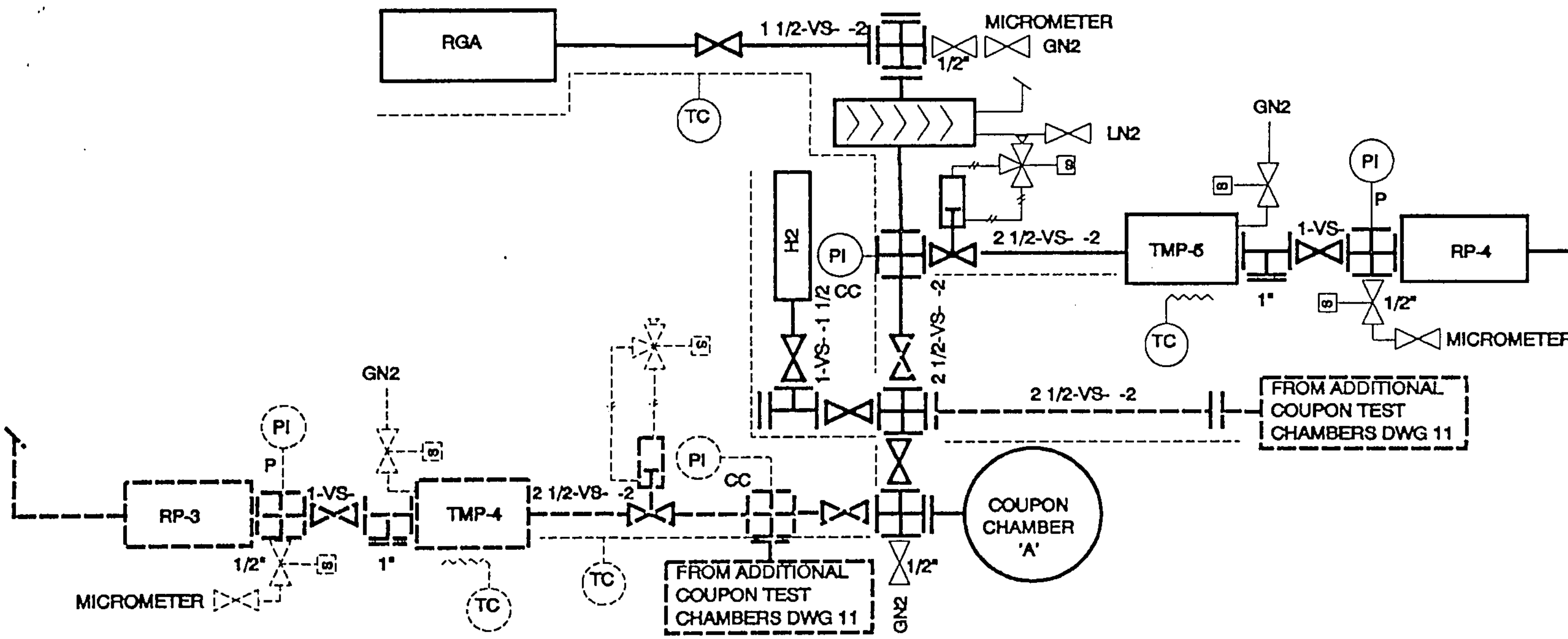
$k_{cu}=Q_c/A_c$

Calibration Correction Factor

$CF=(Q_x*T_a/V_s)/(P_{px} - P_p)$

Coupon Outgassing Rate (corrected)

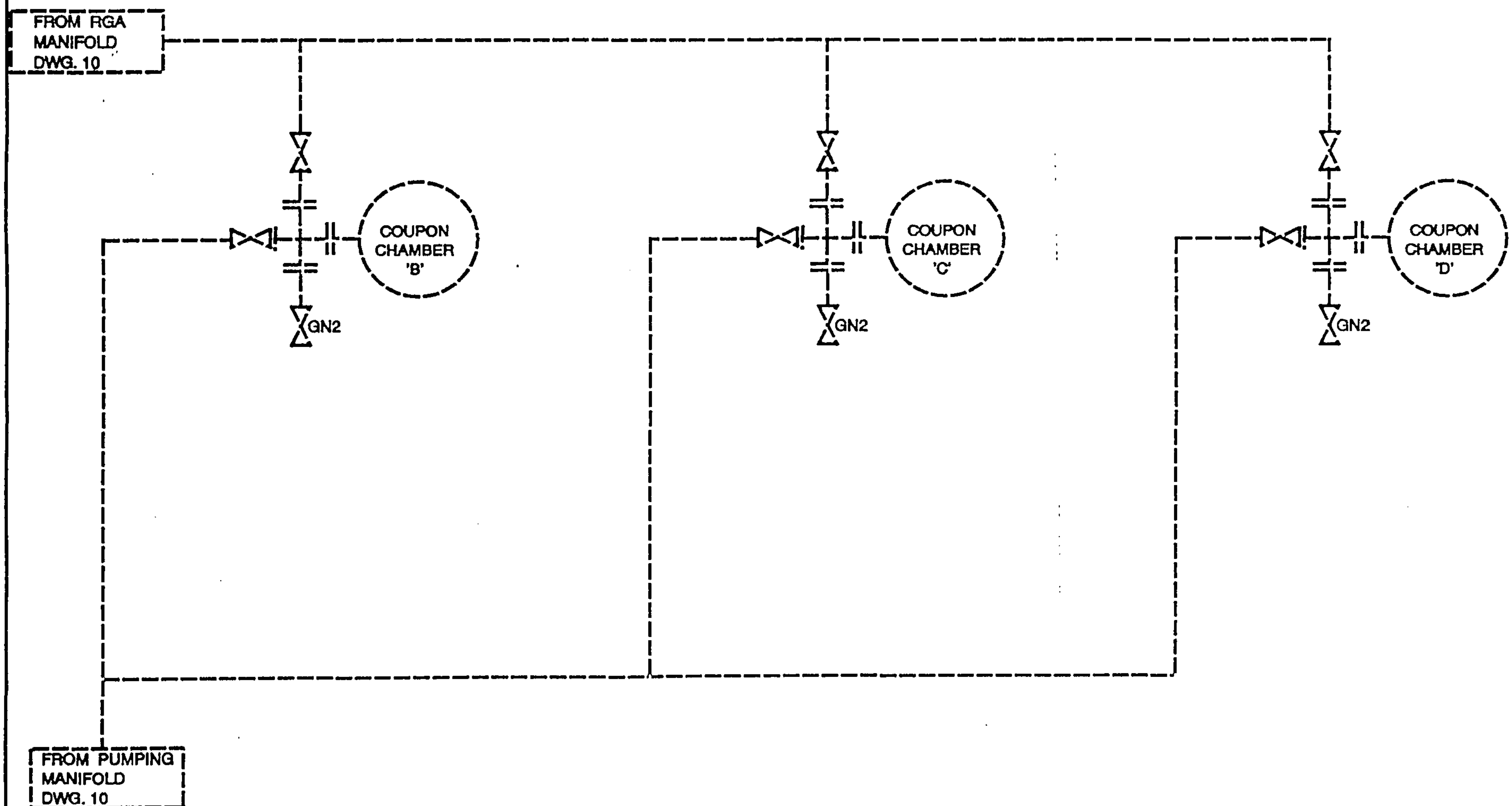
$k_{cc}=k_{cu}*CF$



NOTE:

---------INDICATES LINES OR FITTINGS REQUIRED FOR MULTIPLE COUPON TEST CHAMBERS WHICH WOULD BE SUPPLIED FOR THE FULL CONSTRUCTION PHASE. THESE FITTINGS WILL NOT BE SUPPLIED FOR THE QUALIFICATION PHASE OF THE PROJECT.

CBI	P & I DIAGRAM VACUUM SYSTEMS COUPON TEST LIGO PROJECT CALTECH	BY WAC CHKD ____ DATE 12/2/93 R. O. WEBER ENGINEERING SUPERVISOR	CONTRACT NO. 930212 DWG 10 REV 3 SHT 1



CBI

P & I DIAGRAM
VACUUM SYSTEMS
COUPON TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 11/3/93
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG 11
SHT 1
REV 0

TITLE: INITIAL & FINAL ALIGNMENT DURING INSTALLATION OF LIGO BEAM TUBE MODULES USING GPS SYSTEM - CALTECH

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	28-Dec-93
					REVISED	SDH	31-Mar-94
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 0

1.0 SCOPE:

This procedure defines the method of establishing the LIGO Beam Tube alignment during construction activities and through final alignment (after testing and before bake out). This procedure uses Global Positioning System(GPS) techniques with jigs and fixtures unique to LIGO requirements. Detailed are procedures for Beam Tube Layout, Initial Alignment and Final Inspection of Beam Tube Support positions.

2.0 REFERENCES:

The alignment maintenance procedures for the Beam Tube Module are based on the following references:

2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.

2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.

2.3 Manufacturer's Procedures for Global Positioning System(GPS) Equipment and Computer Software.

3.0 EQUIPMENT:

The following is a listing of alignment equipment selected for use in establishing and maintaining the LIGO beam tube clear aperture of 1.07 meter diameter.

3.1 Global Positioning System Package consisting of the following:
  - i. Base Station Receivers
  - ii. Radio, Software, Modem System, Stands, Etc.
  - iii. Antenna Accessories
  - iv. 386(min) Computer, DOS Format

3.2 Target Reference Rod and antenna adapter

3.3 Beam Tube Reference Point Attachment Layout Fixture(Sketch ALI-1)

3.4 Beam Tube Reference Point Attachment Fixture(Sketch ALI-2)

3.5 Alignment work sheet and data recorder.

3.6 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.

3.7 Personnel transportation(bicycle, motor-scooter, golfcart, etc.

4.0 DOCUMENTATION:

The receiving, recording, calculation and use of data is controlled by data logging forms that will be documented in both hard copy and on 3.5" diskettes formatted to DOS.

4.1 Forms shall be standardized and used to record all data including all dimensional and atmospheric measurements, and will include instrument information including calibration dates, instrument serial numbers and field calibration anomalies.

4.2 Data used to process coordinate points, atmospheric conditions, and instrument information shall be in-put to a spread sheet computer program with abilities to sort for ranges and specific text references.

4.3 Forms are indexed below:
  - i. Inspection Report
  - ii. Data Record
  - iii. Spreadsheet

iv. Project Data Index

4.4 All project documentation shall be signed by the responsible technician and dated with the date of that signing and the date of the actual recordings.

5.0 EXECUTION:

The Alignment Process begins when the LIGO Foundation Matt surface is in place. The Layout of Beam Tube Supports, rail track systems and general reference points is detailed below.

5.1 Layout of Beam Tube Reference Points shall be performed per the following steps:

5.1.1 Set-up Reference receiver at the base monument and log in for satellite communication.

5.1.2 Locate Beam Tube Support Reference Points at detailed intervals using the Roving GPS antenna and Data Collector. Record the designated identification on the data record for the specific LIGO location.

5.1.3 Adequately mark the position "area" on the concrete slab.

5.1.4 Continue steps for all reference points. Assure reference points are adequately marked.

5.2 Installation of Beam Tubes and Supports shall be performed per the following steps:

NOTE: Assure the support is in the MID position of adjustment before bolting to the foundation.

5.2.1 Pull a string line from two Beam Tube Support Reference Points. Measure the distance from the Beam Tube Reference Point along the string line and mark the open tube end distance calculated per the data record. The first Beam Tube Assembly and Support shall be positioned by locating the open end of the tube to the layout reference and centering the weld end to the beam tube support punch mark. This mark may be extended in the same string line fashion as noted previously.

5.2.2 Secure the Beam Tube Support to the foundation mat per the engineering detail.

5.2.3 Fine adjust the lateral and vertical position of the tube before the Clean Room is moved into place.

5.2.4 Repeat step 5.3 for each Beam Tube Installation.

5.2.5 During the installation activities, the beam tube support may be positioned using a temporary support. Align the Beam Tube to best condition until the tube,s permanent support is installed. Repeat the steps after installation of the permanent support.

5.2.6 Mount the Beam Tube Reference Fixture(ALI-1) and level the fixture to Earth. Mark with a punch a 1mm diameter point on the O.D. of the machined stiffener. Recheck point.

