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 III

CDRL #8
DRD #3 ITEMS I THROUGH IV
FINAL QUALIFICATION TEST
PLAN & PROCEDURES

Prepared by

CBI TECHNICAL SERVICES COMPANY
PLAINFIELD, ILLINOIS
APRIL 11, 1994

CBI CONTRACT 930212

Bale out lots of T(t) must also calculate $P(t)_{H_2O}$ and total

Data

Status vectors for contents is not explicitly in the procedure (Now put in to the log files) but it is in the data files

Status vectors for contents is not explicitly in the procedure

Note: Pathway balloons are used in the calculation of the dimensions in the restraint supports - not consistent with the plan at present which uses no-supply balloons.

~~Note HMST1GT the leak is 10^{-10} required 10^{-11} goal~~

~~this is~~

HMST1GT Mixing the dis signatures account and confirms the pre-cleaning purging systems which allows

Confirmed with this in the equipment of the module or section level.

=) Test 1f it is the section the leak replace a using 10^{-11} goal 10^{-10} required

HMST2GT also confirmed in goals and requirements

~~HMT~~ HMST4GT Mixing dis leaks.

New sheets are replacements for old?

must read the other procedures.

RGA to be run continuously during ~~pumpout~~ bake
They have missed the idea of a continuous record
of P(AMU) vs T inc

Will not be able to close pumping system off and
pump only with LN_2 trap because the hydrogen
evolution will be too large.

Hydrogen outgassing should also be measured by accumulation
method

Accumulation measurement of H_2O should also be tried
it gives the readsorption rate

Need steps to bake & hydrocarbons

Alignment Check that the alignment procedure ~~for~~
places the supports before welding the circumferential weld
in the procedure to place the tubes in their supports
individually before circumferential welding

Do not understand the rotation of the beam tube
once welded - This must trigger the expansion
joint

Bakeout

Not planned for direct tube heating - still
uses heater cables.

Pump Port   C-PORT-QT

Note: Make sure air leak calibration is provided to test the leak assessment step type of leaks is needed!

Note: Leak ~~amount~~ ~~rate~~ tightness by RGA measurement not part of QT

Step 3.10.3 Should be make sure that the ultimate ~~[illegible]~~ leak limit for the tube section is 10^{-10} tl/s not 10^{-5} at the cryopump level

Cryopump Tests

Do not need a multi AMU assay of the background gas

~~Cryopump Testing and Vacuum QT~~

Note in all procedures RGA filament should be left on

Recommend Accumulation Rate H_2 measurement on both Cryopump and on the leak.

——— QT

Pump Down   QT Pump down + Outgassing Test

Pressure vs Time data needed

Need Calibration Air leak for any air signature assay

RW

Note about a possible book to write

~~The~~ The calculation view of physics

describe the motion of an expert from calculation to exposition and possible end

Integrability could be the example or the CBR or any other thing in your life

The book to be written for physicists ~~and~~ on how gadgets calculators heuristics and the hard work of doing are all interwoven

It is somewhat autobiographical but also covers how some unique community to distill the wisdom of an ~~exp~~ experiment -

Making things work and ~~drea~~ dreaming but also coupled to theoretical insight.

Needs much more elaboration

CLEANING

SPECIFICATION REQUIREMENTS

CRITICAL PARAMETERS

CLEANING PROCEDURE OPTIONS

CLEANING PROCEDURE DEVELOPMENT

PLANNED APPROACH TO CLEANING

PURCHASED ITEMS

PRECLEAN CAN SECTIONS AT SITE

FINAL CLEAN COMPLETED AND TESTED CAN SECTIONS

CLEANING MAINTENANCE

CLEANING

SPECIFICATION REQUIREMENTS

a. Before leak testing can sections, solvent wipe to remove all visible contaminants.

b. Clean can sections after fabrication (which includes leak testing) in accordance with Caltech specified "steam" cleaning process with Oakite 33 (mild phosphoric acid solution) which consists of following steps.

- Remove hydrocarbons with solvent wipe.
- Spray rinse with hot water at 60°C (140°F).
- Spray at 60°C (140°F) with a 2% by volume Oakite 33 in water solution (or equivalent).
- Hold for five (5) minutes.
- Spray at 60°C (140°F) with a 2% by volume Oakite 33 in water solution (or equivalent).
- Hold for five (5) minutes again.
- Spray rinse with hot water at 60°C (140°F) to remove all traces of Oakite 33 solution.

c. Maintain cleanliness during installation and construction.

d. No visible contaminants in beam tube module before evacuation.

CRITICAL PARAMETERS

a. Effective execution and control of cleaning process.

b. Safe handling and disposal of cleaning solvents and liquids.

c. Automated process execution with limited spot and hand cleaning to minimize cost. (Strictly controlled by limited entry into clean room controlled environment)

d. Limit contamination after "final" cleaning to limit rework and degrade cleanliness.

e. Effective final inspection.

CLEANING

CLEANING PROCEDURE OPTIONS

a. Caltech specified cleaning process:

- Apparently effective procedure with known characteristics.
- Oakite 33 potentially environmentally hazardous.
- Disposal may be costly.

b. CBI steam cleaning and mild acidic passivation procedures:

- Successfully used on high vacuum facilities.
- Known to be effective in cleaning and iron freeing.
- Unknown effects on hydrogen outgassing characteristics.

CLEANING PROCEDURE DEVELOPMENT

a. Caltech specified cleaning process:

- CBI developed draft cleaning procedure CL1N which conforms to specified Oakite 33 cleaning process.
- CBI developed coupon cleaning procedure CLCOUP for outgassing coupons. This procedure also conforms to specified Oakite 33 cleaning process. It includes a blacklight inspection after initial solvent wipe.
- Coupon cleaning procedure used on series of plain and welded coupons to determine comparative outgassing rates. In process of using this procedure, was decided to pursue alternate coupon cleaning procedures to compare with Oakite 33 procedure to determine best and most economical procedure.

CBI also determined costs of handling and neutralizing to dispose of Oakite 33 solution.

CLEANING

CLEANING PROCEDURE DEVELOPMENT (CONT'D)

b. CBI then developed several alternate cleaning procedure based on experience. At the suggestion of Caltech, each procedure included identical oil (hydrocarbon) contamination section to put on even basis for comparing their cleaning capabilities. In addition to measuring outgassing rates of cleaned coupons, a surface analysis was also performed. These procedures were labeled CLCOUPA for OAKITE, CLCOUPAO for steam and CLCOUPA1 for Mirachem 500.

c. CBI also determined costs of executing these alternate processes.

d. As result of outgassing and surface analyses of coupons cleaned by these alternate procedures, decision was made to proceed with using steam cleaning alternate to produce procedure for cleaning of beam tube can sections.

e. Can section steam cleaning procedure identified as CL1N

f. Spray nozzle steam flow rate and pressure and spray head travel speed will be established during Qualification Test Final Steam Cleaning. These parameters will be established to some degree by coorelation with surface temperatures observed during coupon steam cleaning and in part by cleaning results as indicated by final black light inspection.

PLANNED APPROACH TO CLEANING

Approach to cleaning identified as procedure "LIGOCP". Contains brief description of cleaning and cleaning maintenance procedures and additional requirements.

CLEANING

a. Baffles cleaned by fabricator in controlled environment, bagged and sealed for shipment.
b. Preliminary cleaning and protection of tube and expansion joint by manufacturer.

PRECLEAN CAN SECTIONS AT SITE

a. Initially black light inspect per procedure BI1N.
b. Alcohol or acetone solvent wipe to remove hydrocarbons per procedure CL1N.
c. Pre-clean can sections with solvent wipe after attaching stiffeners and expansion joint, when applicable, but before leak testing.

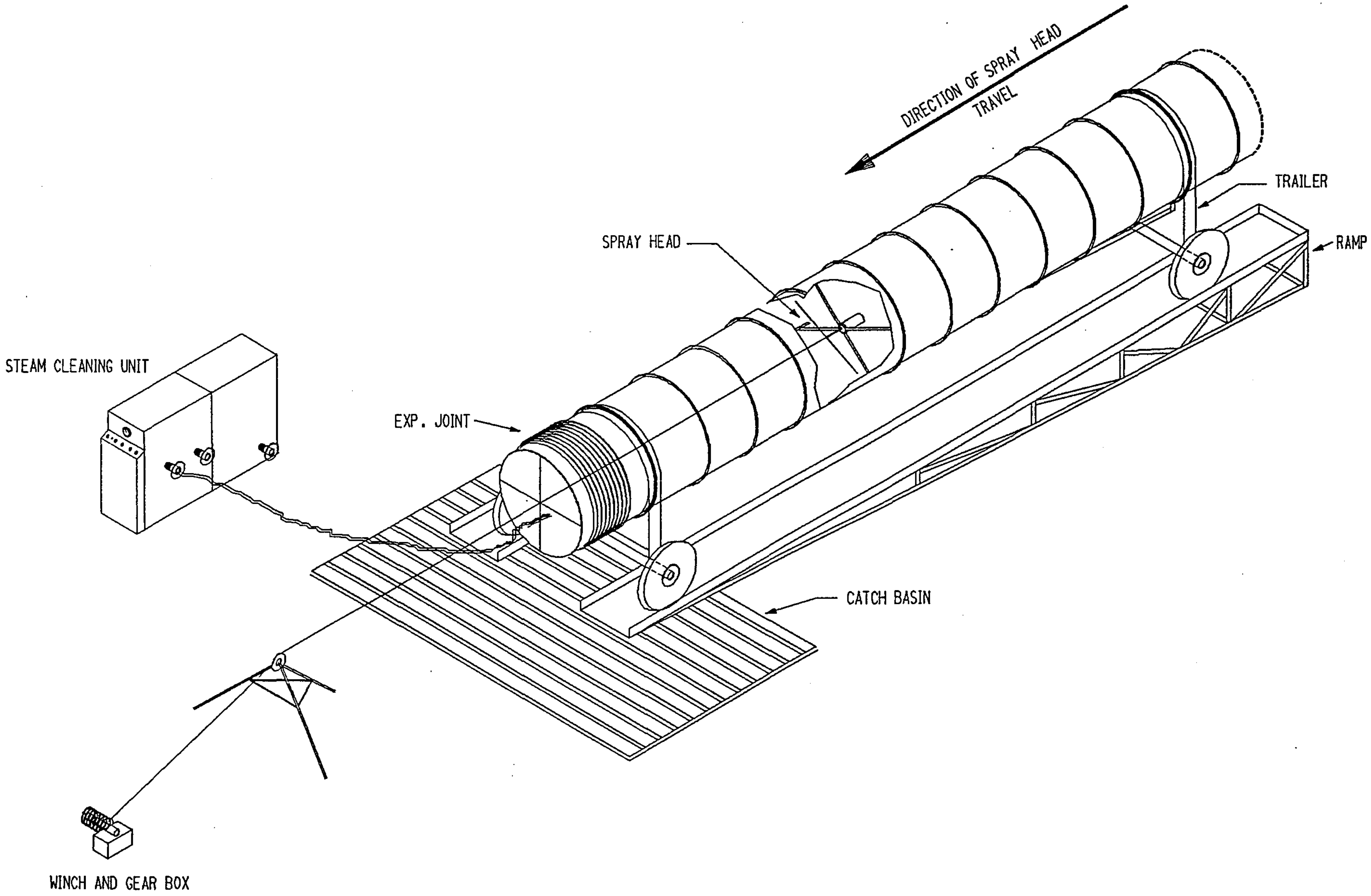
FINAL CLEAN COMPLETED AND TESTED CAN SECTIONS

a. Steam clean using potable tap water (softened as necessary) in accordance with CLIN.
b. Seal tubes after cleaning in security controlled clean room area.