5.2.7 Install the Beam Tube Reference Fixture with the punch sight attachment(ALI-2) and set-up on the punchmark made in step 5.2.6. Attach the GPS antenna and input Reference point data into GPS computer. Record location, elevation and all applicable data into the data collector.

5.2.8 Perform these steps for all Beam Tube Support Reference points.

5.3 Installation of "Through the Cover" Access Ports after Beam Tube Covers are installed:

5.3.1 Lay out reference mark on beam tube machined stiffener using beam tube layout fixture. Determine its position using the as-built dimensions. In-put data into RTK-GPS Data Logger.

5.3.2 Locate and cut, drill &/or bore each designated access penetration above the support and install the weather cover. Apply gasketing as required.

5.3.3 Install and level the Beam Tube Reference point fixture to the machined stiffener. Assure that the fixture is properly located and level to

the punchmark located on the machined stiffener.
5.3.4 Attach a stainless steel tag in the area of the stiffener mark with the proper reference point serial number stamped into the tag.
5.3.5 Mount the GPS antenna to the fixture connection and fine adjust level.
5.3.6 Input Reference Rod data into GPS computer and record location.

5.4 Final Inspection and Adjustment of Beam Tube Modules

The Inspection and Maintenance of Beam Tube alignment is divided into two steps. These are (1)verification of Beam Tube Support Stiffener centerline positions, and (2) adjustment of Beam Tube Supports.

5.4.1 Verification of Beam Tube Support Stiffener centerline positions is performed in the following steps:
5.4.1.1 Set-up receiver base station and log in for satellite communication.
5.4.1.2 Attach the Beam Tube Reference fixture(ALI-2) to the beam tube stiffener and align to the layout punch mark. Install the GPS antenna. Record the position serial number and location on the data collector.
5.4.1.3 Level the fixture on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall log calculate the beam tube rotation in degrees, minutes and seconds for analysis.
5.4.1.4 Using the levelness value and the target coordinates, calculate the location of all support and baffle alignment positions.
5.4.1.5 Determine adjustments for each location. Input adjustments into data logger program.

5.4.2 Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports shall be performed per the following steps:
5.4.2.1 Set-up receiver base station and log in for satellite communication.

Elevation Movement

5.4.2.2 Level the fixture(ALI-2) on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall provide position correction factors(off-sets) for adjusting beam tube centerlines.

5.4.2.3 Attach dial indicators, at all jack locations, to monitor the movements between the beam tube and the fixed support brackets. Set the dial indicators to monitor vertical and horizontal movements.

5.4.2.4 Install jacks between the concrete slab and support frame, and or between the support brackets and the support frame at the designated jacking points. The jacks are to be placed at equal distances from the tube centerline and the hydraulic lines manifolded together so that the jacks will apply equal forces on the supports when raising or lowering. This is done so the jacks will not apply an off center loading to the support and twist the beam tube while raising or lowering the support.

5.4.2.5 Note that the jacks have only 1/2" stroke. Add or remove shims as necessary when the jacks must be re-located to provide additional movement.

5.4.2.6 Re-Zero all dial indicators and slowly loosen the "U" clamps holding the support frame to the fixed support brackets.

5.4.2.7 Extend the jacks until contact the beam tube and pressurize to 100 P.S.I. This will apply a nominal force to the jacks.

DO NOT REMOVE THE "U" CLAMPS. ONLY LOOSEN NUTS ENOUGH TO REMOVE CLAMPING FORCES TO PERMIT MOVEMENT OF THE SUPPORT BEAM.

5.4.2.8 Raise or lower the support frame to the specified movement. Use the dial indicators to measure the amount of movement made during the jacking operation.

Lateral Movement

5.4.2.9 Repeat steps 5.4.2.2 and 5.4.2.3.

5.4.2.10 Install the lateral jacking cylinder between the support frame and the fixed support brackets.

5.4.2.11 Zero all dial indicators and slowly loosen the "U" clamps holding the support frame to the fixed support brackets.

5.4.2.12 Extend the hydraulic cylinder and pressurize to 100 P.S.I. to apply a nominal force to the jacks.

DO NOT REMOVE THE "U" CLAMPS. ONLY LOOSEN NUTS ENOUGH TO REMOVE CLAMPING FORCES TO PERMIT MOVEMENT OF THE SUPPORT BEAM.

5.4.2.13 Move the support frame laterally with the hydraulic cylinder to the specified movement. Use the dial indicators to measure the amount of movement made during the jacking operation.

DO NOT MOVE THE BEAM TUBE IN ANY ONE DIRECTION GREATER THAN 3 CENTIMETERS WITHOUT ASSESSING THE AMOUNT THAT THE BEAM TUBE WILL BE BENT DURING THE ALIGNMENT PROCESS. THE TUBE CAN BE OVERSTRESSED BY APPLYING TOO MUCH FORCE DURING ALIGNMENT. PRESSURE IN THE HYDRAULIC CYLINDER WILL BE USED TO MONITOR THE AMOUNT OF STRESS BEING APPLIED TO THE BEAM TUBE.

ROTATION MOVEMENT

5.4.2.14 Repeat steps 5.4.2.2 and 5.4.2.3.

5.4.2.15 Check the beam tube rotation by setting the alignment fixture on the stiffener and locking it to the reference punch mark. Note the level of the fixture and rotate the beam tube using the leveling jacks. Each of the leveling jacks has a valve that can be closed to permit differential leveling and twist the beam tube.

5.4.2.16 Re-clamp the support frames to the fixed support brackets and confirm that the support has been moved as specified.

FINAL VERIFICATION

5.4.3 Final verification of Beam Tube Support Stiffener centerline positions is performed in the following steps:

5.4.3.1 Set-up receiver base station and log in for satellite communication.

5.4.3.2 Attach the Beam Tube Reference fixture(ALI-2) to the beam tube stiffener and align to the layout punch mark. Install the GPS antenna. Record the position serial number and location on the data collector.

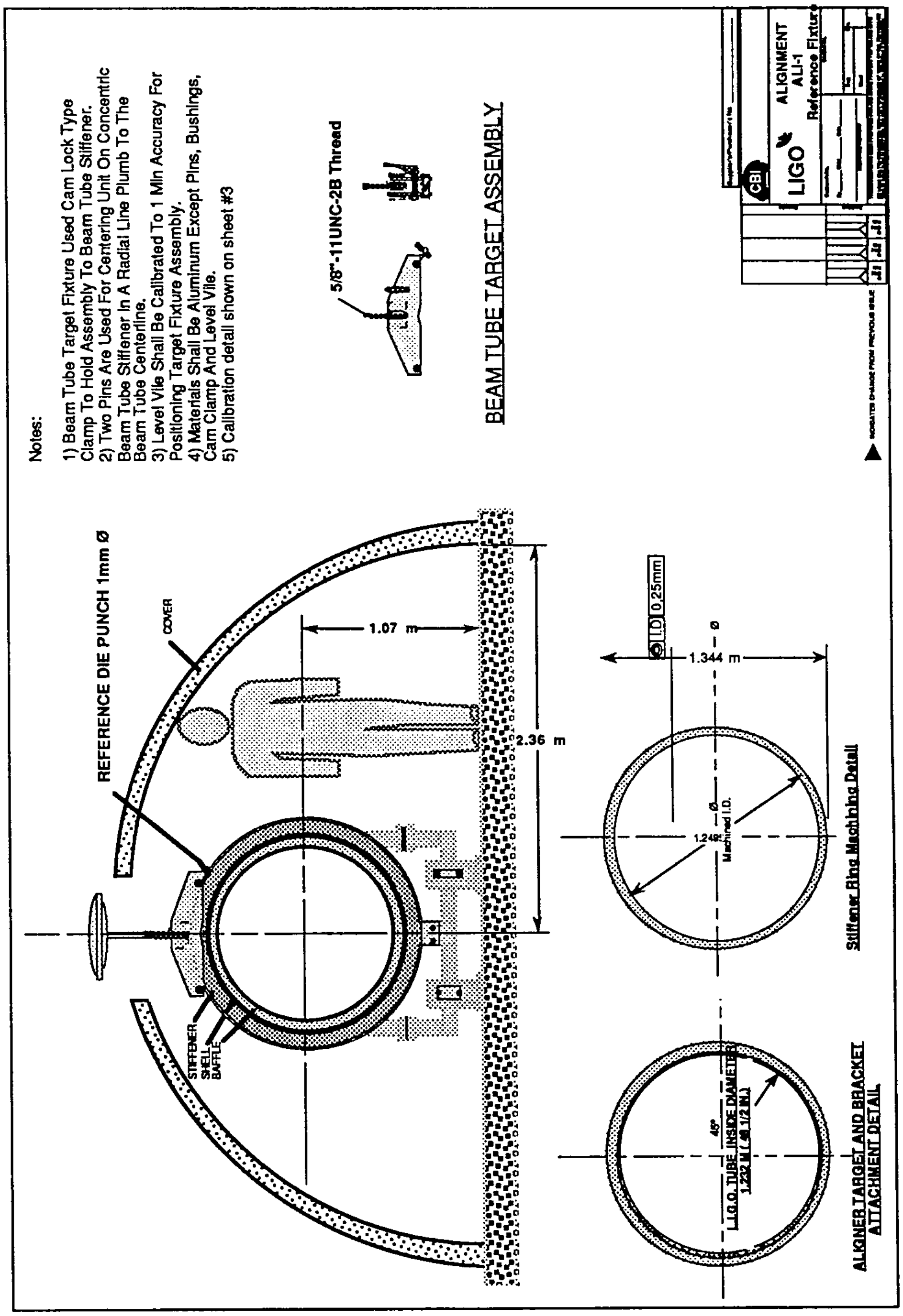
5.4.3.3 Level the fixture on the tube stiffener to within 0.001 in/ft. Record the position serial number and location on the data collector. The data collector shall log calculate the beam tube rotation in degrees, minutes and seconds for analysis.

5.4.3.4 Calculate the location of all support and baffle alignment positions and document as-built beam tube centerline.

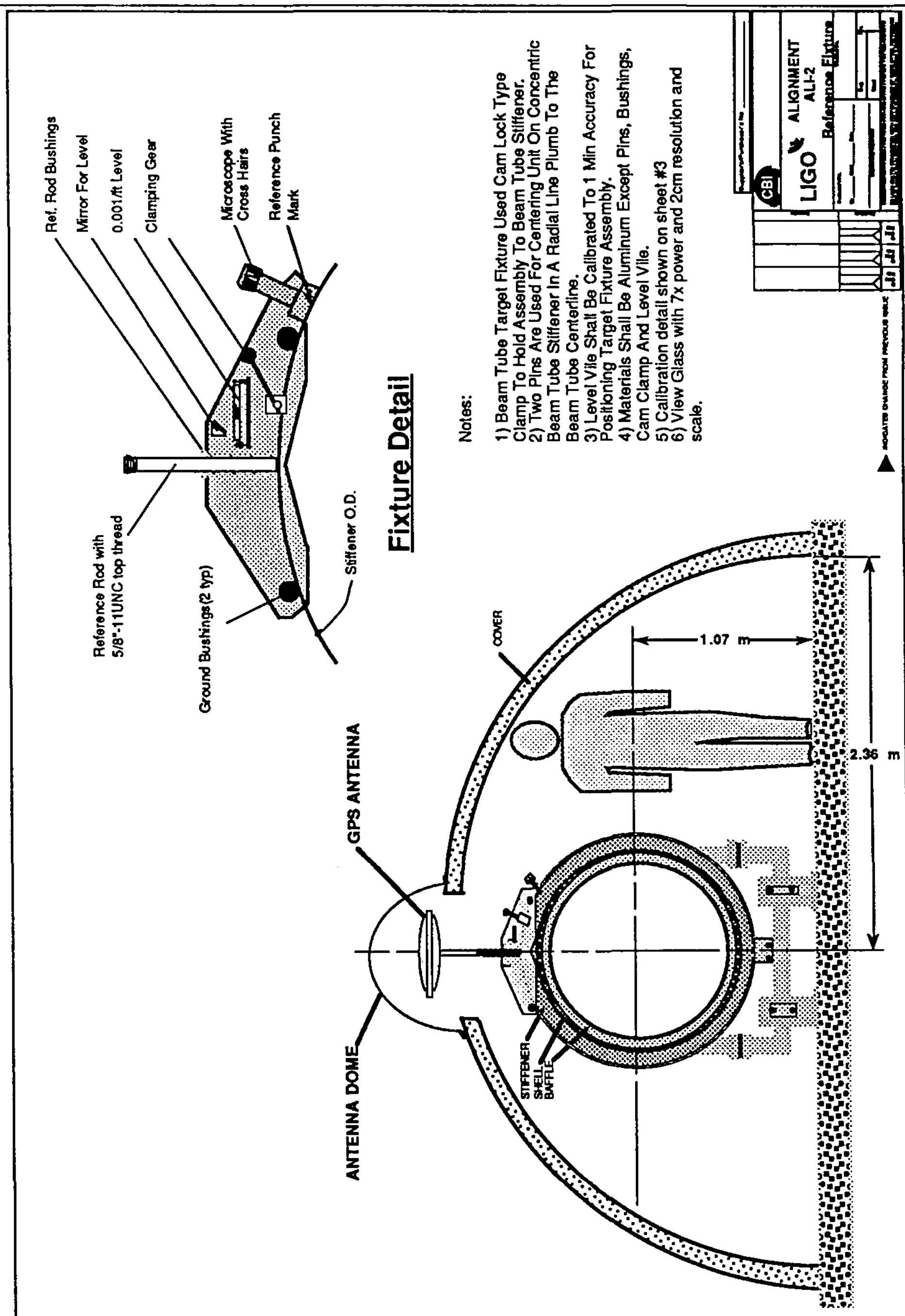
6.0 CALIBRATION:

Since the GPS equipment under goes a calibration during each use, the formal documents recording the calibrations are suggested to be a checklist type file attached to the alignment report. The equipment shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

TITLE: INITIAL & FINAL ALIGNMENT DURING INSTALLATION OF LIGO BEAM TUBE MODULES USING GPS SYSTEM - CALTECH



REFERENCE FIXTURE ALI-1



REFERENCE FIXTURE ALI-2

CBI

DOC ID	ALM-B
REV. NO.	1
CONTRACT	930212

TITLE: ALIGNMENT MAINTENANCE USING GLOBAL POSITIONING SYSTEM(GPS) - CALTECH

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	21-Dec-93
					REVISED	SDH	29-Dec-93
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO.

1.0 SCOPE:

This procedure defines the method of maintaining the LIGO tube alignment using the Global Positioning System(GPS). Detailed are procedures for reference verification, set-up and inspection of tube positions at each support.

2.0 REFERENCES:

2.1 The alignment methods and tolerances are based on the data contained in the following references:

2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.

2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.

2.3 Manufacturer's Procedures for Global Positioning System receivers and transmitters.

2.4 As-Built Beam Tube coordinates converted from WGS-84 to State/Plane Rectangular System(N-E-Up).

3.0 EQUIPMENT:

The following is a listing of alignment equipment selected for use in maintaining the LIGO beam tube clear aperture of 1.07 meter diameter.

3.1 Global Positioning System Package consisting of the following:

- i. Base Station Receivers
- ii. Radio, Software, Modem System, Stands, Etc.

3.0 **EQUIPMENT: (Cont.)**

iii. Antenna Accessories
iv. 386(min) Computer, DOS Format

3.2 Target Reference Rod and antenna adapter
3.3 Depth Micrometer 0,00 to 75mm..
3.4 Inside Micrometer for 50mm - 200mm.
3.5 Master Machinist Level, 15" Length with 10 second accuracy minimum.
3.6 Alignment work sheet and data recorder.
3.7 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.

4.0 **EXECUTION:**

The Inspection and Maintenance of Beam Tube alignment is divided into two steps. These are (1)verification of Reference Rod positions (2)inspection and adjustment of Beam Tube Supports.

4.1 Verification of Reference Rod is performed in the following steps:
4.1.1 Set-up receiver base station and log in for satellite communication.
4.1.2 Attach Leveling Plate to Beam Tube Reference Rod and level rod using adjuster bolts inside cover area and Master Machinist Level to 1 min arc Max.
4.1.3 Mount the GPS antenna to the Primary[1] Reference Rod and level the rod to Earth.
4.1.4 Input Reference Rod data into GPS computer and record location.
4.1.5 Calculate position location with Beam Tube Reference Pin Location and determine theoretical off-sets.

4.2 Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports shall be performed per the following steps:
4.2.1 Verify Beam Tube rotation by checking the flat level using the Master Machinist Level. Adjust support to re-level tube.

[1] Primary refers to current Reference Monument being measured.

4.2.2 Measure elevation of Beam Tube Reference Pin using inside micrometer. Adjust Beam Tube Support for achieve proper elevation.
4.2.3 Measure off-set from Primary Reference Rod to Beam Tube Reference Pin. Adjust support to achieve proper location.
4.2.4 Record all adjustments and final off-sets for purpose of tracking beam tube and cover movements.

5.0 <u>CALIBRATION:</u>

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

3.0 EQUIPMENT:

The following is a listing of alignment equipment selected for use in qualifying the RTK-GPS method for LIGO beam tube alignment.

3.1 Global Positioning System Package consisting of the following:
   i. Base Station Receivers
   ii. Radio, Software, Modem System, Stands, Etc.
   iii. Antenna Accessories
   iv. 386(min) Computer, DOS Format
   v. Antenna Adapter with 5/8"-11unc thread, Five(5) required.

3.2 Target Reference Rod and antenna adapter

3.3 Beam Tube Reference Cross-Bar Assemblies(GPS-1), Thriteen(13) Required.

3.4 Base Monuments(Sketch GPS-2), Five(5) Required).

3.5 K&E Light Weight Stand, two(2) required.

3.6 Alignment work sheet and data recorder.

3.7 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.

3.8 Optical Theodolite with 2 sec. precision.

3.9 Optical Jig Transit with Coincidence Level.

3.10 Lateral Adjusters and collars.

3.11 Target Fixtures and Single-axis positioners, thriteen(13) required(Sketch GPS-3).

3.12 Adapter plate for 3.5-8un to 5/8"-11unc thread, Five(5) required.

3.13 Optical micrometer for jig transit.

3.14 Steel tape rule 30 meter stainless steel.

4.0 EXECUTION:

The qualification of the Beam Tube alignment system using RTK-GPS is divided into four steps. These are 1) set-up of Base Monument Coordinates and Beam Tube Support reference positions; 2)verification of support positions using standard Optical and Surveying techniques; 3)inspection of Beam Tube Support position using the RTK-GPS method; and 4)Determination of RTK-GPS accuracy and repeatability for millwright type adjustments.

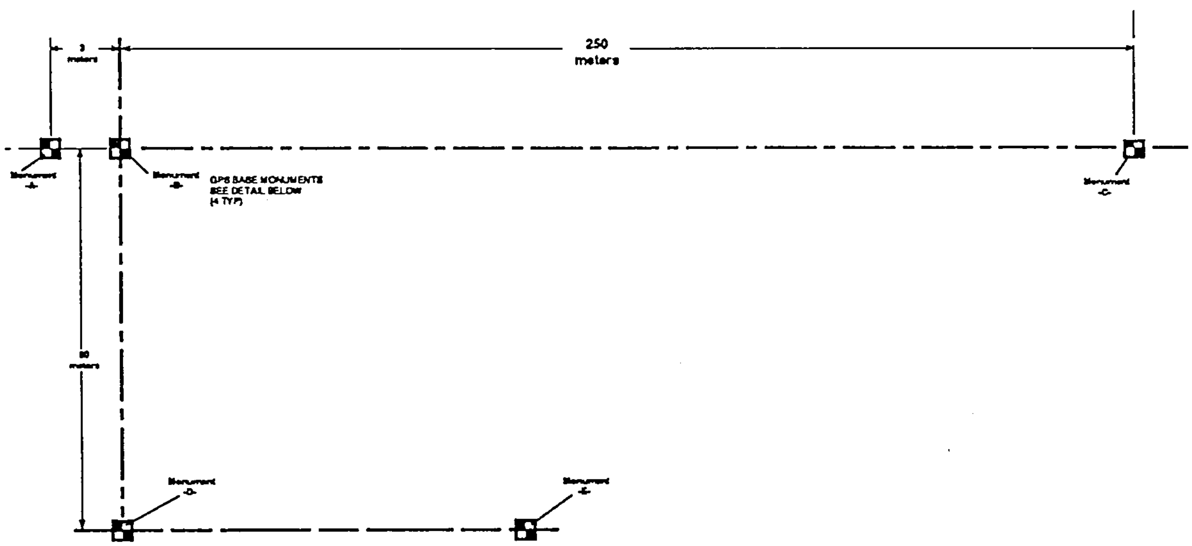


Figure 1.4a

4.1 Set-up the Base Monument Reference System. Follow the steps noted below:

4.1.1 Set-up Five(5) Base Monuments "A" thru "E" per Figure 4.1a.

4.1.2 Survey the location and elevation of each monument and define a Cartesian Coordinate Plane with a reference to magnetic North. A Total Station system or standard theodolite/distance method can be used.

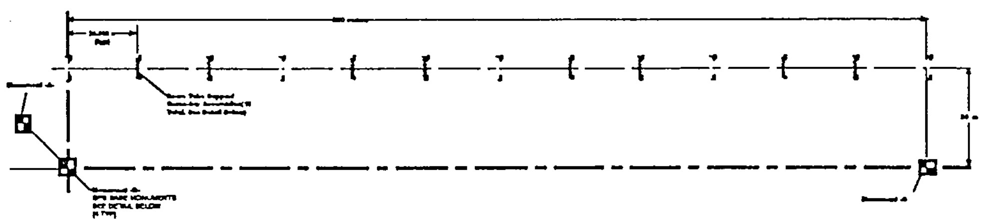
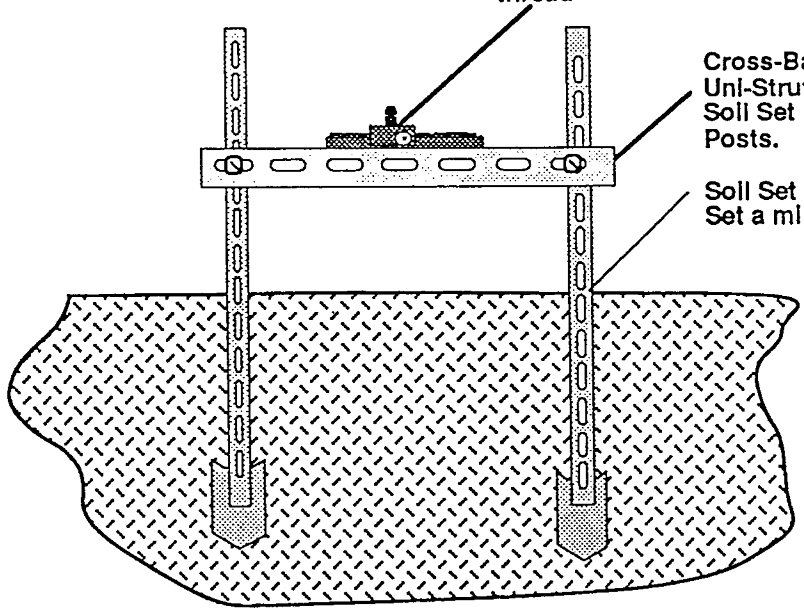


Figure 1.4b

4.1.3 Set-up a steel tape and layout the 30 meters to the beam tube support centerline. Use a jig transit to locate the positions of the cross-bar assemblies. A steel tape should be used for location. See Figure 1.4b.



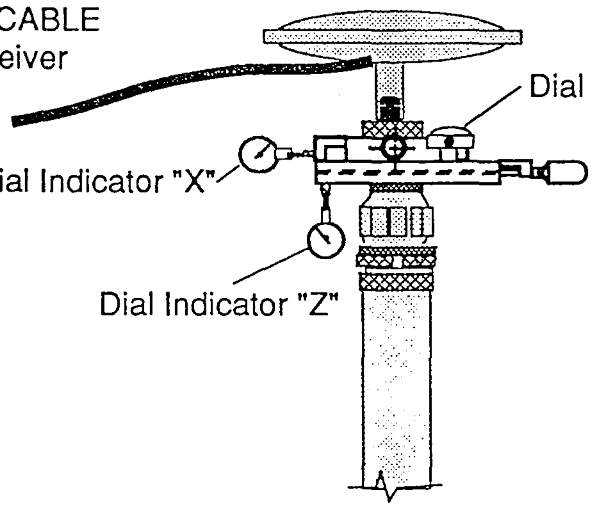
BEAM TUBE REFERENCE
Cross-Bar Assembly
(typ 13 places)

Figure 1.4c

4.1.4 Install the cross-bar assemblies and lateral adjusters(13 total). See Figure 1.4c.
4.1.5 Perform a new set-up with a steel tape and layout the 30 meters to the beam tube support centerline. Use a jig transit equiped with an optical micrometer and locate each target attached to the lateral adjuster to within ±0,25mm(0.010"). Re-take the dimensions using the steel tape.
4.1.6 Using a Tilt Level, shoot each elevation at the base monuments and the beam tube support targets. Use the GPS adapter to reference the elevation.
4.1.7 Locate and record all data for each target mounted to the cross-bar lateral adjuster. Adjust the elevation data to a straight plane.

4.2 GPS Measurement of Base Monuments and Support Tube locations are performed in the following steps:
4.2.1 Set-up receiver base station at the "A" base monument and log in for satellite communication. Initialize system and establish the coordinate system referenced in step 4.1 by using the other three(3) base monuments. Establish error and compare the results with the initial standard method survey performed in step 4.1.1.
4.2.2 Repeat the step above using different base monuments as beginning points.
4.2.3 Repeat the step 4.2.1 during the night.
4.2.4 Repeat the step 4.2.1 by switching receivers(from Base to Rover).

4.3 GPS Measurement of Lateral and Vertical Displacement using calibrated adjusters.
4.3.1 Support a Three-Axis lateral/vertical adjuster on a tripod or light weight stand on Monument "E."
4.3.2 Mount an adapter for the GPS antenna on the vertical adjuster. Initialize the GPS roving antenna and install on the three-axis adjuster.



3-Axis Lateral/Vertical Adjuster

Figure 4.3a

4.3.1 Install dial indicators for measuring movement for the three-axis adjuster. Zero the GPS and the Dial indicator readings. See Figure 4.3a.
4.3.2 Move the support laterally 4.00cm using the dial indicators for reference. Record the dial indicator and RTK-GPS reading. Compute the difference. Return to the initial point using the GPS readings for reference. Record all data.
4.3.3 Repeat 4.3.2 for both lateral axis.
4.3.4 Repeat 4.3.2 for all three axis.
4.3.5 Repeat 4.3.2 for all three axis using 3.00cm movements.
4.3.6 Repeat 4.3.2 for all three axis using 2.00cm movements.
4.3.7 Repeat 4.3.2 for all three axis using 1.00cm movements.
4.2.3 Repeat the steps 4.3.2 thru 7 during the night.
4.2.4 Repeat the steps 4.3.2 thru 7 by switching receivers(from Base to Rover).

4.4 Calculation of GPS and Known Movement Differences shall be performed per the following steps:

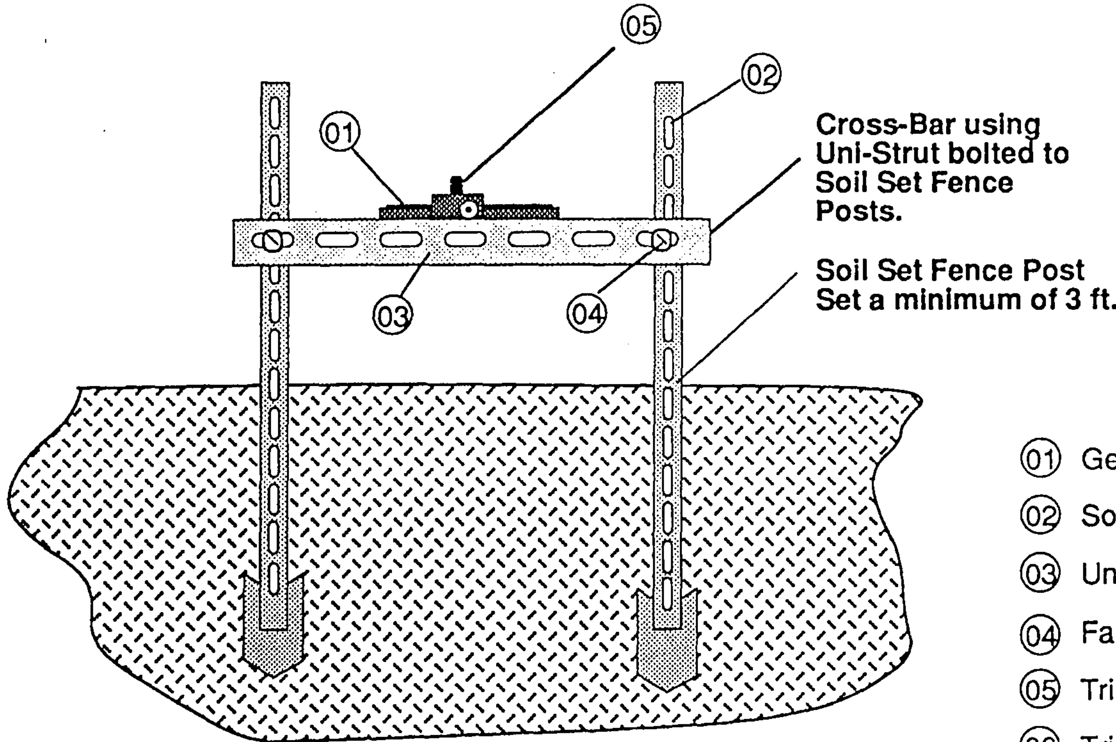
4.4.1 Using the data obtained in previous steps noted above, tablize data to indicate the accuracy of the GPS vs. the known and surveyed locations.

4.4.2 Determine the final accuracy of the RTK-GPS and the relationship of Beam Tube Diameter to the final tolerance aperture.

4.4.3 Generate a report with data and equipment information to be provided to the LIGO Management Team with recommendations for alignment methods.

5.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.



(01) Gear Rack with Scale ES-N31,231

(02) Soil Fence Post MMC#6004T11

(03) Unistrut WWG#4A974

(04) Fasteners for Unistrut 4A985, 6 & 7

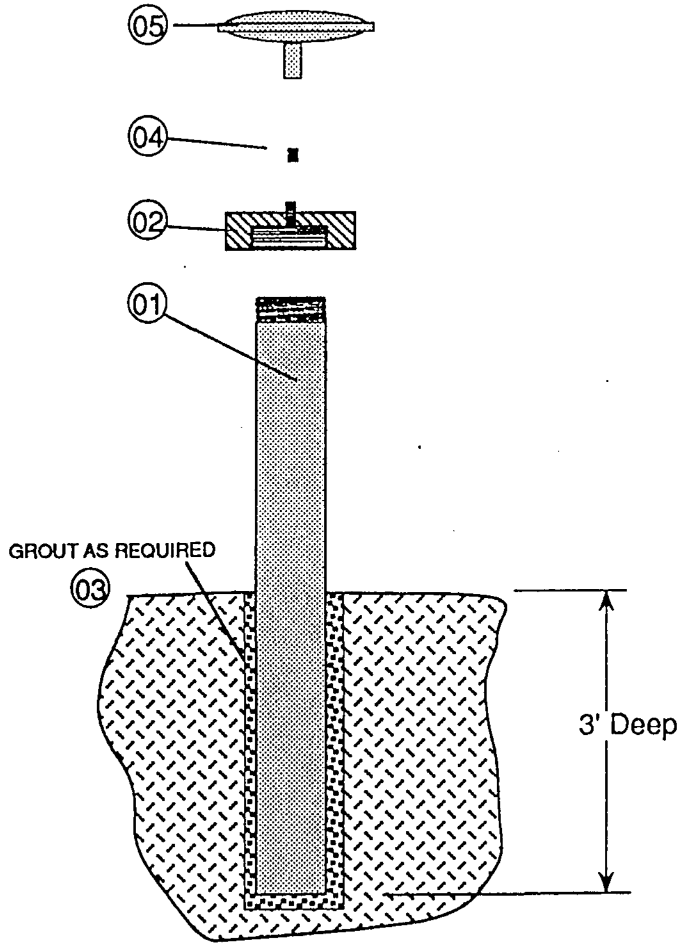
(05) Trimble Antenna Adapter 5/8"-11unc Thread

(06) Trimble GPS Antenna

BEAM TUBE REFERENCE
Cross-Bar Assembly
(typ 13 places)

CBI LIGO Beam Tube Ref. Cross-Bar Assembly

INDICATES CHANGE FROM PREVIOUS ISSUE

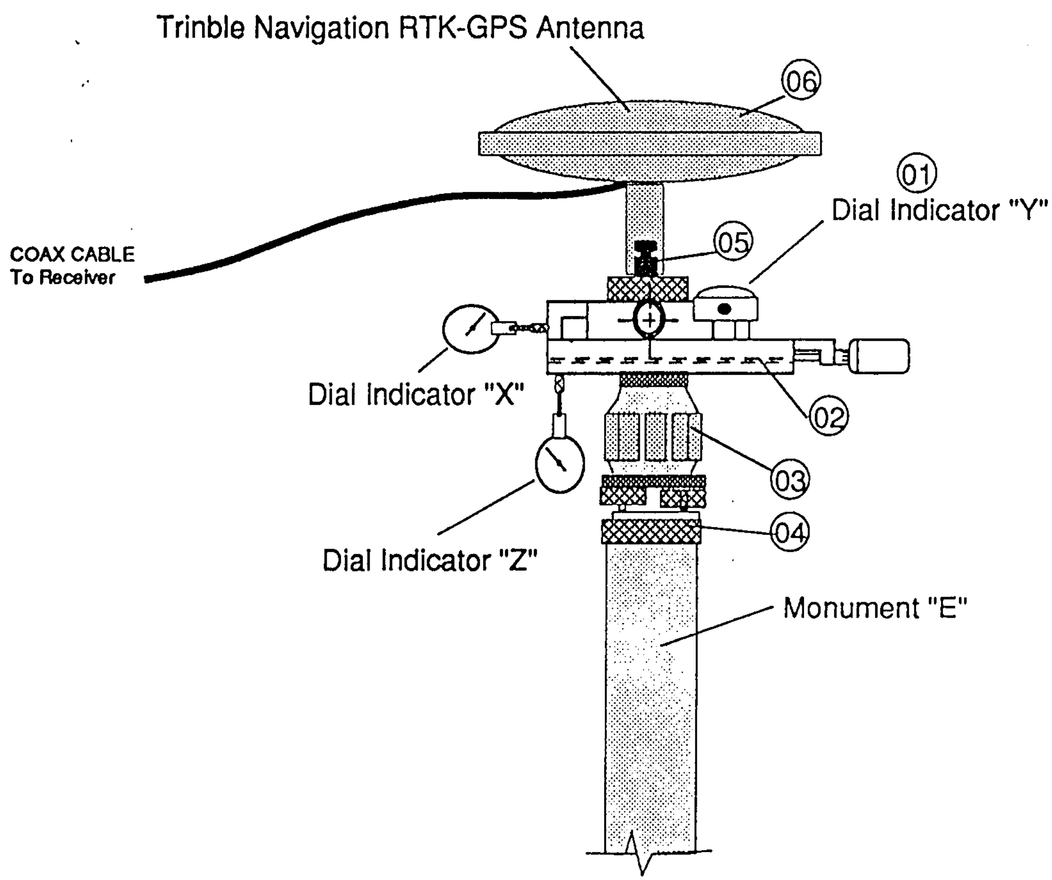


BASE MONUMENT DETAIL
(typ 5 places)

- (01) 3 1.2"Ø Conduit or Pipe TOE 3 1/2"-8un x 7 Foot Length
- (02) Adapter 3.5"-8un to 5/8"-11unc
- (03) Grout or Concrete for Fill
- (04) Trimble Antenna Adapter 5/8"-11unc Thread
- (05) Trimble GPS Antenna

INDICATES CHANGE FROM PREVIOUS ISSUE

CBI
LIGO
Beam Tube Ref.
Cross-Bar
Assembly



(01) Dial Indicator AGD-2

(02) K&E Lateral Adjuster #71-5085

(03) K&E Precision Lift #71-5060

(04) 3.5"-8un to 5/8"-11unc Adapter Plate

(05) Trimble Antenna Adapter 5/8"-11unc Thread

(06) Trimble GPS Antenna

3-Axis Lateral/Vertical Adjuster

Supplier's/Purchaser's No.