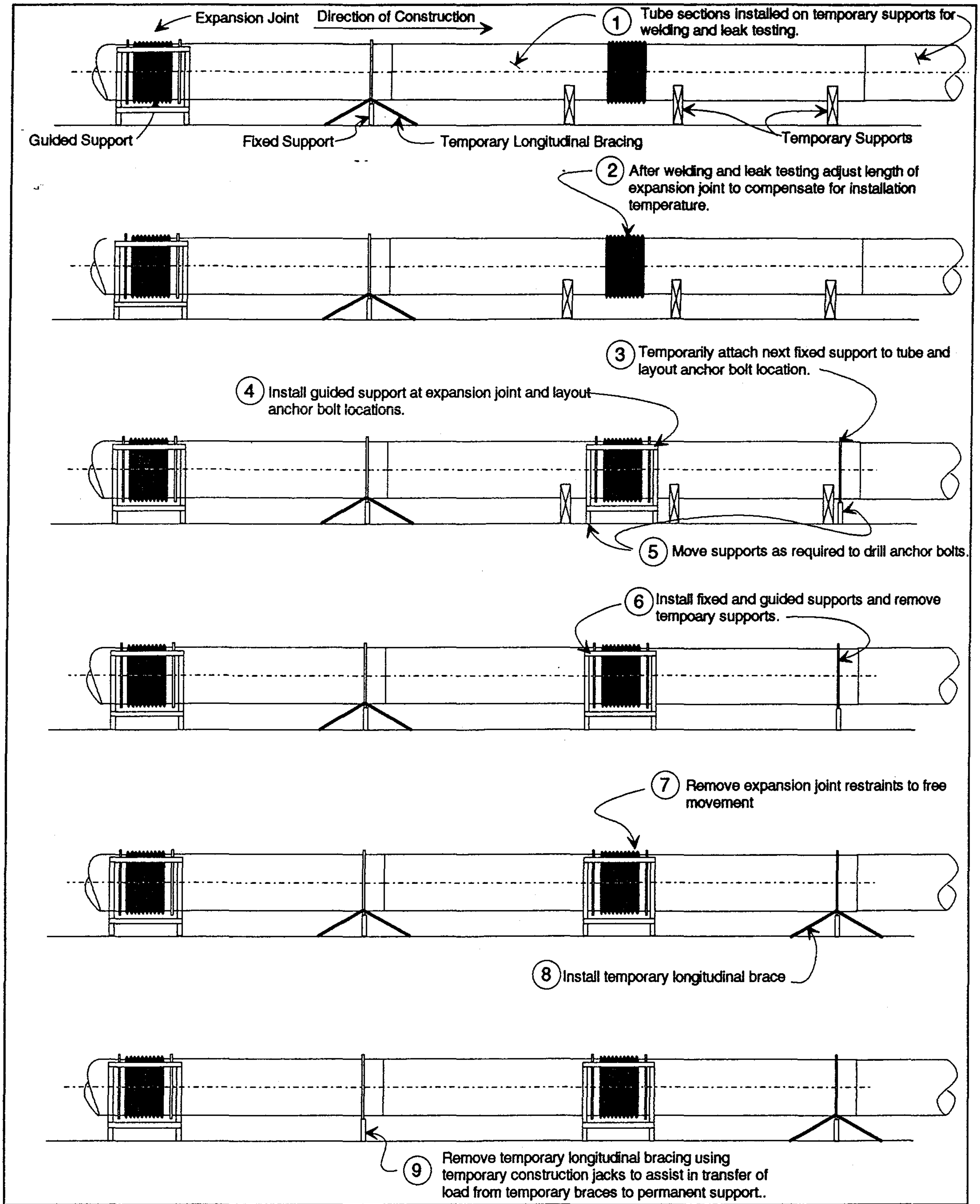
CLEANING MAINTENANCE

a. Positive filtered air flow & pressure within installed tubes per procedure BDF1.
b. Filtered air at ~~1500~~ 250 cfm to have 0°F dewpoint (humidity) and cleanliness controls.
c. Traveling clean room used as can sections installed per procedure CR1TSM (Class 10,000).
d. Cleaning Apparel Specification CRWA-1 controls dress in restricted area.

CLEANING



CAN SECTION FINAL CLEANING SET-UP



① Tube sections installed on temporary supports for welding and leak testing.

② After welding and leak testing adjust length of expansion joint to compensate for installation temperature.

③ Temporarily attach next fixed support to tube and layout anchor bolt location.

④ Install guided support at expansion joint and layout anchor bolt locations.

⑤ Move supports as required to drill anchor bolts.

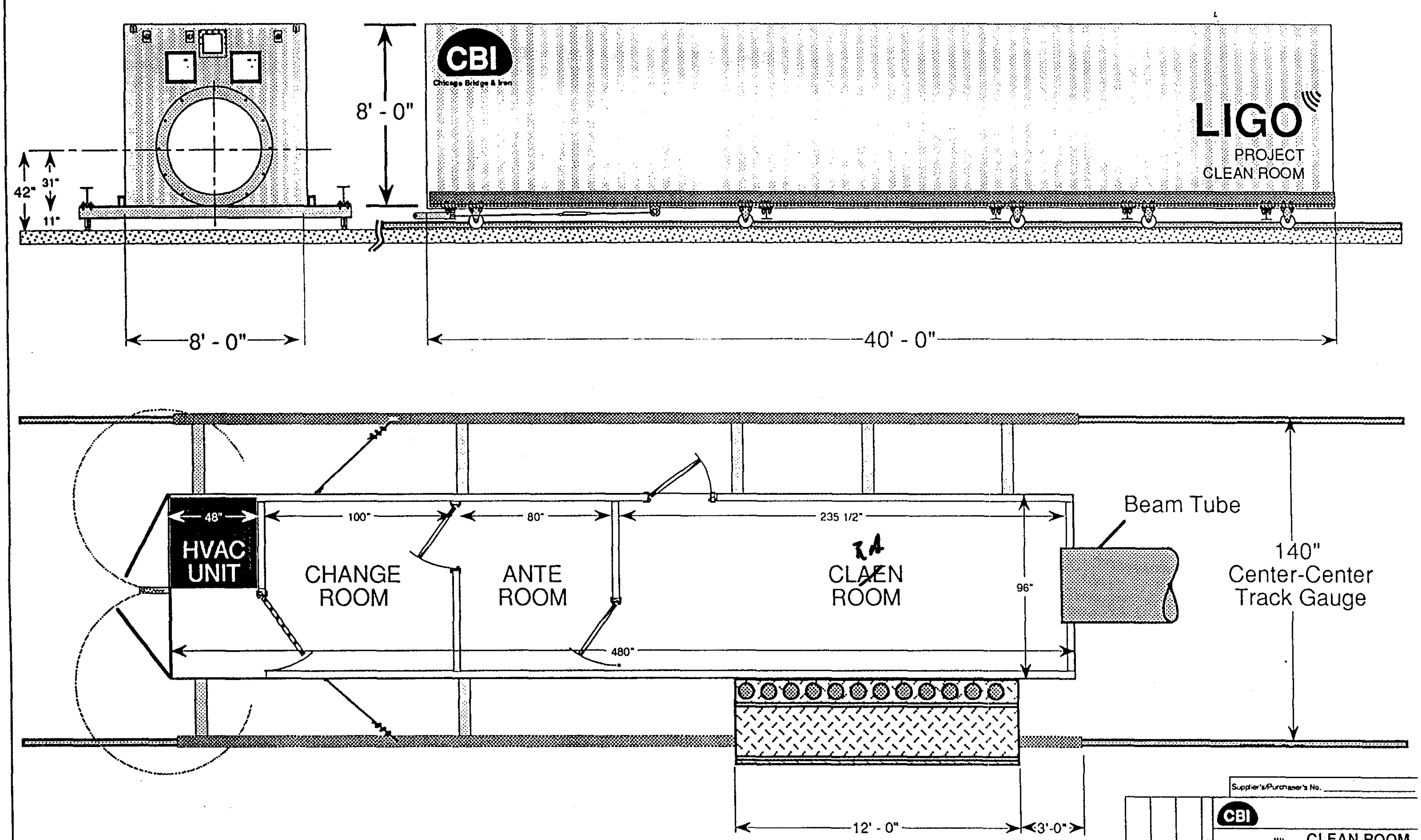
⑥ Install fixed and guided supports and remove tempoary supports.

⑦ Remove expansion joint restraints to free movement

⑧ Install temporary longitudinal brace

⑨ Remove temporary longitudinal bracing using temporary construction jacks to assist in transfer of load from temporary braces to permanent support..

SUBJECT	CBI	**OFFICE**	**REVISION:**		**REFERENCE NO.**
BEAM TUBE ERECTION SEQUENCE REQUIRED TO RESIST CONSTRUCTION EXPANSION JOINT LOADS ON FIXED SUPPORTS	**MADE** MRS	**CHK'D**	**MADE**	**CHK'D**	**SHT___OF___**
	DATE 4/22/94	**DATE**	**DATE**	**DATE**	



INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ______

CBI

LIGO

CLEAN ROOM GENERAL Views and Dimensions

Customer's No.

By ______ Chkd ______ Date ______

Engineering Supervisor

Contract No.

Dwg

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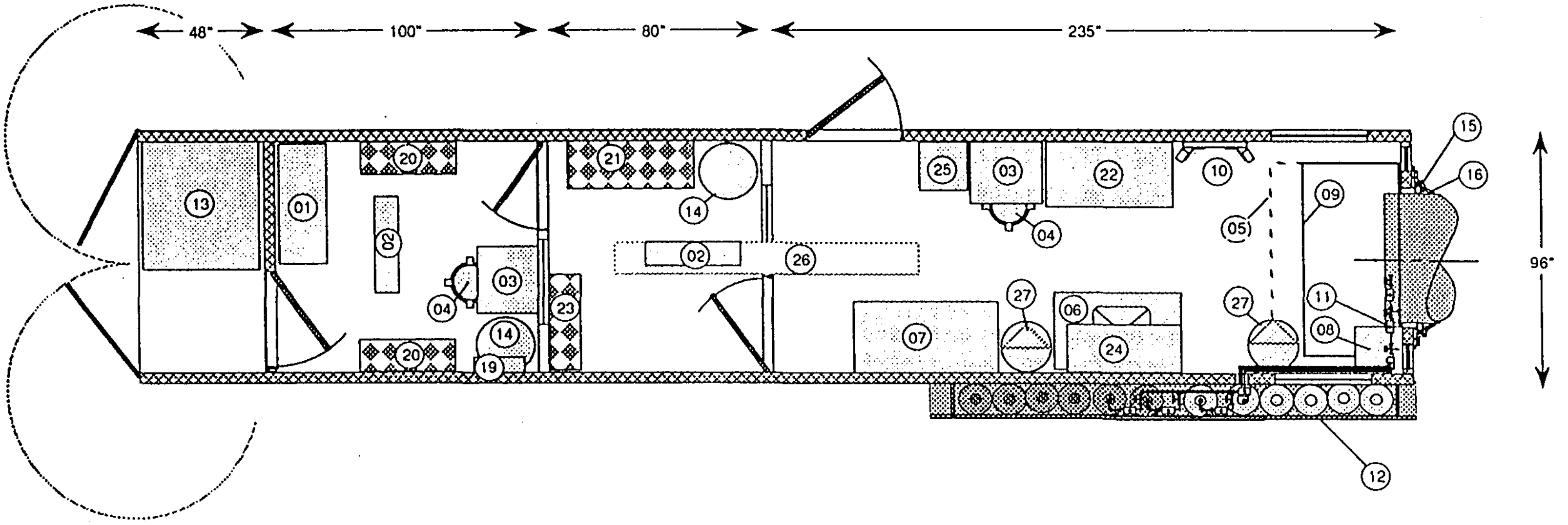

EQUIPMENT LISTING

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
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	Olly 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

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

Supplier's/Purchaser's No. ______

CBI

LIGO

CLEAN ROOM EQUIPMENT PLAN VIEW

Customer's No

By ______ Chkd ______ Date ______

Engineering Supervisor

Contract No

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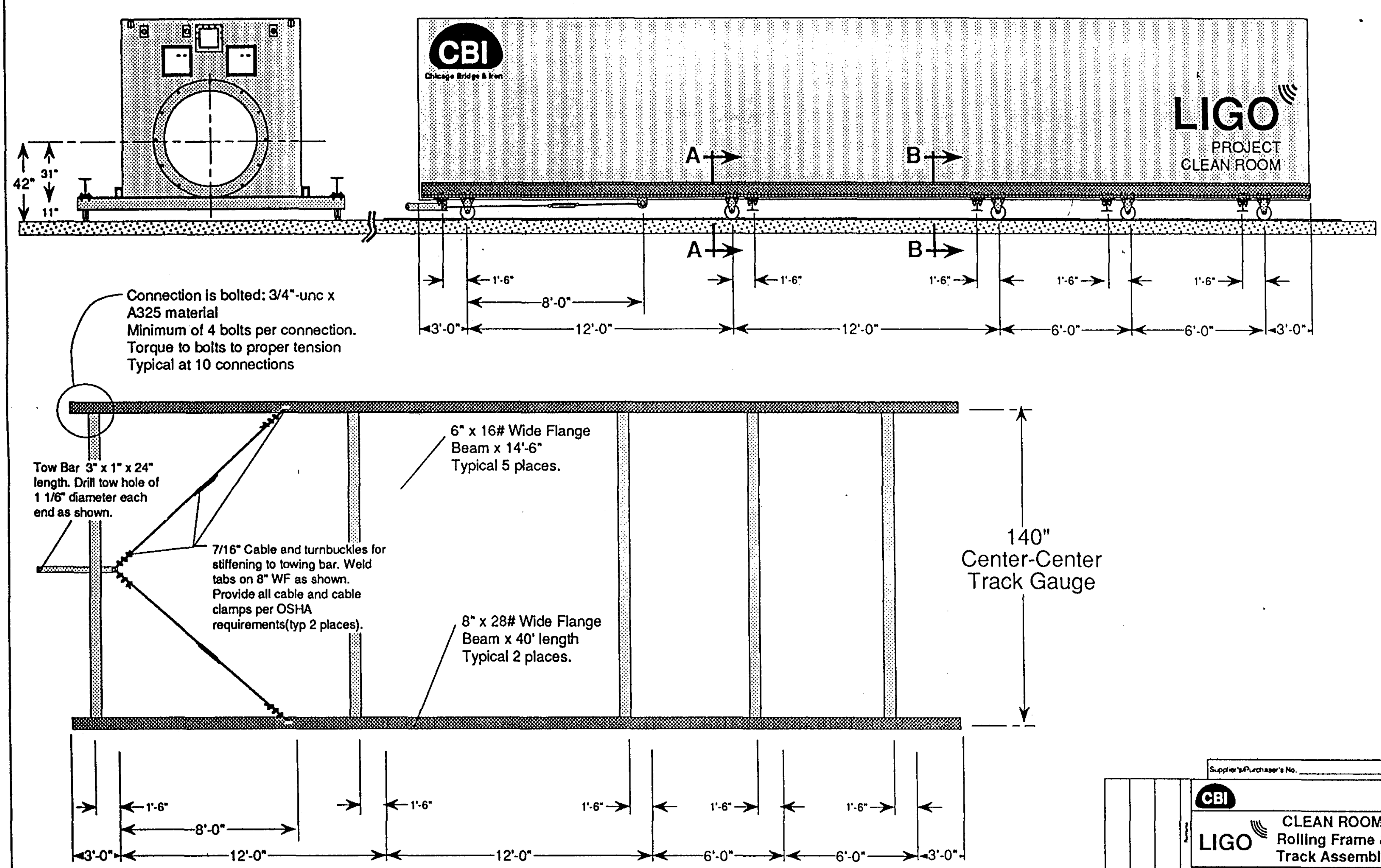

Connection is bolted: 3/4"-unc x
A325 material
Minimum of 4 bolts per connection.
Torque to bolts to proper tension
Typical at 10 connections

Tow Bar 3" x 1" x 24" length. Drill tow hole of 1 1/6" diameter each end as shown.

6" x 16# Wide Flange
Beam x 14'-6"
Typical 5 places.

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.

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Supplier's/Purchaser's No. ____________

CBI

LIGO

CLEAN ROOM
Rolling Frame &
Track Assembly

Customer's No.
By ______ Chkd ______ Date ________
Engineering Supervisor

Contract No.
Dwg.
Sheet

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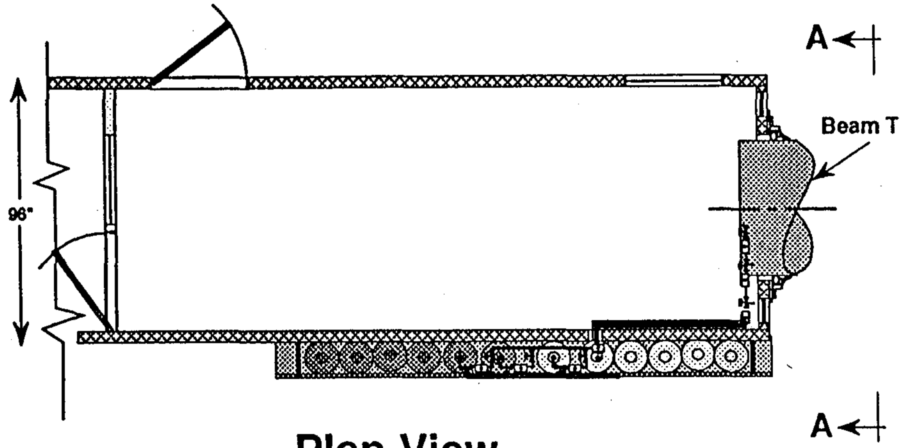
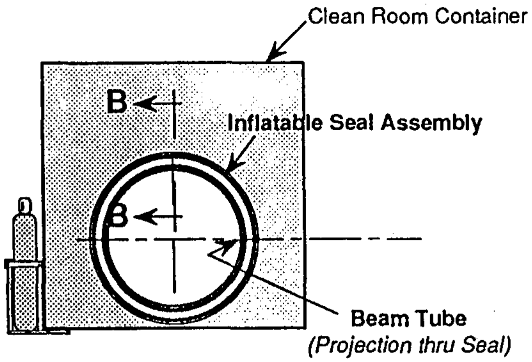
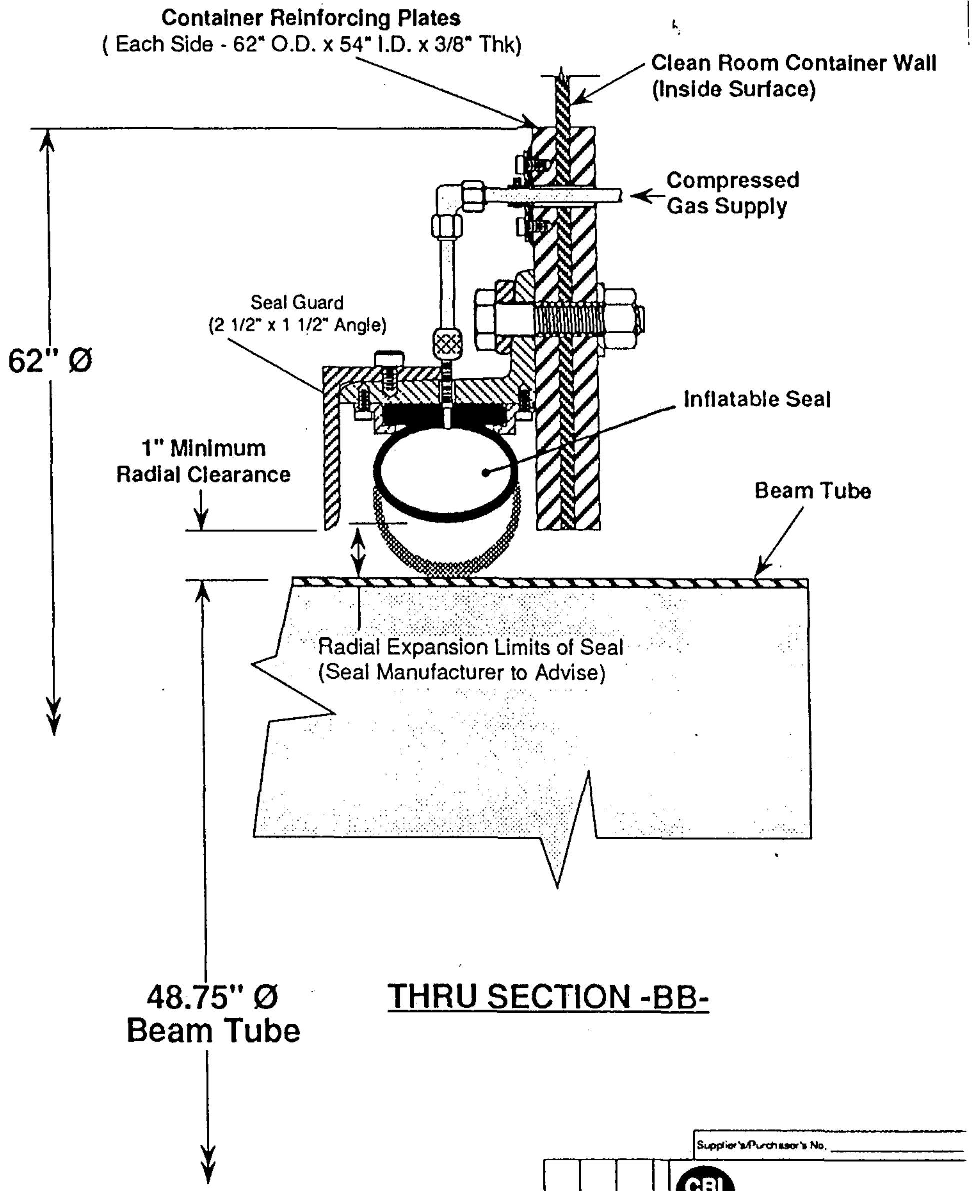


Plan View

Section of Clean Room



END VIEW -AA-



THRU SECTION -BB-

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Supplier's/Purchaser's No. ______

CBI

LIGO

CLEAN ROOM
Inflatable Seal
Detail

Customer's No.

Contract No.