CBI

LIGO 3-Axis Lateral/Vertical Adjuster

INDICATES CHANGE FROM PREVIOUS ISSUE

DOC ID ALI-A
REV. NO. 0
CONTRACT 930212

TITLE:	INITIAL & FINAL ALIGNMENT DURING CONSTRUCTION AND INSTALLATION OF LIGO BEAM TUBE ASSEMBLIES - CALTECH	PAGE NO. 1 OF 12

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	28-Dec-93
					REVISED	0	
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 0

1.0 SCOPE:

This procedure defines the method of establishing the LIGO Beam Tube alignment during construction activities and through final alignment after bake out and testing. This procedure uses conventional optical tooling and techniques with jigs and fixtures unique to LIGO requirements. Detailed are procedures for Reference Verification, Beam Tube Layout, Initial Alignment and Final Inspection of Beam Tube Support positions between each Reference Monument established by Cal Tech.

2.0 REFERENCES:

2.1 The alignment maintenance procedures for the Beam Tube Module are based on the following references:

- 2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.
- 2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.
- 2.3 Manufacturer's Procedures for Alignment Optical Tooling and Equipment.
- 2.4 As-Built Monument data and Beam Tube coordinates converted to State/Plane Rectangular System(N-E-Up).

3.0 EQUIPMENT:

The following is a listing of Alignment Equipment selected for use in maintaining the LIGO beam tube clear aperture of 1.07 meter diameter between the Reference Monuments.

3.1 Precision Theodolite with accuracy of 1.0 second of an arc(max), minimum effective aperture of 30 millimeters, Optical Plummet, and the scope barrel sized to receive an optical micrometer. Also included are power packs, carrying case and misc. appurtenances.
3.2 Integrated Instrument and Target Mounting Adapter for Reference Monuments(See Sketch ALI-1).
3.3 Beam Tube Reference Point Target Attachment fixture(See Sketch ALI-2).
3.4 Calibrated Steel Tape(min 30 meter length, two required).
3.5 2-axis Precision Lateral Adjusters with adapter plate and rotation collars.
3.6 3-Axis Precision Lateral and Vertical adjusters with minimum 1 inch travel.
3.7 Precision Lift Device.
3.8 Reference Point Target Stand(See Sketch ALI-3).
3.9 Beam Tube Reference Point Adapter Fixture(ALI-4).
3.10 Clamp-On Target Holder Assembly(See Sketch ALI-5).
3.11 Magnetic Thermometer range 0°to 50°C(12 required).
3.12 Master Machinist Level, 15" Length with 10 second accuracy minimum.
3.13 Alignment work sheet and data record (Worksheet Software preferred).
3.14 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.
3.15 486 or Macintosh Computer with printer.
3.16 Personnel transportation(bicycle, motor-scooter, golf-cart, etc.
3.17 Misc. Optical equipment including target light sources, targets, K&E Light-Weight Stand, etc.
3.18 Beam Tube Support Reference Plate(ALI-6) and Reference Plate Installation Fixture(ALI-7).

4.0 DOCUMENTATION:

The receiving, recording, calculation and use of data is controlled by data logging forms that will be documented in both hard copy and on 3.5" diskettes formatted to DOS &/or Mac.

4.1 Forms shall be standardized and used to record all data including all dimensional and atmospheric measurements, and will include instrument information including calibration dates, instrument serial numbers and field calibration anomalies.

4.2 Data used to process coordinate points, atmospheric conditions, and instrument information shall be in-put to a spread sheet computer program with abilities to sort for ranges and specific text references.

4.3 Sample forms are indexed below and attached to this procedure.

- i. Sample Inspection Report
- ii. Sample Data Record
- iii. Sample Spreadsheet
- iv. Sample Project Data Index

4.4 All project documentation shall be signed by the responsible technician and dated with the date of that signing and the date of the actual recordings.

5.0 EXECUTION:

The Alignment Process begins when the following is complete:

1) LIGO Matt surface is in place
2) The Reference Monuments are in-place
3) The Location Data for each monument has been received by the Inspection Team.

5.1 Arrangement of Reference Monument data to State/Plane Rectangular Coordinates.

5.1.1 Input and compute Reference Monument Data into the computer program and calculate monument positions into rectangular and specific angular data needed to verify monument positions in the field.

5.2 Verification of Reference Monuments is performed in the following steps:

5.2.1 Install the Integrated Instrument and Target Mounting Adapter(ALI-1) to three(3) Reference Monuments. Mount the theodolite to the Primary[1] Reference Monument and level to Earth.

5.2.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.

5.2.3 Shoot and record positions of each Secondary Reference Monument and record in the data record. Flop instrument scope, zero horizontal plane and re-shoot. Record in the data record.

5.2.4 Compare readings with as-built positions and determine the Cal Tech Reference Monument data accuracy and calculate error. If the monuments are within acceptable limits of ± 2 seconds of an arc, continue to 5.2 "Transferring Reference Points to Beam Tube Mat." If a deviation outside accepted limits occur, continue the following steps.

5.2.5 Field calibrate the theodolite and document results. If the instrument is outside manufacturer's recommended limits, replace or repair instrument. If field calibration is found acceptable continue with 5.2.6.

5.2.6 Perform steps 5.2.1 thru 5.2.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 5.2 "Transferring Reference Points to Beam Tube Mat."

5.3 Transferring Reference Points to the Beam Tube Mat is performed per the following steps:

5.3.1 Install the Integrated Instrument and Target Mounting Adapter(ALI-1) to the first(beginning) three(3) Reference Monuments. Mount the theodolite

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[1] Primary refers to current Reference Monument being measured.

[2] Secondary Reference monument refers to monuments used as target reference.

to the Primary Reference Monument(the First Monument) and level to Earth.

5.3.2 Mount targets to Secondary Reference Monument(s) and level to Earth.

5.3.3 Shoot and record positions of the Secondary Reference Monuments and record in the data record. Flop instrument scope, zero horizontal plane and re-shoot. Record in the data record.

5.3.4 Position the 3-Axis Precision Lateral/Lift Adjuster on the Beam Tube Mat and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the reference target fixture and target to the vertical adjuster adapter plate.

5.3.5 With the Theodolite in the same position and plane used in 5.3.3, Using the data record, turn the horizontal angle calculated for the Primary[3] Beam Tube Reference Target.

5.3.6 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.

5.3.7 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.

5.3.8 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 5.3.5 thru 7. Record displacement differences on data record. Compare and determine discrepancies.

5.3.9 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Beam Tube Target third axis.

5.3.10 Once the Primary Beam Tube Reference Target is determined, this point becomes the **"Primary Beam Tube Reference Point"** with a designated

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[3] Primary refers to current Beam Tube Reference Point being measured.

identification on the data record for the specific LIGO location.

5.3.11 Layout four reference points to re-locate the center location and its elevation. Remove the 3-Axis Precision Lateral/Lift Adjuster.

5.3.12 Install a Beam Tube Reference Point Target Attachment Fixture(ALI-2) at the Primary Reference Point using the Layout as reference.

5.3.13 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.

5.3.14 Install the Two-Axis lateral adjusters to the Primary Beam Tube Reference Point Target Attachment Fixture(ALI-2). Install the theodolite adapter and theodolite. Shoot the Primary and Secondary Reference Monument Targets and record data. Using the distance finder, shoot and record the distance to the the Primary and Secondary Reference Monument Targets. Calculate and determine Beam Tube Reference Point Position. Record As-Built position on the data record. Adjustments shall be made when this point is used as reference.

5.3.15 Remove theodolite and move to next Primary Reference Monument. Repeat Steps 5.3.1 thru 14 for each Beam Tube Reference Point.

5.4 **Layout of Beam Tube Support Positions** shall be performed per the following steps:

NOTE: It is recommended this activity be carried out during periods of stable temperatures such as cloudy days or evenings between midnight and sunrise. This is to decrease the effects of surface convection.

5.4.1 Measure a distance of 0.71 meters from the Primary and Secondary Beam Tube Reference points perpendicular from the beam tube centerline. Mark the foundation mat with a punch and paint the mark. Install a Two-Axis lateral adjuster to a trivet and set-up over the punch mark. Install the theodolite adapter and theodolite. Buck-in to the Primary Beam Tube Reference point and the Primary Reference Monument Target and turn to the calculated as-built position of the Primary Beam Tube Centerline.

5.4.2 Install the Three-Axis positioning target to a trivet at the Secondary punch mark laid out in step 5.1.4. Align the axis to the beam tube centerline.

5.4.3 Center the theodolite to the established Secondary punch mark target.

5.4.4 Use a steel tape measure and the theodolite to position the Beam Tube Support Reference Plate(ALI-6) and Installation Fixture(ALI-7) at the first support location. Align the fixture to within ±1cm. Secure the beam tube reference plate with screws and/or epoxy.

5.4.5 Move to the next support location and repeat step 5.4.4 for each support location.

5.4.6 When all supports between the Primary and Secondary Beam Tube Reference Points are complete, Remove the Theodolite from the Primary Reference Point adapter and replace it with a Target fixture.

5.4.7 Set-up a K&E Light-Weight Stand equipped with a two Axis precision lateral adjuster and a theodolite adapter over the first Beam Tube Support Reference Plate.

5.4.8 Using the Theodolite equipped with an Optical Plummet, buck-in to the Primary and Secondary Beam Tube Reference Point Targets using the lateral adjuster for centering.

5.4.9 Using the instrument scope, shoot a point on the next Beam Tube Support Reference Plate. Mark the point using an automatic punch and fill the point with white paint.

5.4.10 Move to the next Beam Tube Support Reference Plate and center to the layout punch mark using the instrument Optical Plummet and lateral adjusters. Buck-in to the Primary and Secondary Beam Tube Reference Point Targets and shoot the next Beam Tube Support Reference Plate. Mark the point using an automatic punch and fill the point with white paint. Reverse the scope and layout/check and mark on the previous support plate.

5.4.11 Continue Step 5.4.10 for all support plates between the Beam Tube Reference Points(Reference Monuments). There is an estimated total of 13 beam tube supports per beam tube module. This is an estimated 384 beam tube supports per LIGO site.
5.4.12 When all support plates are complete, move equipment to the next Beam Tube Module location and repeat steps 5.4.1 thru 5.4.11. There are a total of 32 beam tube modules per LIGO site.

5.5 **Installation of Beam Tubes and Supports** shall be performed per the following steps:
5.5.1 Pull a string line from two Beam Tube Support Reference Plates that cross the Mid Station Beam Tube Reference Point location. Use magnets centered to the punch marks laid out in step 5.4. Measure the distance from the Beam Tube Reference Point(Mid Station) along the string line and mark the open tube end distance calculated per the data record. The first Beam Tube Assembly and Support shall be positioned by locating the open end of the tube to the layout reference and centering the weld end to the beam tube support plate punch mark. This mark may be extended in the same string line fashion as noted previously.

NOTE: Assure the support is in the MID position of adjustment before bolting to the foundation.

5.5.2 Secure the support to the foundation mat per the engineering detail.
5.5.3 Fine adjust the lateral and vertical position of the tube before the Clean Room is moved into place.

5.6 Final Inspection and Adjustment of Beam Tube Modules after Bake-Out and Testing Activities

5.6.1 **Verification of Reference Monuments** is performed in the following steps:
5.6.1.1 Mount the theodolite to the Primary[1] Reference Monument and level to Earth.
5.6.1.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.
5.6.1.3 Shoot and record positions of Secondary Reference Monuments and record of work sheet. Flop instrument scope, zero horizontal plane and re-shoot. Record on work sheet.
5.6.1.4 Compare readings with as-built positions and determine if monuments are a current valid reference. If the monuments are within acceptable limits of ± 2 seconds of an arc, continue to 5.6.2 "Transferring Reference Points inside Beam Tube Cover." If a greater deviation than ±5 seconds occurs continue the following steps.
5.6.1.5 Perform steps 5.6.1.1 thru 5.6.1.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 5.6.2 "Transferring Reference Points inside Beam Tube Cover."