By ______ Chkd ______ Date ______

Engineering Supervisor

Dwg CRS-5-ISS

Sheet Sht 1 of 2

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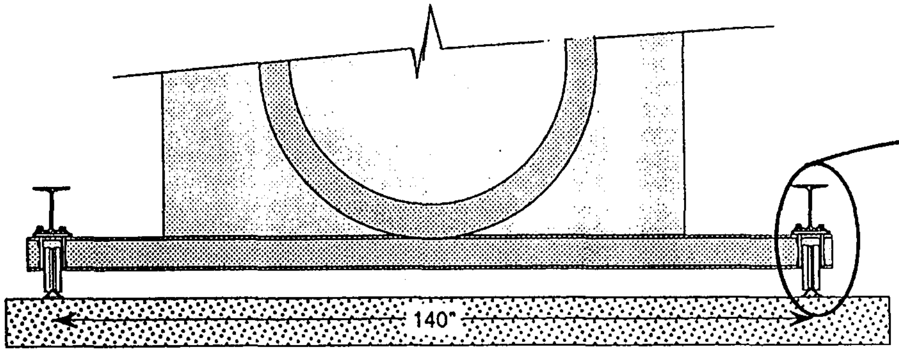
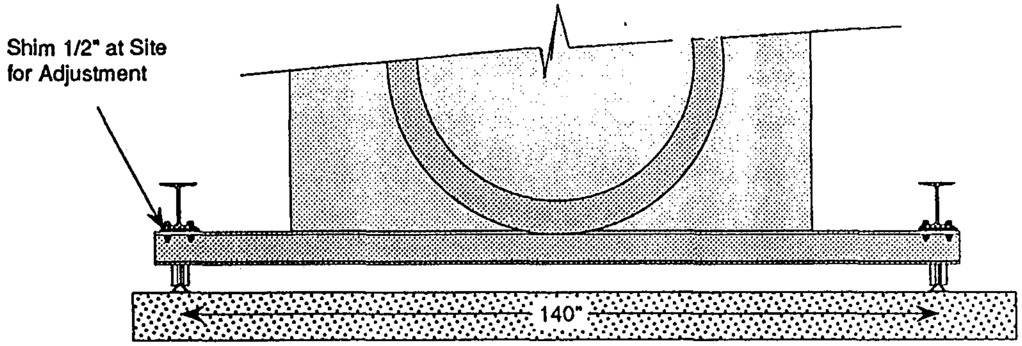
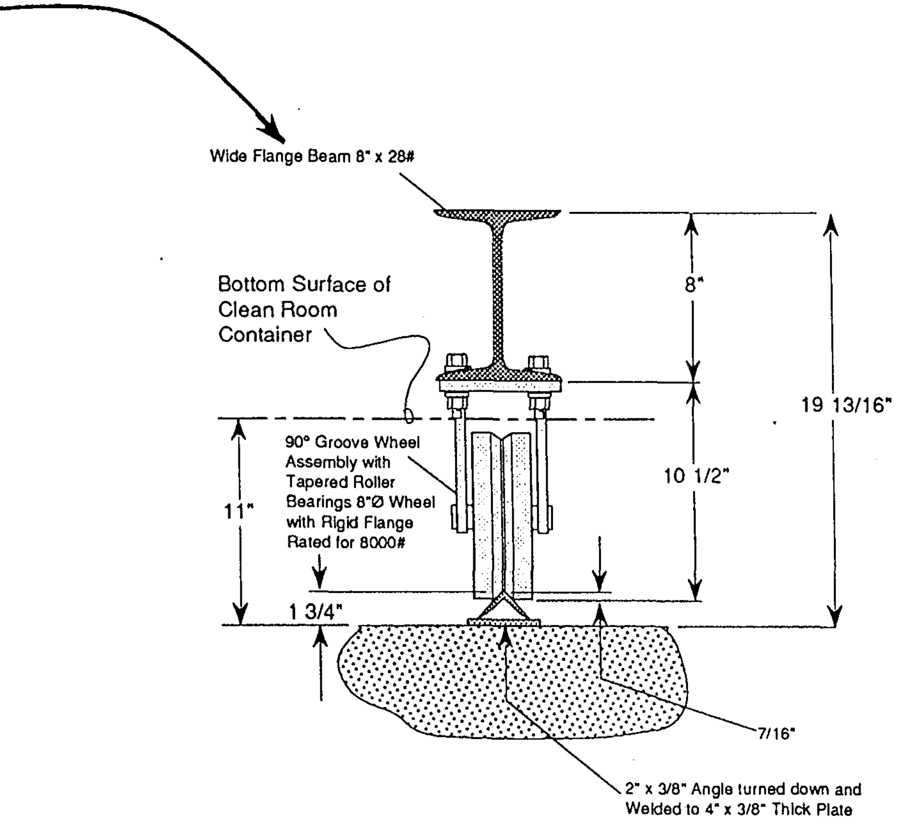


Sectional View -AA-



Sectional View -BB-



Supplier's/Purchaser's No. ____

CBI

LIGO

CLEAN ROOM
Rolling Frame &
Track Assembly

Customer's No
Contract No
By ____ Chkd ____ Date ____
Engineering Supervisor
Dwg
Sheet

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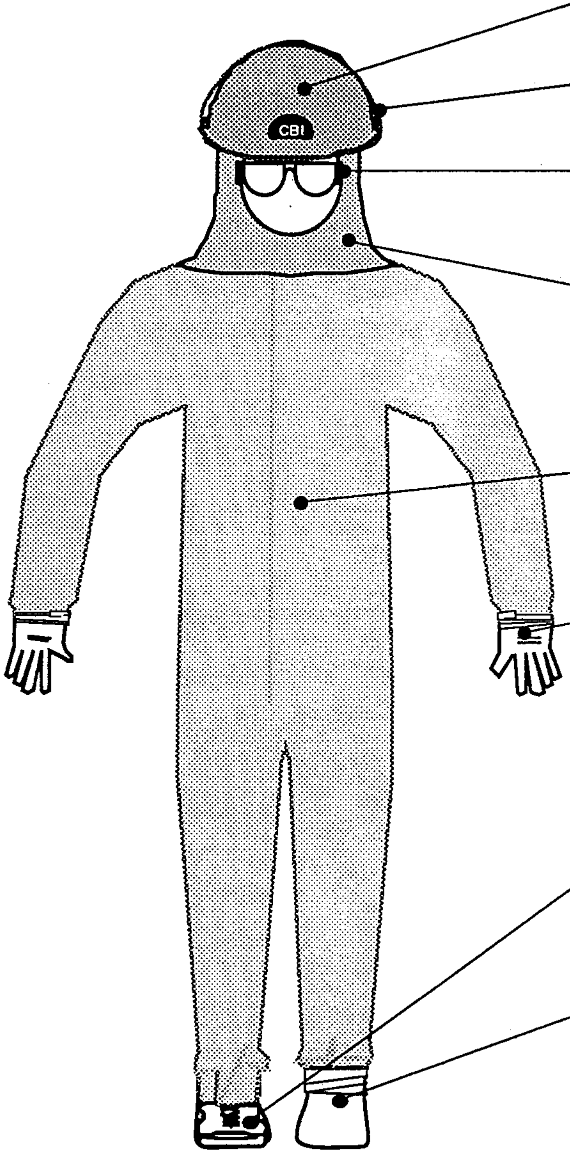


CBI Hard Hat
Shall Meet CBI Safety Standards

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

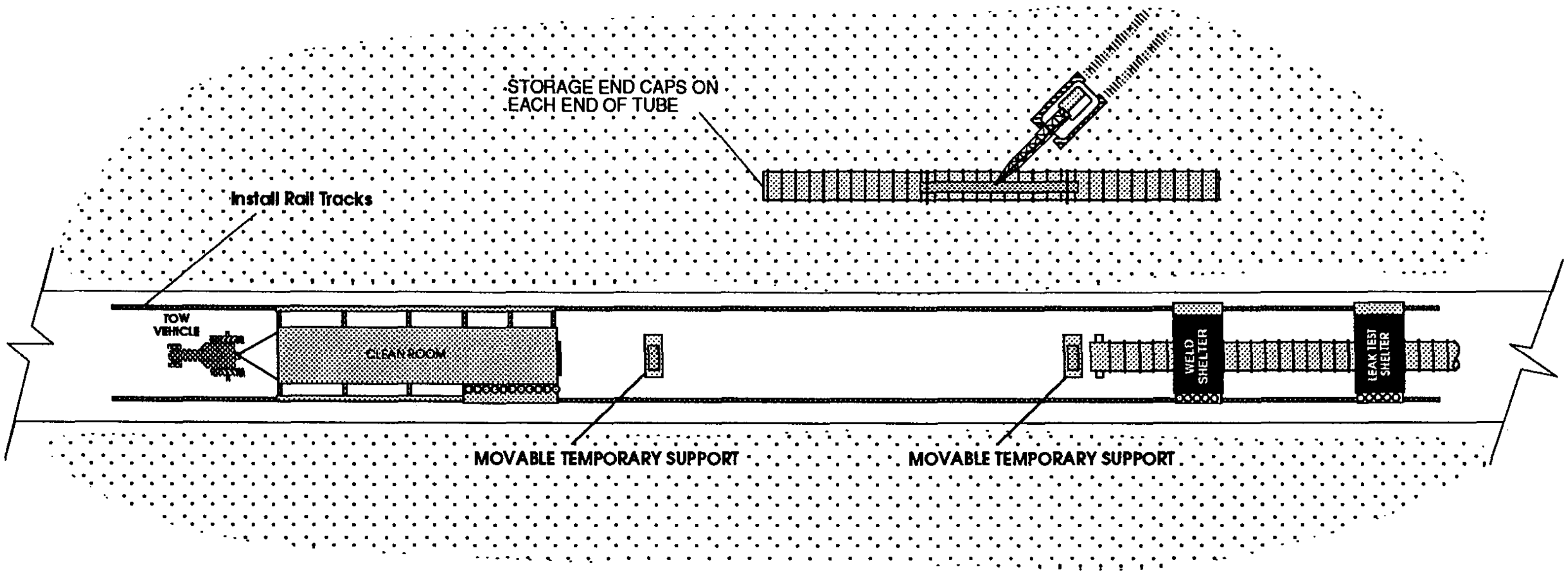
Washable Clean Room Rated Coveralls
Rated For Class 100 Clean Room Applications Zipper Front With Gripper Adjustments On Sleeves, Collar And Pant Legs. Pockets shall be removed or sewn closed.