5.6.2 Transferring Reference Points inside Beam Tube Cover is performed per the following steps:
5.6.2.1 Install the 3-Axis Precision Lateral/Lift Adjuster on the beam tube reference fixture and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the

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[1] Primary refers to current Reference Monument being measured.
[2] Secondary Reference monument refers to monuments used as target reference.

reference target fixture and target to the vertical adjuster adapter plate.

5.6.2.2 With the Theodolite in the same position and plane used in 5.6.1, Turn to the As-built angle recorded for the Primary[3] Beam Tube Reference Target.

5.6.2.3 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.

5.6.2.4 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.

5.6.2.5 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 5.6.2.2 thru 4. Record displacement differences on work sheet. Compare and determine discrepancies.

5.6.2.6 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Precision Lift.

5.6.2.7 Once the Primary Beam Tube Reference Target is determined, this point becomes the **"Primary Beam Tube Reference Point"** with a designated identification on the work sheet for the specific LIGO location.

5.6.2.8 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.

5.6.3 Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports shall be performed per the following steps:

5.6.3.1 Set-up the Theodolite Mounting Bracket at the reference position.

[3] Primary refers to current Beam Tube Reference Point being measured.

5.6.3.2 Mount the 2-Axis Lateral Adjusters on the mounting bracket with one parallel to the Beam Tube Centerline and the other perpendicular to the centerline.
5.6.3.3 Mount the Theodolite to the Lateral adjusters and level to Earth. Use the Optical Plummet on the base of the Theodolite and center on the Primary Beam Tube Reference Point.by using the lateral adjusters.
5.6.3.4 Align the Theodolite to the Primary Reference Monument Target and set the horizontal scale on the instrument to the as-built angle.Shoot the Primary Reference Monument Target and adjust elevation using the Precision Lift. Verify the elevation using a scale or tape fixed to the Beam Tube Reference Point and measure to the centerline of the Theodolite scope.
5.6.3.5 Rotate the Theodolite parallel to the Beam Tube Centerline and fine adjust the instrument to the as-built angle. Record the displacement at the previous Secondary Beam Tube Reference Target (and the next Secondary Beam Tube Reference Target). Flop the instrument's scope and repeat the steps 5.6.3.3 & 5.6.3.4.
5.6.3.6. Record any difference in readings exceed the theodolite's resolution, record the data and proceed unless the discrepancy is beyond an acceptance range. If so, tear down the set-up and repeat steps noted in 5.6.2. During continued alignment surveys in which Secondary Beam Tube Reference targets are established, Repeat the step noted in 5.6.3.5 and record data.
5.6.3.7 Install the Beam Tube Target in the Alignment Stiffener located near the first support. Shoot the position of the target and record the displacement on the worksheet.
5.6.3.8 If adjustment is necessary, perform adjustment per the designed method listed in the installation procedure and re-shoot the final position. Record on the worksheet. NOTE: It is preferred that both position readings(before and after adjustments) are recorded in order to determine specific foundation or structural patterns occurring in relation to time.

5.6.3.9 Using a Machinist Level, check the rotation of the beam alignment stiffener to assure the adjustment was performed without rotating the tube.

5.6.3.10 After successful Beam Tube positioning is obtained, remove the Beam Tube Target and move to the next beam tube alignment stiffener. Install the target on the stiffener and repeat steps 5.6.3.6. and 7.

5.6.3.11 When the supports for the 250 meter Beam Tube Module have all been aligned, verify the next Secondary Reference Monument Location by repeating steps noted in Section 4.1; re-establish the Beam Tube Reference Point per the steps noted in Section 5.6.2 and continue with alignment and adjustment per section 5.6.3.

6.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

DOC ID	ALM-A
REV. NO.	1
CONTRACT	930212

TITLE:	ALIGNMENT MAINTENANCE PROCEDURE - USING OPTICAL TOOLING TECHNIQUES - CALTECH	PAGE NO. 1 OF 6

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	21-Dec-93
					REVISED	SDH	28-Dec-93
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 1

1.0 SCOPE:

This procedure defines the method of maintaining the LIGO tube alignment using conventional optical tooling and techniques. Detailed are procedures for reference verification, set-up and inspection of tube positions at each support.

2.0 REFERENCES:

2.1 The alignment maintenance procedures for the Beam Tube Module are based on the following references:

2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.
2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.
2.3 Manufacturer's Procedures for Alignment Optical Tooling and Equipment.
2.4 As-Built Monument data and Beam Tube coordinates converted to State/Plane Rectangular System(N-E-Up).

3.0 EQUIPMENT:

The following is a listing of Alignment Equipment selected for use in maintaining the LIGO beam tube clear aperature of 1.07 meter diameter.

3.1 Precision Theodolite with accuracy of 1.0 second of an arc(max) and minimum effective aperture of 30 millimeters. Also included are power packs, carrying case and misc. appurtenances.
3.2 Integrated instrument and target support for mounting to reference monuments.
3.3 Beam Tube Stiffener instrument and target mounting system.
3.4 Reference Point target attachment fixture.
3.5 Calibrated Steel Tape(min 30 meter length).
3.6 2-axis Precision Lateral Adjusters with adapter plate and rotation collars.
3.7 3-Axis Precision Lateral and Vertical adjusters with minimum 1 inch travel.
3.8 Precision Lift Device.
3.9 Integrated instrument and target stand for mounting to the tube stiffener ring system.
3.10 Removable target and bushings.
3.11 Magnetic Thermometer range 0°to 50°C(3 required).
3.12 Master Machinist Level, 15" Length with 10 second accuracy minimum.
3.13 Alignment work sheet and data recorder.
3.14 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.

4.0 EXECUTION:

The Inspection and Maintenance of Beam Tube alignment is divided into three steps. These are (1)verification of Reference Monument positions (2)Transferring of reference points inside Beam Tube Covers and (3)Inspection and Adjustment of Beam Tube Supports.

4.1 **Verification of Reference Monuments** is performed in the following steps:

4.1.1 Mount the theodolite to the Primary[1] Reference Monument and level to Earth.

[1] Primary refers to current Reference Monument being measured.

4.1.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.
4.1.3 Shoot and record positions of Secondary Reference Monuments and record of work sheet. Flop instrument scope, zero horizontal plane and re-shoot. Record on work sheet.
4.1.4 Compare readings with as-built positions and determine if monuments are a current valid reference. If the monuments are within acceptable limits of ± 2 seconds of an arc, continue to 4.2 "Transferring Reference Points inside Beam Tube Cover." If a greater deviation than ±5 seconds occurs continue the following steps.
4.1.5 Perform steps 4.1.1 thru 4.1.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 4.2 "Transferring Reference Points inside Beam Tube Cover."

4.2 Transferring Reference Points inside Beam Tube Cover is performed per the following steps:

4.2.1 Install the 3-Axis Precision Lateral/Lift Adjuster on the beam tube reference fixture and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the reference target fixture and target to the vertical adjuster adapter plate.
4.2.2 With the Theodolite in the same position and plane used in 4.1, Turn to the As-built angle recorded for the Primary[3] Beam Tube Reference Target.
4.2.3 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built

[2] Secondary Reference monument refers to monuments used as target reference.
[3] Primary refers to current Beam Tube Reference Point being measured.

distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.

4.2.4 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.

4.2.5 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 4.2.2 thru 4. Record displacement differences on work sheet. Compare and determine discrepancies.

4.2.6 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Precision Lift.

4.2.7 Once the Primary Beam Tube Reference Target is determined, this point becomes the **"Primary Beam Tube Reference Point"** with a designated identification on the work sheet for the specific LIGO location.

4.2.8 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.

4.3 Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports shall be performed per the following steps:

4.3.1 Set-up the Theodolite Mounting Bracket at the reference position.

4.3.2 Mount the 2-Axis Lateral Adjusters on the mounting bracket with one parallel to the Beam Tube Centerline and the other perpendicular to the centerline.

4.3.3 Mount the Theodolite to the Lateral adjusters and level to Earth. Use the Optical Plummet on the base of the Theodolite and center on the Primary Beam Tube Reference Point.by using the lateral adjusters.

4.3.4 Align the Theodolite to the Primary Reference Monument Target and set the horizontal scale on the instrument to the as-built angle.Shoot the Primary Reference Monument Target and adjust elevation using the Precision Lift. Verify the elevation using a scale or tape fixed to the Beam Tube Reference Point and measure to the centerline of the Theodolite scope.

4.3.5 Rotate the Theodolite parallel to the Beam Tube Centerline and fine adjust the instrument to the as-built angle. Record the displacement at the previous Secondary Beam Tube Reference Target (and the next Secondary Beam Tube Reference Target). Flop the instrument's scope and repeat the steps 4.3.3 & 4.3.4.

4.3.6. Record any difference in readings exceed the theodolite's resolution, record the data and proceed unless the discrepancy is beyond an acceptance range. If so, tear down the set-up and repeat steps noted in 4.2. During continued alignment surveys in which Secondary Beam Tube Reference targets are established, Repeat the step noted in 4.3.5 and record data.

4.3.7 Install the Beam Tube Target in the Alignment Stiffener located near the first support. Shoot the position of the target and record the displacement on the worksheet.

4.3.8 If adjustment is necessary, perform adjustment per the designed method listed in the installation procedure and re-shoot the final position. Record on the worksheet. NOTE: It is preferred that both position readings(before and after adjustments) are recorded in order to determine specific foundation or structural patterns occuring in relation to time.

4.3.9 Using a Machinist Level, check the rotation of the beam alignment stiffener to assure the adjustment was performed without rotating the tube.

4.3.10 After successful Beam Tube positioning is obtained, remove the Beam Tube Target and move to the next beam tube alignment stiffener. Install the target on the stiffener and repeat steps 4.3.6. and 7.

4.3.11 When the supports for the 250 meter Beam Tube Module have all been aligned, verify the next Secondary Reference Monument Location by repeating steps noted in Section 4.1; re-establish the Beam

Tube Reference Point per the steps noted in Section 4.2 and continue with alignment and adjustment per section 4.3.

5.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

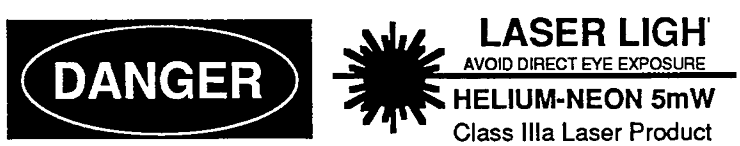
ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	28-Dec-93
					REVISED	0	
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 0

1.0 SCOPE:

This procedure defines the method of establishing the LIGO Beam Tube alignment during construction activities and through final alignment after bake out and testing. This procedure uses Optical Tooling and Alignment Laser techniques with jigs and fixtures unique to LIGO requirements. Detailed are procedures for Reference Verification, Beam Tube Layout, Initial Alignment and Final Inspection of Beam Tube Support positions between each Reference Monument established by Cal Tech.

2.0 SAFETY:

The use of Lasers is a safety issue requiring proper instruction, handling and equipment. Read all manufacturer's literature and follow all CBI and OSHA guidelines regarding its use.



3.0 **REFERENCES**:

2.1 The alignment maintenance procedures for the Beam Tube Module are based on the following references:

3.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.
3.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.
3.3 Manufacturer's Procedures for Alignment Lasers and Optical Tooling and Equipment.
3.4 As-Built Monument data and Beam Tube coordinates converted to State/Plane Rectangular System(N-E-Up).

4.0 **EQUIPMENT**:

The following is a listing of Alignment Equipment selected for use in maintaining the LIGO beam tube clear aperture of 1.07 meter diameter between the Reference Monuments.

4.1 Precision Theodolite with accuracy of 1.0 second of an arc(max), minimum effective aperture of 30 millimeters, and the scope barrel sized to receive an optical micrometer. Also included are power packs, carrying case and misc. appurtenances.
4.2 Integrated Instrument and Target Mounting Adapter for Reference Monuments(See Sketch ALI-1).
4.3 Beam Tube Reference Point Target Attachment fixture(See Sketch ALI-2).
4.4 Calibrated Steel Tape(min 30 meter length, two required).
4.5 2-axis Precision Lateral Adjusters with adapter plate and rotation collars.
4.6 3-Axis Precision Lateral and Vertical adjusters with minimum 1 inch travel.
4.7 Open
4.8 Reference Point Target Stand(See Sketch ALI-3).
4.9 Beam Tube Reference Point Adapter Fixture(ALI-4).

4.10 Clamp-On Target Holder Assembly(See Sketch ALI-5).
4.11 Magnetic Thermometer range 0°to 50°C(12 required).
4.12 Master Machinist Level, 15" Length with 10 second accuracy minimum.
4.13 Alignment work sheet and data record (Worksheet Software preferred).
4.14 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.
4.15 486 or Macintosh Computer with printer.
4.16 Personnel transportation(bicycle, motor-scooter, golfcart, etc.
4.17 Alignment Laser: Helium-Neon 5 mW, Class IIIa Laser Product with Optical Plummet.
4.18 Beam Tube Support Reference Plate(ALI-6) and Reference Plate Installation Fixture(ALI-7).

5.0 DOCUMENTATION:

The receiving, recording, calculation and use of data is controlled by data logging forms that will be documented in both hard copy and on 3.5" diskettes formatted to DOS &/or Mac.

5.1 Forms shall be standardized and used to record all data including all dimensional and atmospheric measurements, and will include instrument information including calibration dates, instrument serial numbers and field calibration anomalies.
5.2 Data used to process coordinate points, atmospheric conditions, and instrument information shall be in-put to a spread sheet computer program with abilities to sort for ranges and specific text references.
5.3 Sample forms are indexed below and attached to this procedure.
 i. Sample Inspection Report
 ii. Sample Data Record
 iii. Sample Spreadsheet
 iv. Sample Project Data Index

5.4 All project documentation shall be signed by the responsible technician and dated with the date of that signing and the date of the actual recordings.

6.0 EXECUTION:

The Alignment Process begins when the following is complete:

1) LIGO Matt surface is in place
2) The Reference Monuments are in-place
3) The Location Data for each monument has been received by the Inspection Team.

6.1 Arrangement of Reference Monument data to State/Plane Rectangular Coordinates.

6.1.1 Input and compute Reference Monument Data into the computer program and calculate monument positions into rectangular and specific angular data needed to verify monument positions in the field.

6.2 Verification of Reference Monuments is performed in the following steps:

6.2.1 Install the Integrated Instrument and Target Mounting Adapter(ALI-1) to three(3) Reference Monuments. Mount the theodolite to the Primary[1] Reference Monument and level to Earth.

6.2.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.

6.2.3 Shoot and record positions of each Secondary Reference Monument and record in the data record. Flop instrument scope, zero horizontal plane and re-shoot. Record in the data record.

6.2.4 Compare readings with as-built positions and determine the Cal Tech Reference Monument data accuracy and calculate error. If the monuments are within acceptable limits of ± 2 seconds of an arc,

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[1] Primary refers to current Reference Monument being measured.

[2] Secondary Reference monument refers to monuments used as target reference.

continue to 6.2 "Transferring Reference Points to Beam Tube Mat." If a deviation outside accepted limits occur, continue the following steps.

6.2.5 Field calibrate the theodolite and document results. If the instrument is outside manufacturer's recommended limits, replace or repair instrument. If field calibration is found acceptable continue with 6.2.6.

6.2.6 Perform steps 6.2.1 thru 6.2.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 6.2 "Transferring Reference Points to Beam Tube Mat."

6.3 **Transferring Reference Points to the Beam Tube Mat** is performed per the following steps:

6.3.1 Install the Integrated Instrument and Target Mounting Adapter(ALI-1) to the first(beginning) three(3) Reference Monuments. Mount the theodolite to the Primary Reference Monument(the First Monument) and level to Earth.

6.3.2 Mount targets to Secondary Reference Monument(s) and level to Earth.

6.3.3 Shoot and record positions of the Secondary Reference Monuments and record in the data record. Flop instrument scope, zero horizontal plane and re-shoot. Record in the data record.

6.3.4 Position the 3-Axis Precision Lateral/Lift Adjuster on the Beam Tube Mat and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the reference target fixture and target to the vertical adjuster adapter plate.

6.3.5 With the Theodolite in the same position and plane used in 6.3.3, Using the data record, turn the horizontal angle calculated for the Primary[3] Beam Tube Reference Target.

[3] Primary refers to current Beam Tube Reference Point being measured.

6.3.6 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.

6.3.7 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.

6.3.8 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 6.3.5 thru 7. Record displacement differences on data record. Compare and determine discrepancies.

6.3.9 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Beam Tube Target third axis.

6.3.10 Once the Primary Beam Tube Reference Target is determined, this point becomes the **"Primary Beam Tube Reference Point"** with a designated identification on the data record for the specific LIGO location.

6.3.11 Layout four reference points to re-locate the center location and its elevation. Remove the 3-Axis Precision Lateral/Lift Adjuster.

6.3.12 Install a Beam Tube Reference Point Target Attachment Fixture(ALI-2) at the Primary Reference Point using the Layout as reference.

6.3.13 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.

6.3.14 Install the Two-Axis lateral adjusters to the Primary Beam Tube Reference Point Target Attachment Fixture(ALI-2). Install the theodolite adapter and theodolite. Shoot the Primary and Secondary Reference Monument Targets and record data. Using the distance finder, shoot and record the distance to the the Primary and Secondary Reference Monument Targets. Calculate and determine Beam Tube Reference Point Position. Record As-Built position on the data record. Adjustments shall be made when this point is used as reference.

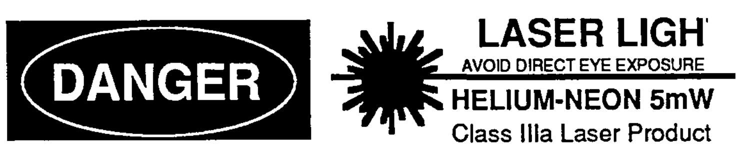
6.3.15 Remove theodolite and move to next Primary Reference Monument. Repeat Steps 6.3.1 thru 14 for each Beam Tube Reference Point.

6.4 Layout of Beam Tube Support Positions shall be performed per the following steps:

> **NOTE: It is recommended this activity be carried out during periods of stable temperatures such as cloudy days or evenings between midnight and sunrise. This is to decrease the effects of surface convection.**

6.4.1 Measure a distance of 0.71 meters from the Primary and Secondary Beam Tube Reference points perpendicular from the beam tube centerline. Mark the foundation mat with a punch and paint the mark. Install a Two-Axis lateral adjuster to a trivet and set-up over the punch mark. Install the Laser adapter and the Laser.

6.4.2 Install the Three-Axis positioning target to a trivet at the Secondary punch mark laid out in step 6.1.4. Align the axis to the beam tube centerline.



6.4.3 Switch On Laser and center the beam to the Secondary Target to within 1 cm maximum.

6.4.4 Use a steel tape measure and the laser to position the Beam Tube Support Reference Plate(ALI-6) and Installation Fixture(ALI-7) at the first support location. Align the fixture to within ±1cm. Secure the beam tube reference plate with screws and/or epoxy.

6.4.5 Move to the next support location and repeat step 6.4.4 for each support location.
6.4.6 Continue Step 6.4.4 for all support plates between the Beam Tube Reference Points(Reference Monuments). There is an estimated total of 13 beam tube supports per beam tube module. This is an estimated 384 beam tube supports per LIGO site.
6.4.12 When all support plates are complete, move equipment to the next Beam Tube Module location and repeat steps 6.4.1 thru 6.4.11. There are a total of 32 beam tube modules per LIGO site.

6.5 Installation of Beam Tubes and Supports shall be performed per the following steps:
6.5.1 Pull a string line from two Beam Tube Support Reference Plates that cross the Mid Station Beam Tube Reference Point location. Use magnets centered to the punch marks laid out in step 6.4. Measure the distance from the Beam Tube Reference Point(Mid Station) along the string line and mark the open tube end distance calculated per the data record. The first Beam Tube Assembly and Support shall be positioned by locating the open end of the tube to the layout reference and centering the weld end to the beam tube support plate punch mark. This mark may be extended in the same string line fashion as noted previously.

NOTE: Assure the support is in the MID position of adjustment before bolting to the foundation.

6.5.2 Secure the support to the foundation mat per the engineering detail.
6.5.3 Using a Machinist Level, check the rotation of the Beam Tube Support before fit-up and set support adjusters to level out the reference surface.
6.5.4 Fine adjust the lateral and vertical position of the tube before the Clean Room is moved into place.

6.6 Final Inspection and Adjustment of Beam Tube Modules after Bake-Out and Testing Activities

6.6.1 **Verification of Reference Monuments** is performed in the following steps:

6.6.1.1 Mount the theodolite to the Primary[1] Reference Monument and level to Earth.

6.6.1.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.

6.6.1.3 Shoot and record positions of Secondary Reference Monuments and record of work sheet. Flop instrument scope, zero horizontal plane and re-shoot. Record on work sheet.

6.6.1.4 Compare readings with as-built positions and determine if monuments are a current valid reference. If the monuments are within acceptable limits of ± 2 seconds of an arc, continue to 6.6.2 "Transferring Reference Points inside Beam Tube Cover." If a greater deviation than ±5 seconds occurs continue the following steps.

6.6.1.5 Perform steps 6.6.1.1 thru 6.6.1.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 6.6.2 "Transferring Reference Points inside Beam Tube Cover."

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1 Primary refers to current Reference Monument being measured.

2 Secondary Reference monument refers to monuments used as target reference.

6.6.2 Transferring Reference Points inside Beam Tube Cover is performed per the following steps:

6.6.2.1 Install the Beam Tube Reference Target Stand with the 3-Axis Precision Lateral/Lift Adjuster and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the reference target to the vertical adjuster plate.

6.6.2.2 With the Theodolite in the same position and plane used in 5.6.1, Turn to the As-built angle recorded for the Primary[3] Beam Tube Reference Target.

6.6.2.3 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.

6.6.2.4 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.

6.6.2.5 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 6.6.2.2 thru 4. Record displacement differences on work sheet. Compare and determine discrepancies.

6.6.2.6 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Precision Lift.

6.6.2.7 Once the Primary Beam Tube Reference Target is determined, this point becomes the "**Primary**

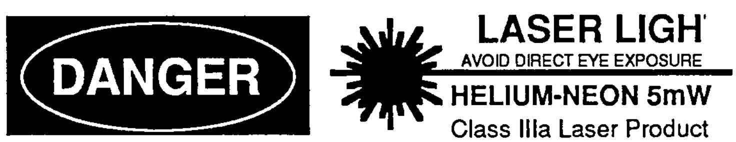
[3] Primary refers to current Beam Tube Reference Point being measured.

Beam Tube Reference Point" with a designated identification on the work sheet for the specific LIGO location.

6.6.2.8 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.

6.6.2.9 Move the Theodolite to the next Reference Monument install it in place of the target. Move the target to the next Secondary Reference Monument. Repeat Steps 6.6.1.1 thru 6.6.2.8.

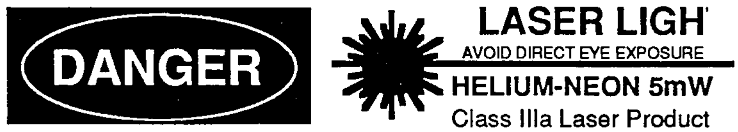
6.6.3 **Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports** shall be performed per the following steps:



6.6.3.1 Set-up the Alignment Laser Stand in a position within range of equipment adjustment. Mount the Single Axis Lateral Adjuster on the stand perpendicular to the centerline. Install the adapter plate to the Lateral adjuster. Mount the Alignment Laser to the adapter plate.

6.6.3.2 Switch on the Alignment Laser and begin alignment of the beam by centering on the Primary Reference Point Target and the next Secondary Reference Point Target. Alignment shall be within 1 cm maximum.

6.6.3.3 Install the Beam Tube Target on the Alignment Stiffener located near the first support. Level the Beam Tube Target and clamp it to the stiffener. Inspect the position of the target and record the displacement on the worksheet.



6.6.3.4 If Beam Tube Support adjustment is necessary, perform adjustment per the designed method listed in the installation procedure and re-inspect the final position. Record on the worksheet. NOTE: It is preferred that both position readings(before and after adjustments) are recorded in order to determine specific foundation or structural patterns occurring in relation to time.
6.6.3.5 Using a Machinist Level, check the rotation of the Beam Tube Support to assure the adjustment was performed without rotating the tube.
6.6.3.6 After successful Beam Tube positioning is obtained, remove the Beam Tube Target and move to the next beam tube alignment stiffener. Install the target on the stiffener and repeat steps 6.6.3.3. thru 5.
6.6.3.7 When the supports for the 250 meter Beam Tube Module have all been aligned, verify the next Secondary Reference Monument Location by repeating steps noted in Section 6.1; re-establish the next Secondary Beam Tube Reference Point per the steps noted in Section 6.6.2 and continue with alignment and adjustment per section 6.6.3.