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

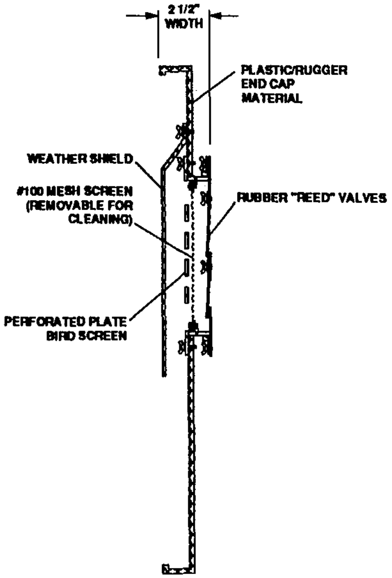
Disposable White Shoe Covers
Shoe Covers Shall Be Secured To Coverall Pant Leg Using Coverall Gripper Adjustment And White Cloth Tape

FIGURE 4.1

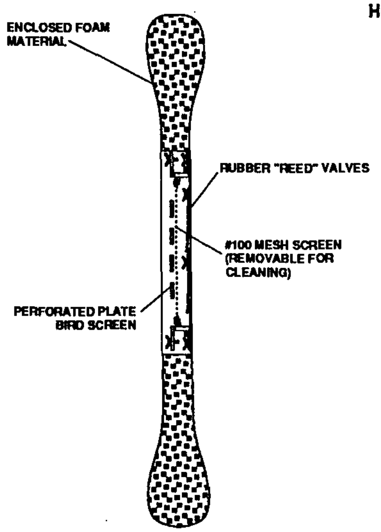


PREPARATION FOR FIT-UP OF BEAM TUBE SECTION

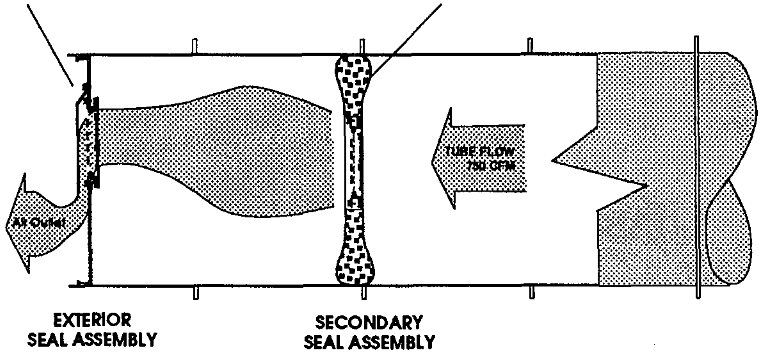
FRAME 1



EXTERIOR SEAL ASSEMBLY



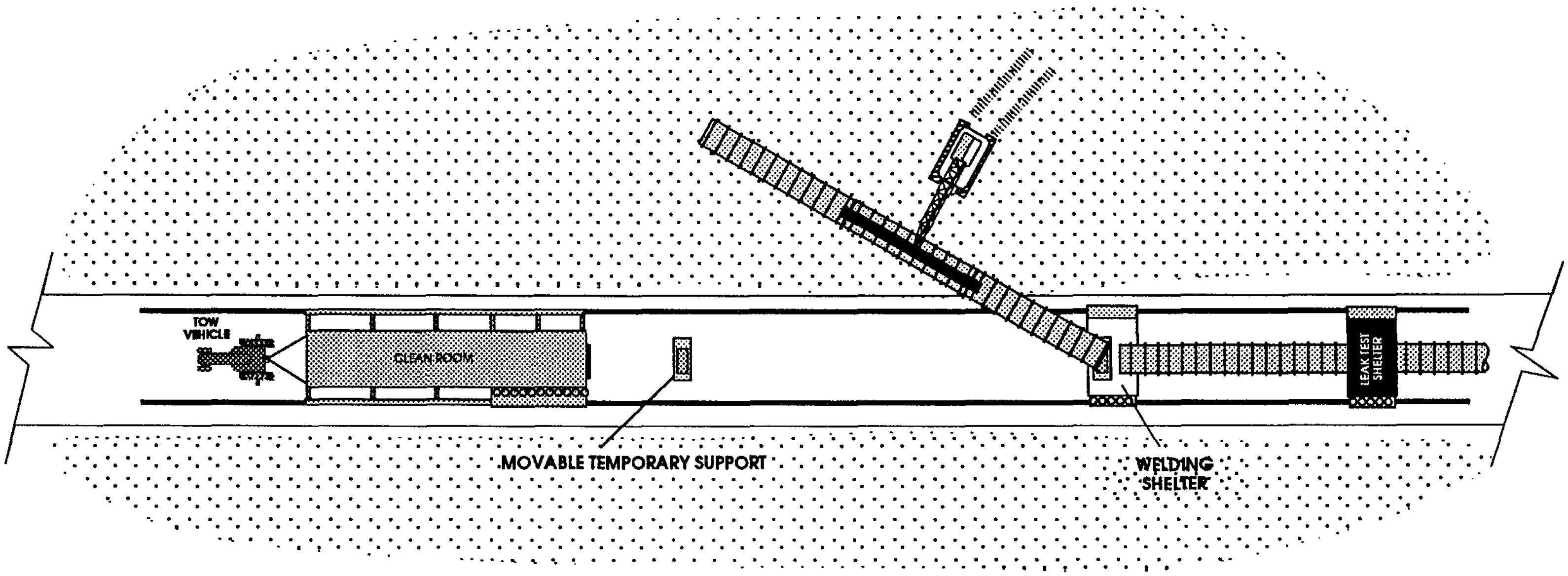
SECONDARY SEAL ASSEMBLY



PLASTIC SEAL IS INSTALLED IN CLEAN ROOM AND REMOVED UNDER COVER OF WELD HOOD

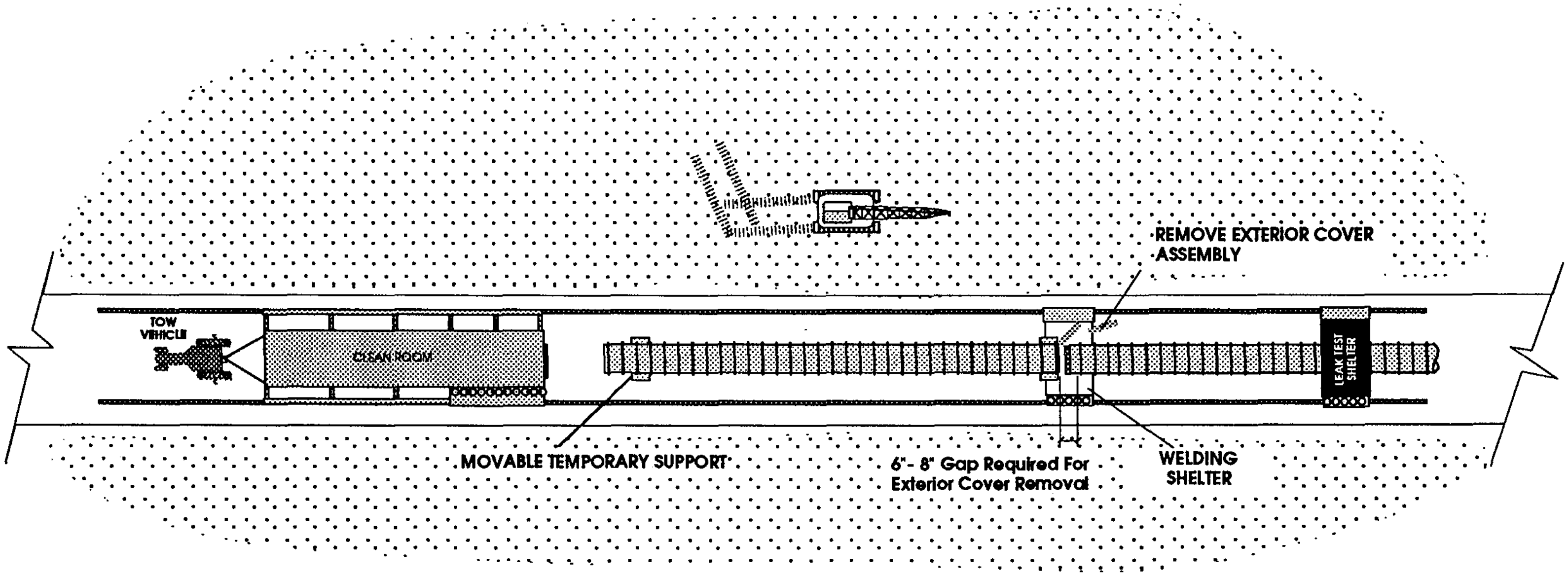
FOAM SEAL ASSEMBLY IS INSTALLED IN CLEAN ROOM BEFORE INSTALLATION OF PLASTIC SEAL. THIS SEAL REMAINS IN PLACE UNTIL COMPLETED VACUUM TESING

SEAL ASSEMBLIES USED DURING CONSTRUCTION



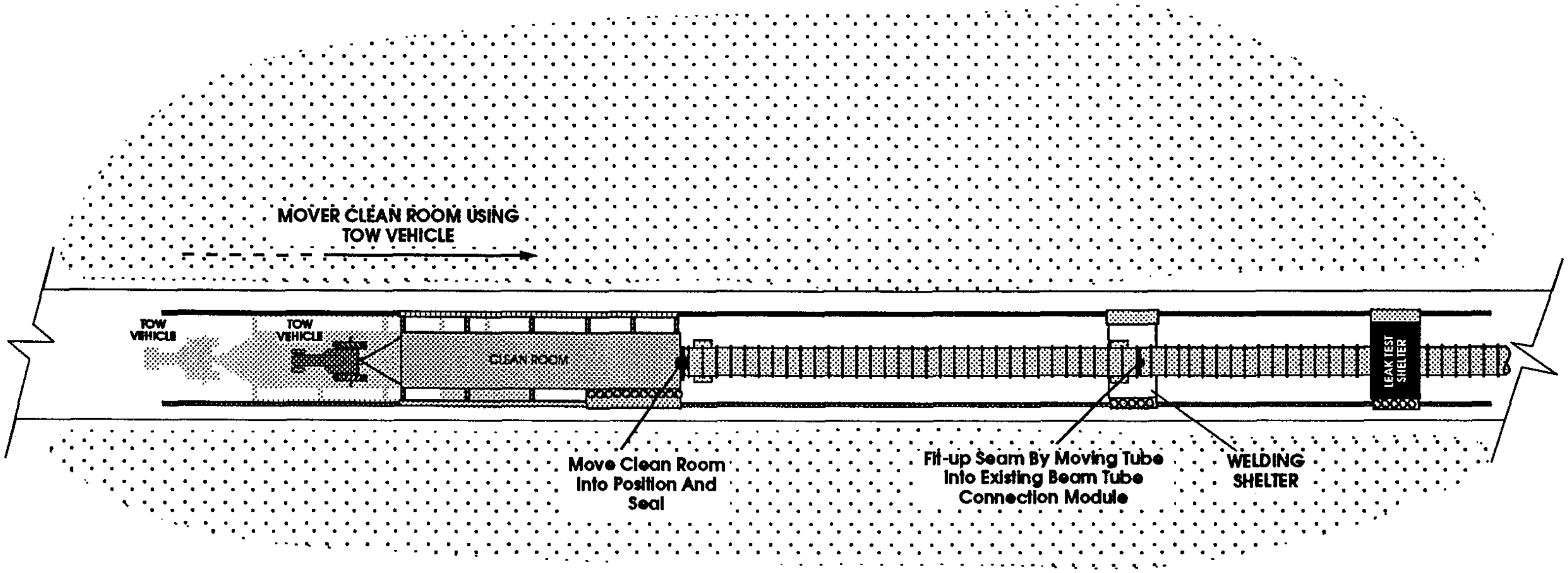
RIGGING AND INSTALLATION OF BEAM TUBE
(WELD HOOD MOVED INTO POSIITION, ROOF NOT SHOWN FOR CLARITY)

FRAME 2



BEAM TUBE IN PLACE ON MOVABLE SUPPORTS

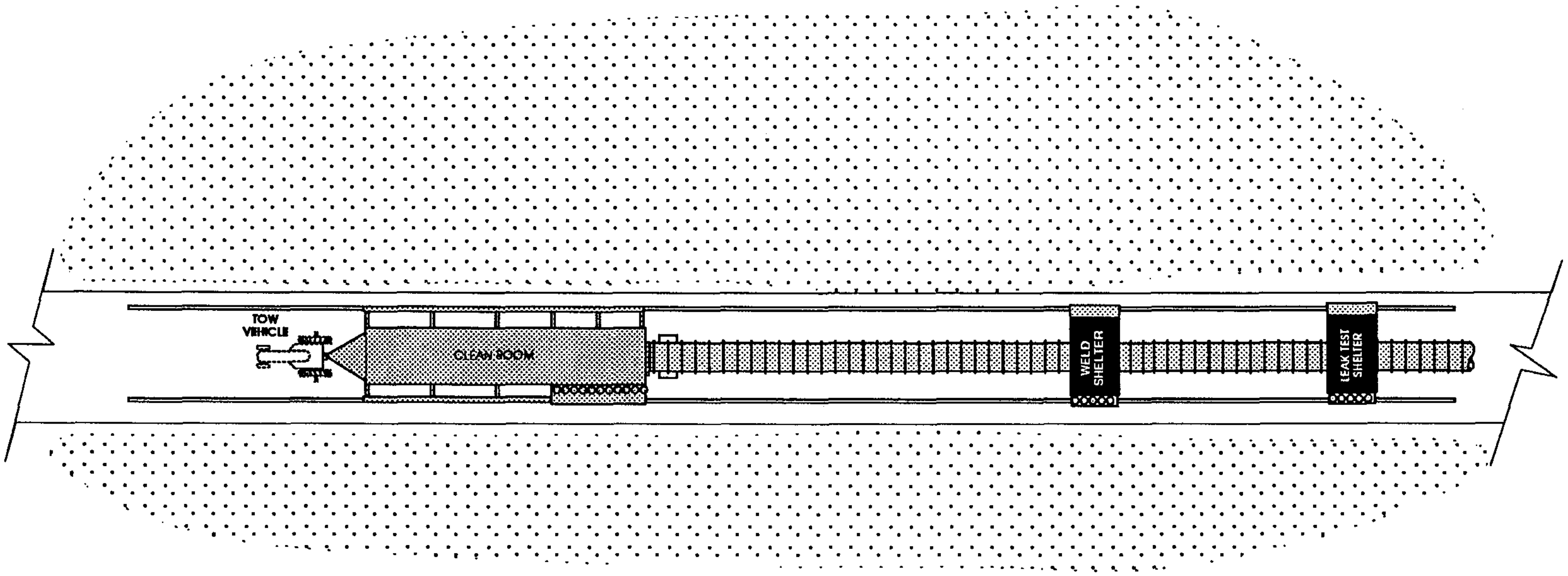
GAP BETWEEN TUBES TO REMOVE COVER ASSEMBLIES



CONNECTION OF CLEAN ROOM AND FIT-UP OF SEAM

CLEAN ROOM MOVED INTO POSITION AND SEAL INFLATED

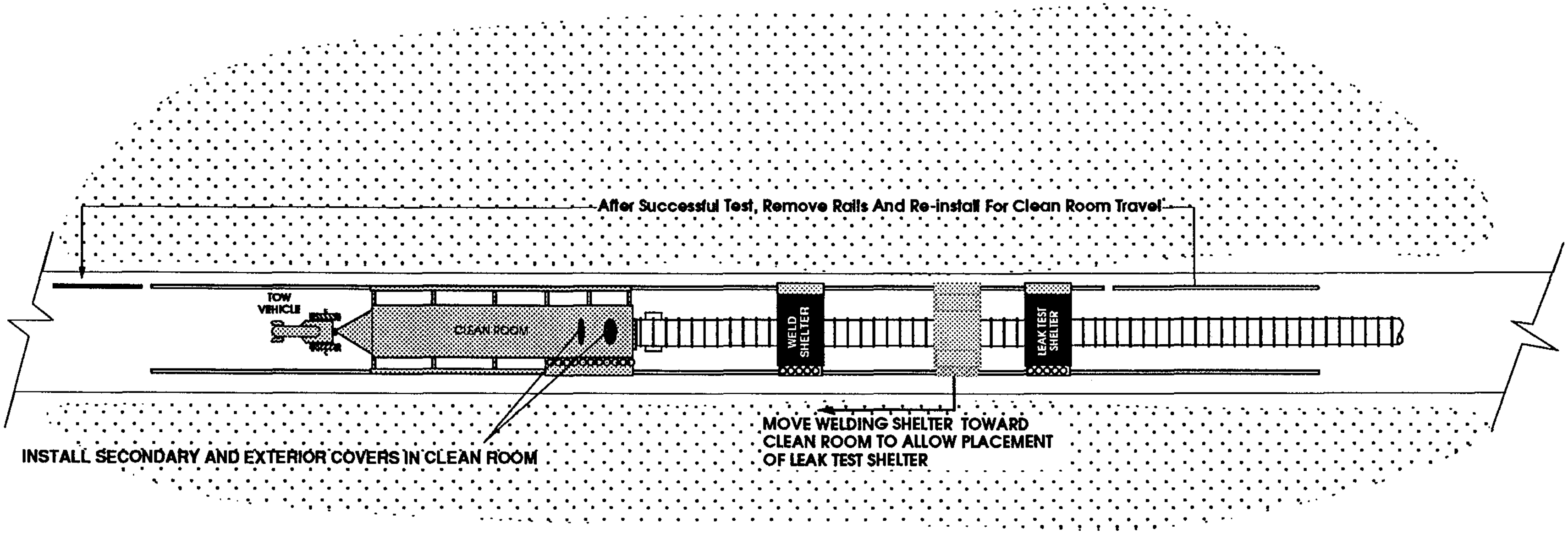
CHICAGO BRIDGE & IRON



WELDING OF SEAM

FRAME 5

CHICAGO BRIDGE & IRON



After Successful Test, Remove Rails And Re-install For Clean Room Travel

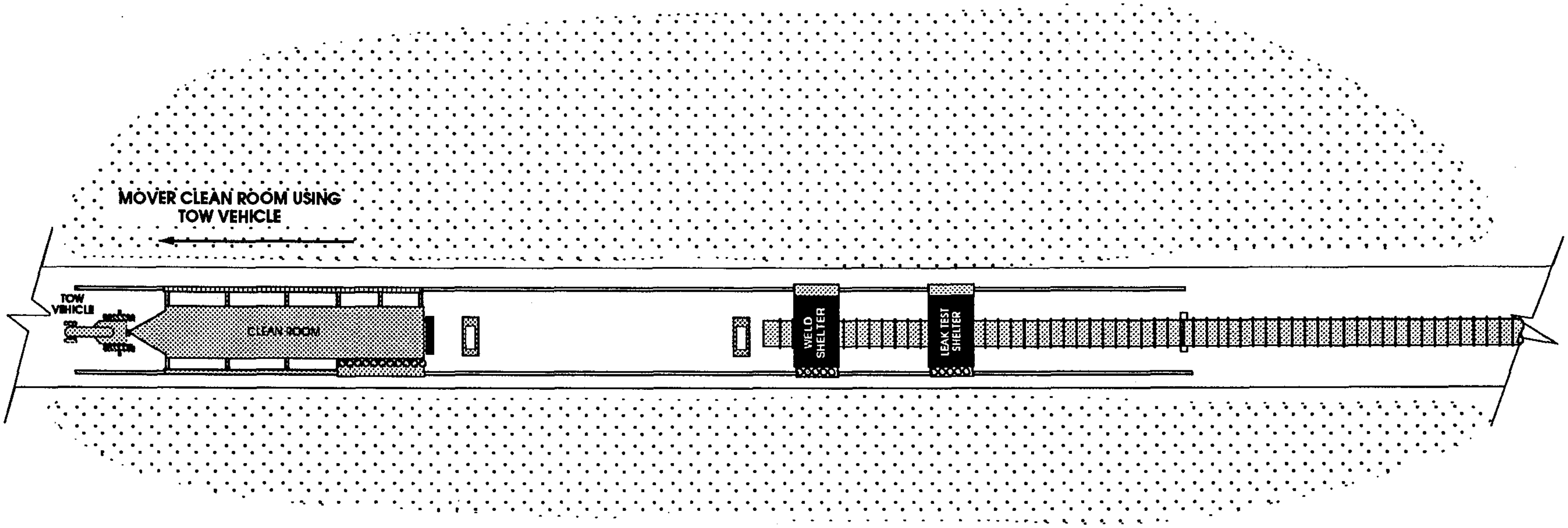
INSTALL SECONDARY AND EXTERIOR COVERS IN CLEAN ROOM

MOVE WELDING SHELTER TOWARD
CLEAN ROOM TO ALLOW PLACEMENT
OF LEAK TEST SHELTER

TESTING OF SEAM

MOVE WELD HOOD TOWARD CLEAN ROOM AND ROLL TEST HOOD OVER TUBE

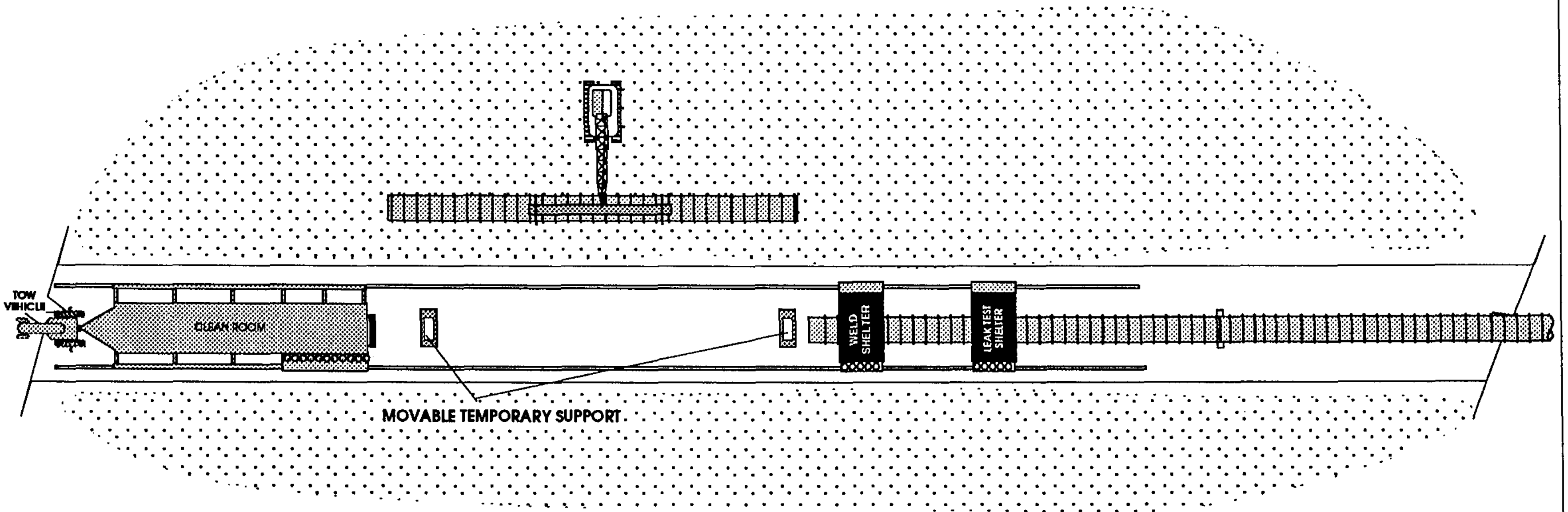
FRAME 6



SET-UP FOR NEW BEAM TUBE INSTALLATION

MOVE WELD HOOD TOWARD CLEAN ROOM AND ROLL TEST HOOD OVER TUBE

FRAME 8



PREPARATION FOR FIT-UP OF NEXT BEAM TUBE SECTION

FRAME 9

ALIGNMENT

REQUIREMENTS:

a. Align the beam tube to ensure that no part of the beam tube will intrude into the 1.07 meter minimum clear aperture.

b. During the construction process align each beam tube section to a level of accuracy that permits final alignment within the construction adjustment allowance for the supports.

c. Final align the beam tube module after construction to the final alignment that ensures the beam tube (including the baffles) will not intrude into the 1.07 meter clear aperture. This alignment uses only the adjustment allowance allotted for construction.

d. Prepare and install a system for operational alignment of the beam tube. This system will provide the means to periodically monitor and adjust the alignment of the beam tube. The system will provide a support adjustment range of +/- 7.5 cm in both the vertical and horizontal directions.

e. Provide the most accurate and reasonably priced alignment system that minimizes the beam tube diameter.