7.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

CBI

DOC ID	ALM-C
REV. NO.	1
CONTRACT	930212

TITLE: ALIGNMENT MAINTENANCE PROCEDURE - USING OPTICAL TOOLING & ALIGNMENT LASER

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	21-Dec-93
					REVISED	SDH	28-Dec-93
					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 1

1.0 SCOPE:

This procedure defines the method of maintaining the LIGO tube alignment using conventional optical tooling and Alignment Laser techniques. Detailed are procedures for reference verification, set-up and inspection of tube positions at each support.

2.0 REFERENCES:

2.1 The alignment maintenance procedures for the Beam Tube Module are based on the following references:

- 2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.
- 2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.
- 2.3 Manufacturer's Procedures for Alignment Optical Tooling, Alignment Lasers and Accessory Equipment.
- 2.4 As-Built Monument data and Beam Tube coordinates converted to State/Plane Rectangular System(N-E-Up).

3.0 EQUIPMENT:

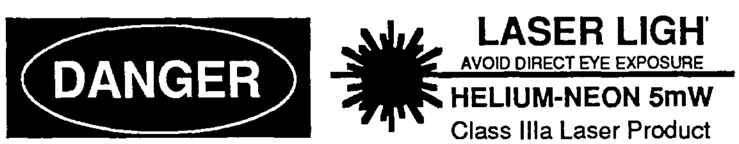
The following is a listing of Alignment Equipment selected for use in maintaining the LIGO beam tube clear aperture of 1.07 meter diameter.

- 3.1 Precision Theodolite with minimum accuracy of 1.0 second of an arc(max) and minimum effective aperture of 30 millimeters. Also included are power packs, carrying case and misc. appurtenances.

3.2 Integrated instrument and target support for mounting to reference monuments.
3.3 Beam Tube Reference Point Instrument Stand.
3.4 Reference Point target attachment fixture.
3.5 Calibrated Steel Tape(min 30 meter length).
3.6 2-axis Precision Lateral Adjusters with adapter plate and rotation collar.
3.7 3-Axis Precision Lateral and Vertical adjusters with minimum 1 inch travel.
3.8 Alignment Laser: Helium-Neon 5 mW, Class IIIa Laser Product.
3.9 Beam Tube Reference Point Target Stand
3.10 Clamp-On Target Holder Assembly.
3.11 Magnetic Thermometer range 0°to 50°C(3 required).
3.12 Master Machinist Level, 15" Length with 10 second accuracy minimum.
3.13 Alignment work sheet and data recorder.
3.14 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.
3.15 "LASER IN USE" Warning signs and barricade tape.

4.0 SAFETY:

The use of Lasers is a safety issue requiring proper instruction, handling and equipment. Read all manufacturer's literature and follow all CBI and OSHA guidelines regarding its use.



5.3.5 Using a Machinist Level, check the rotation of the Beam Tube Support to assure the adjustment was performed without rotating the tube.

5.3.6 After successful Beam Tube positioning is obtained, remove the Beam Tube Target and move to the next beam tube alignment stiffener. Install the target on the stiffener and repeat steps 5.3.3. thru 5.

5.3.7 When the supports for the 250 meter Beam Tube Module have all been aligned, verify the next Secondary Reference Monument Location by repeating steps noted in Section 5.1; re-establish the next Secondary Beam Tube Reference Point per the steps noted in Section 5.2 and continue with alignment and adjustment per section 5.3.

6.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.

ENGR	WELD	Corp QA	Corp CONST	MFG		BY	DATE
					PREPARED	SDH	21-Dec-93
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					AUTHORIZED		
					REFERENCE STANDARD		REV. NO. 1

1.0 SCOPE:

This procedure defines the method of maintaining the LIGO tube alignment using conventional optical tooling and Alignment Laser techniques. Detailed are procedures for reference verification, set-up and inspection of tube positions at each support.

2.0 REFERENCES:

2.1 The alignment maintenance procedures for the Beam Tube Module are based on the following references:

2.1 Summary of concepts and Reference Design for a Laser Gravitational-Wave Observatory, CAL TECH; Feb-92.

2.2 Chicago Bridge & Iron Safety Manual for L.I.G.O. Project.

2.3 Manufacturer's Procedures for Alignment Optical Tooling, Alignment Lasers and Accessory Equipment.

2.4 As-Built Monument data and Beam Tube coordinates converted to State/Plane Rectangular System(N-E-Up).

3.0 EQUIPMENT:

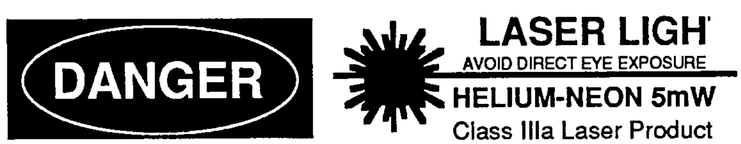
The following is a listing of Alignment Equipment selected for use in maintaining the LIGO beam tube clear aperture of 1.07 meter diameter.

3.1 Precision Theodolite with minimum accuracy of 1.0 second of an arc(max) and minimum effective aperture of 30 millimeters. Also included are power packs, carrying case and misc. appurtenances.

3.2 Integrated instrument and target support for mounting to reference monuments.
3.3 Beam Tube Reference Point Instrument Stand.
3.4 Reference Point target attachment fixture.
3.5 Calibrated Steel Tape(min 30 meter length).
3.6 2-axis Precision Lateral Adjusters with adapter plate and rotation collar.
3.7 3-Axis Precision Lateral and Vertical adjusters with minimum 1 inch travel.
3.8 Alignment Laser: Helium-Neon 5 mW, Class IIIa Laser Product.
3.9 Beam Tube Reference Point Target Stand
3.10 Clamp-On Target Holder Assembly.
3.11 Magnetic Thermometer range 0°to 50°C(3 required).
3.12 Master Machinist Level, 15" Length with 10 second accuracy minimum.
3.13 Alignment work sheet and data recorder.
3.14 Miscellaneous Tools including flashlights, shop lights, wrenches, screwdrivers, etc.
3.15 "LASER IN USE" Warning signs and barricade tape.

4.0 SAFETY:

The use of Lasers is a safety issue requiring proper instruction, handling and equipment. Read all manufacturer's literature and follow all CBI and OSHA guidelines regarding its use.



5.0 EXECUTION:

The Inspection and Maintenance of Beam Tube alignment is divided into three steps. These are (1)verification of Reference Monument positions (2)Transferring of reference points inside Beam Tube Covers and (3)Inspection and Adjustment of Beam Tube Supports using an Alignment Laser.

5.1 **Verification of Reference Monuments** is performed in the following steps:

5.1.1 Mount the theodolite to the Primary[1] Reference Monument and level to Earth.

5.1.2 Mount targets to Secondary[2] Reference Monuments on each side of the Primary Monument and level to Earth.

5.1.3 Shoot and record positions of Secondary Reference Monuments and record of work sheet. Flop instrument scope, zero horizontal plane and re-shoot. Record on work sheet.

5.1.4 Compare readings with as-built positions and determine if monuments are a current valid reference. If the monuments are within acceptable limits of ± 2 seconds of an arc, continue to 5.2 "Transferring Reference Points inside Beam Tube Cover." If a greater deviation than ±5 seconds occurs continue the following steps.

5.1.5 Perform steps 5.1.1 thru 5.1.3 and determine if only a single monument is out of position or there are others. If required, perform a Global Positioning System(GPS) survey to determine new Reference Monument Coordinates. Compute GPS data to State/Plane Rectangular Coordinates and re-adjust Beam Tube coordinates for reference. When complete, continue to 5.2 "Transferring Reference Points inside Beam Tube Cover."

5.2 **Transferring Reference Points inside Beam Tube Cover** is performed per the following steps:

---

[1] Primary refers to current Reference Monument being measured.

[2] Secondary Reference monument refers to monuments used as target reference.

5.2.1 Install the Beam Tube Reference Target Stand with the 3-Axis Precision Lateral/Lift Adjuster and set the two horizontal adjusters parallel & perpendicular to the beam tube centerline and the third vertical adjuster plumb to Earth. Mount the reference target to the vertical adjuster plate.
5.2.2 With the Theodolite in the same position and plane used in 5.1, Turn to the As-built angle recorded for the Primary[3] Beam Tube Reference Target.
5.2.3 Use the Theodolite Distance Meter to set the Primary Beam Tube Reference Target at the as-built distance from the Primary Reference Monument. Adjust the target using the Precision Lateral Adjuster set perpendicular to the Beam Tube Centerline. When practical, verify the distance reading with a calibrated steel tape.
5.2.4 Use the Precision Lateral Adjuster that is set parallel to the Beam Tube Centerline to locate the Primary Beam Tube Reference Target in the parallel plane.
5.2.5 Flop the Theodolite scope, zero horizontal plane and re-shoot. Repeat steps 5.2.2 thru 5. Record displacement differences on work sheet. Compare and determine discrepancies.
5.2.6 Level the barrel on the Theodolite scope or set the scope on the designated as-built vertical angle and sight in the Primary Beam Tube Reference Target. Adjust the target elevation using the Precision Lift.
5.2.7 Once the Primary Beam Tube Reference Target is determined, this point becomes the **"Primary Beam Tube Reference Point"** with a designated identification on the work sheet for the specific LIGO location.
5.2.8 Remove the Theodolite from the Primary Reference Monument and replace it with a target. This new target will be designated the Primary Monument Target.
5.2.9 Move the Theodolite to the next Reference Monument install it in place of the target. Move

[3] Primary refers to current Beam Tube Reference Point being measured.

the target to the next Secondary Reference Monument. Repeat Steps 5.1.1 thru 5.2.8.

5.3 **Inspection of Beam Tube Alignment and Adjustment of Beam Tube Supports** shall be performed per the following steps:
5.3.1 Set-up the Alignment Laser Stand in a position within range of equipment adjustment. Mount the Single Axis Lateral Adjuster on the stand perpendicular to the centerline. Install the adapter plate to the Lateral adjuster. Mount the Alignment Laser to the adapter plate.

DANGER

LASER LIGH
AVOID DIRECT EYE EXPOSURE
HELIUM-NEON 5mW
Class IIIa Laser Product

5.3.2 Switch on the Alignment Laser and begin alignment of the beam by centering on the Primary Reference Point Target and the next Secondary Reference Point Target. Alignment shall be within 1 cm maximum.
5.3.3 Install the Beam Tube Target on the Alignment Stiffener located near the first support. Level the Beam Tube Target and clamp it to the stiffener. Inspect the position of the target and record the displacement on the worksheet.

DANGER

LASER LIGH
AVOID DIRECT EYE EXPOSURE
HELIUM-NEON 5mW
Class IIIa Laser Product

5.3.4 If Beam Tube Support adjustment is necessary, perform adjustment per the designed method listed in the installation procedure and re-inspect the final position. Record on the worksheet. NOTE: It is preferred that both position readings(before and after adjustments) are recorded in order to determine specific foundation or structural patterns occurring in relation to time.

5.3.5 Using a Machinist Level, check the rotation of the Beam Tube Support to assure the adjustment was performed without rotating the tube.

5.3.6 After successful Beam Tube positioning is obtained, remove the Beam Tube Target and move to the next beam tube alignment stiffener. Install the target on the stiffener and repeat steps 5.3.3. thru 5.

5.3.7 When the supports for the 250 meter Beam Tube Module have all been aligned, verify the next Secondary Reference Monument Location by repeating steps noted in Section 5.1; re-establish the next Secondary Beam Tube Reference Point per the steps noted in Section 5.2 and continue with alignment and adjustment per section 5.3.

6.0 CALIBRATION:

Equipment Shall be handled, calibrated and stored per manufacturer's requirements. All calibration shall be traceable to national and international standards. All equipment shall be inventoried with serial numbers, calibration dates, and logs detailing operation and duration of equipment use.