ALIGNMENT

CRITICAL PARAMETERS:

Thought that this had been changed

a. Establishment of the 1.07 meter clear aperture between the monuments spaced at 250 meters provided by Caltech.

b. Determination of the beam tube centerline at the baffle locations using an external alignment measuring system.

c. Confirm by calculation and/or measurement the critical dimensions of beam tube parts that cannot be checked during the final alignment of the beam tube.

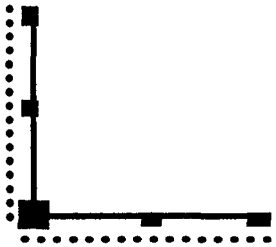
d. Develop the most cost effective method to accomplish the initial and operational alignments that meet the specified requirements.

CHICAGO BRIDGE & IRON

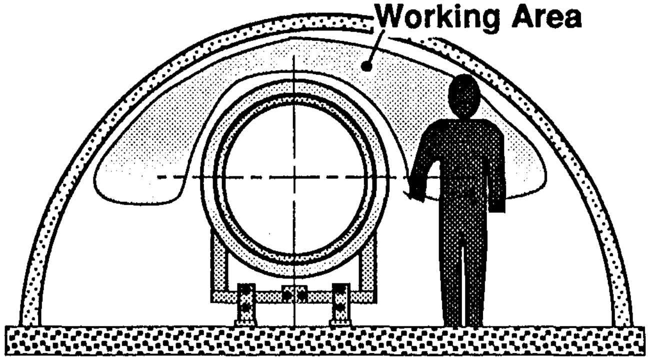
LIGO ALIGNMENT REQUIREMENTS

Approx. 25 mmØ
(1.00 inch)

POSITIONING TOLERANCE = ± 0.0127 me~~n~~ters(0.500 inch)



OVERALL DISTANCE = 250 meters (Distance To Reference Monuments)



AREA FOR ALIGNMENT ACTIVITY = Average of 0.5 meters

LIGO ALIGNMENT METHODS

Standard Surveying Techniques

Positives:

- Standard Equipment And Techniques Available
- Known Accuracies And Confidence Levels
- Low Technical Training Requirements

Negatives:

- Accuracies Over Long Distances Limited
- Effects Of Surface Temperatures On Straightness Of Light
- High Maintenance And Calibration Costs
- Manpower Requirements For Two Or More Technicians
- Minimum Of 250 M Monuments And Reference Points Required

Optical Tooling And Alignment Lasers

Positives:

- High Degree Of Accuracy
- Proven Techniques And Confidence Levels
- Equipment Availability
- Maintenance Activity Requires Only One Or Two Technicans

Negatives:

- Accuracies Over Long Distances Limited
- Effects Of Surface Temperatures On Straightness Of Light
- High Maintenance And Calibration Costs
- Minimum Of 250 M Monuments And Reference Points Required

Global Positioning System (GPS)

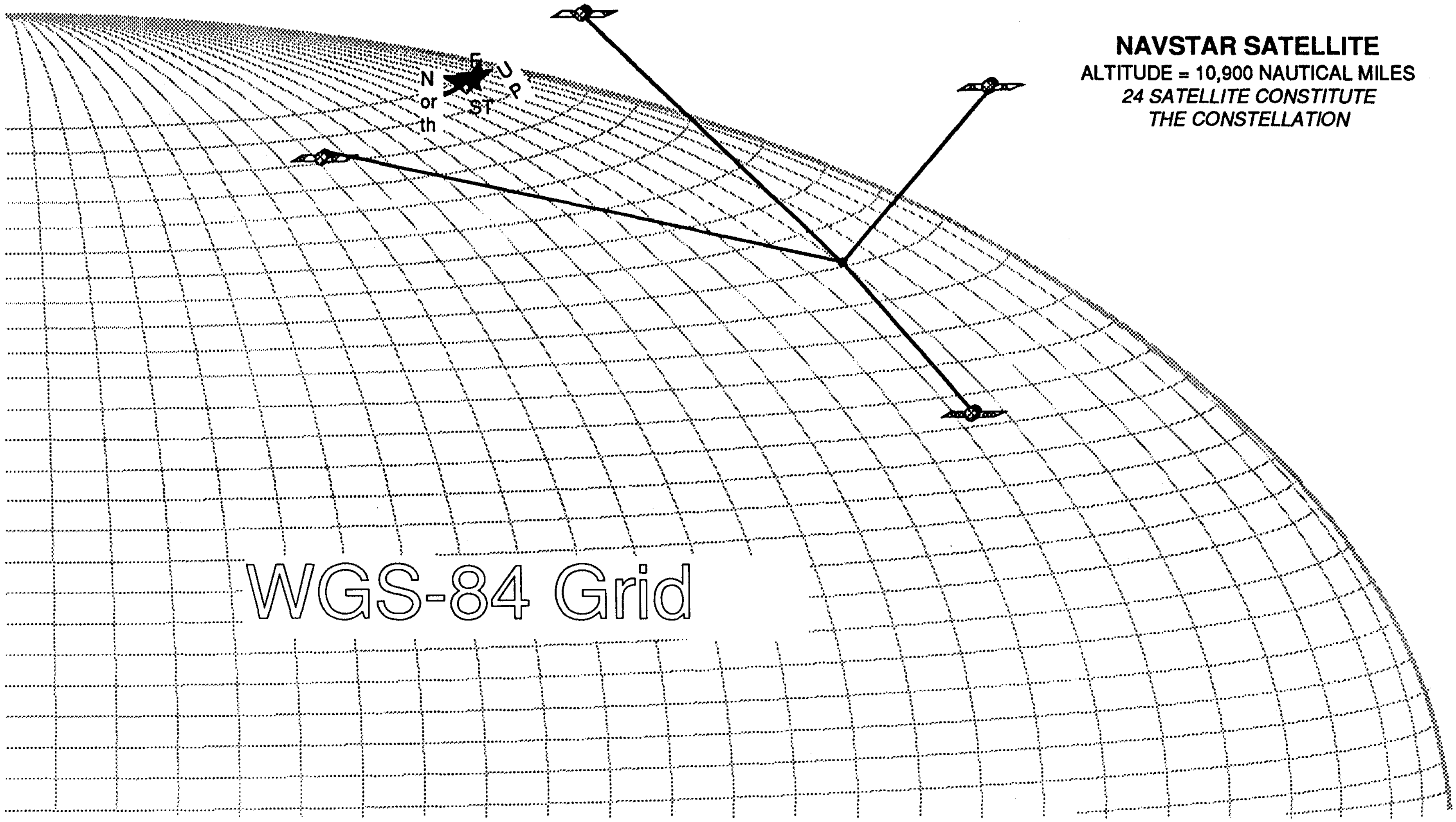
Positives:

- Adequate Accuracy Level
- → Accuracy Not Effected By Length Of Measurement
- Equipment Availability And Technical Advancements
- Minumum Calibration And Maintenance Costs
- Maintenance Activity Requires Only One Technican
- Minimum Of Reference Monuments Required

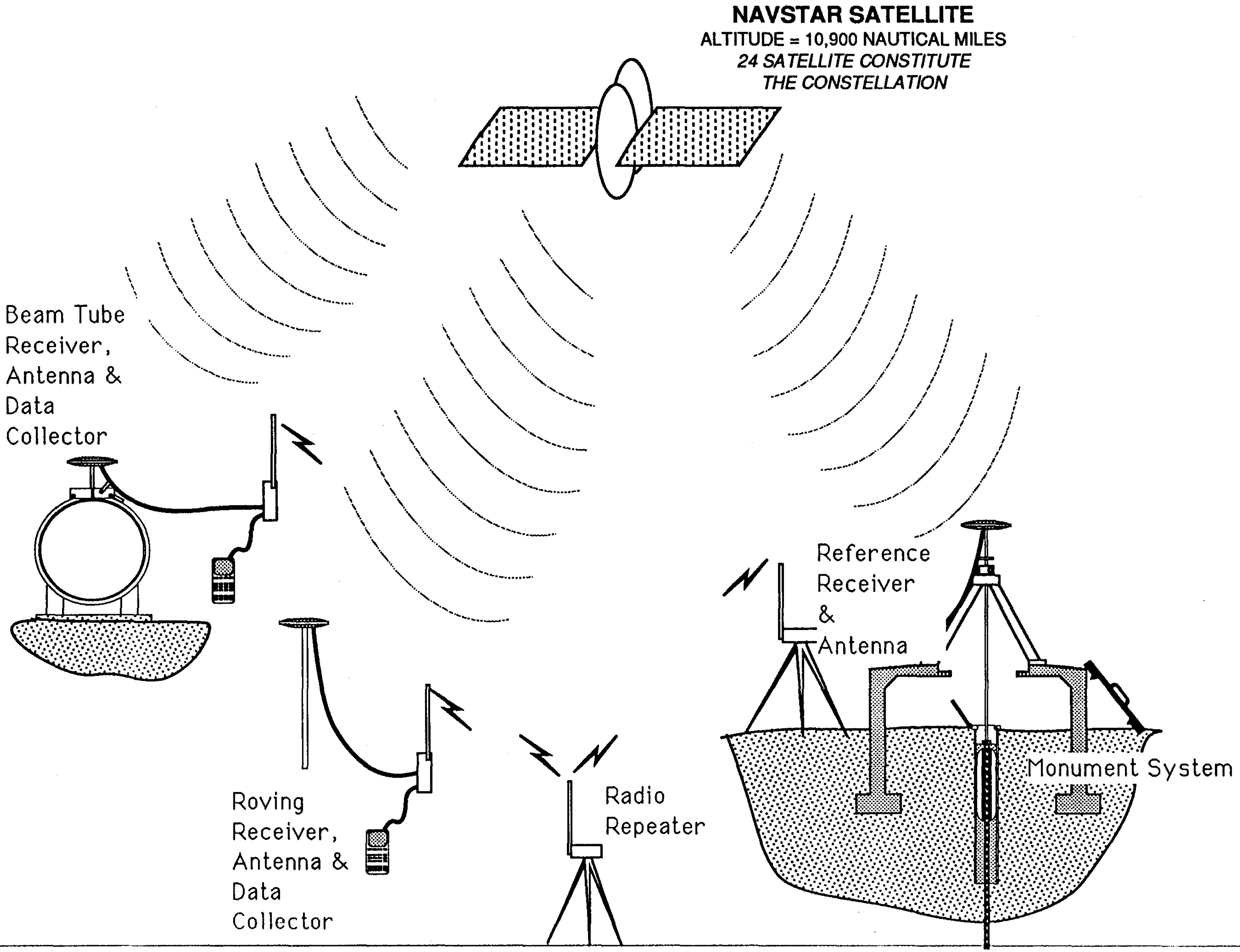
Negatives:

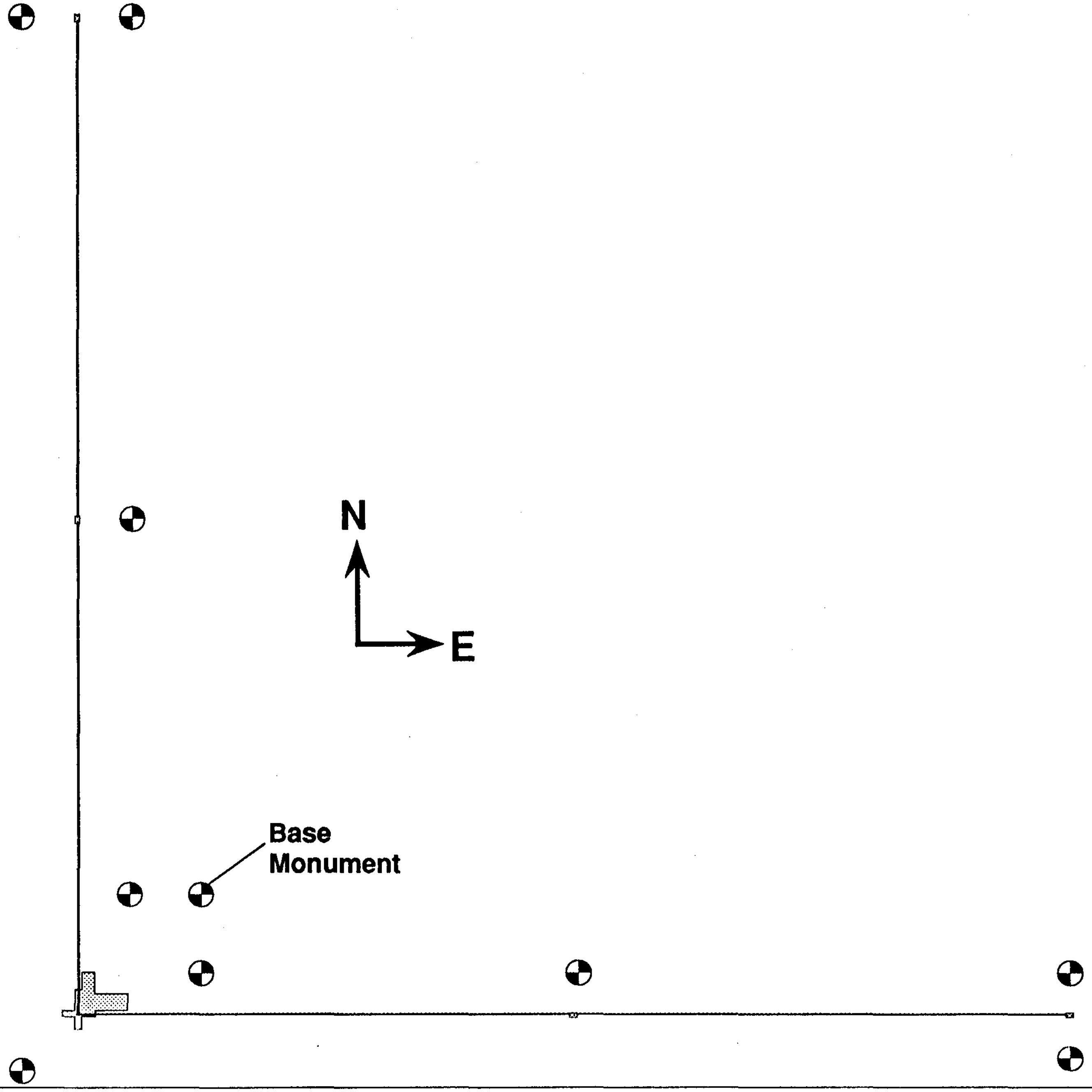
- New Technology With Limited Confidence Levels
- Access To Horizon For Satellite Communication
- Initial Costs Of Equipment And Training

LIGO ALIGNMENT - GPS



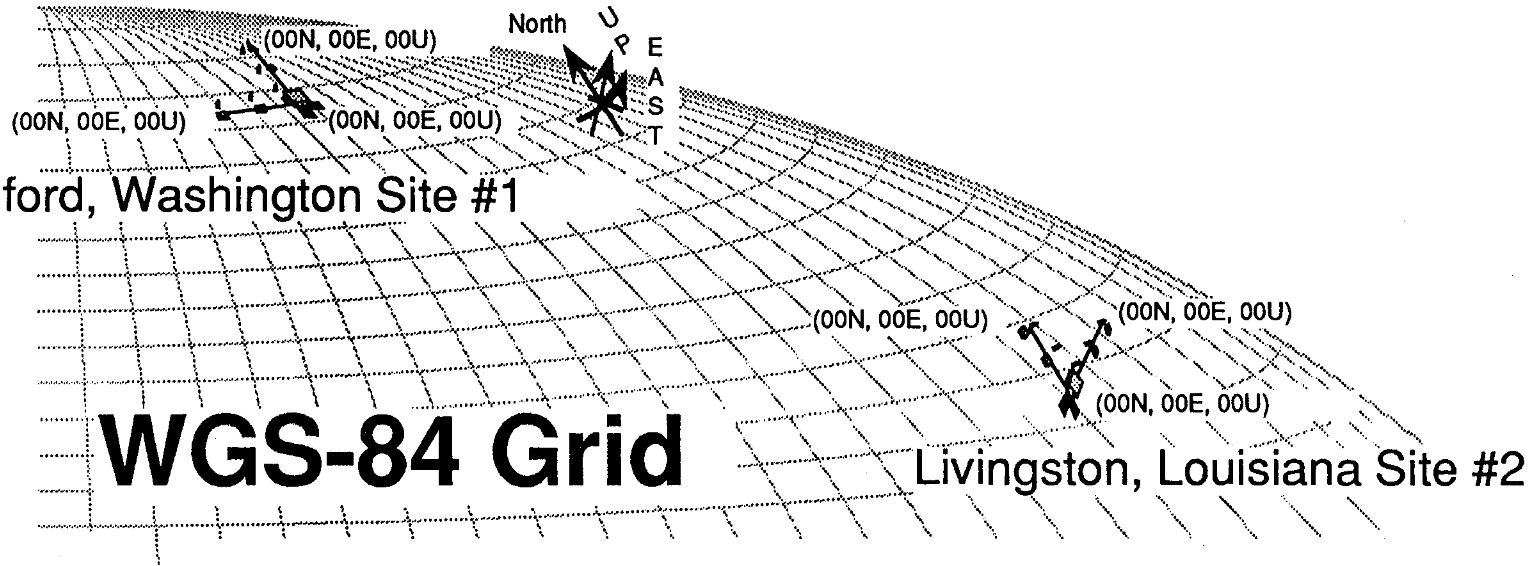
NAVSTAR SATELLITE
ALTITUDE = 10,900 NAUTICAL MILES
24 SATELLITE CONSTITUTE
THE CONSTELLATION


NAVSTAR SATELLITE
ALTITUDE = 10,900 NAUTICAL MILES
24 SATELLITE CONSTITUTE
THE CONSTELLATION
Beam Tube Receiver, Antenna & Data Collector
Reference Receiver & Antenna
Monument System
Roving Receiver, Antenna & Data Collector
Radio Repeater


N
E
Base
Monument

CHICAGO BRIDGE & IRON

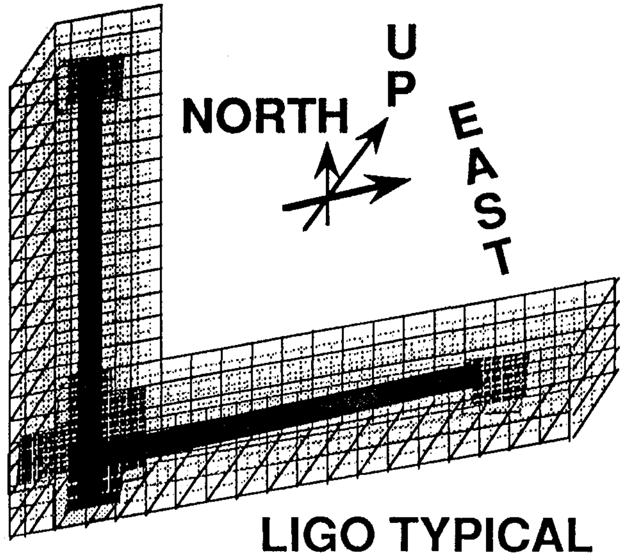
LIGO ALIGNMENT - GPS



Hanford, Washington Site #1

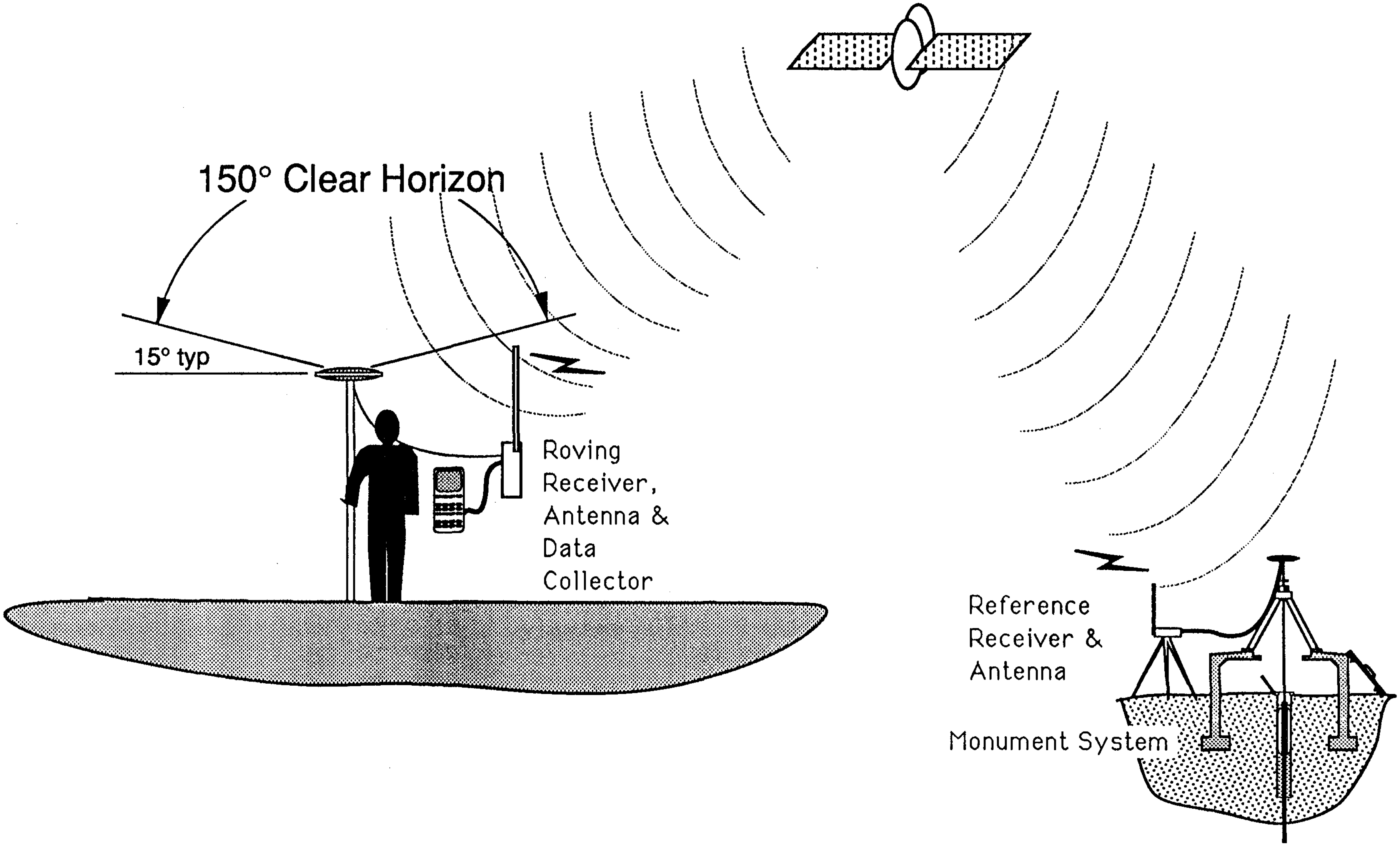
WGS-84 Grid

Livingston, Louisiana Site #2

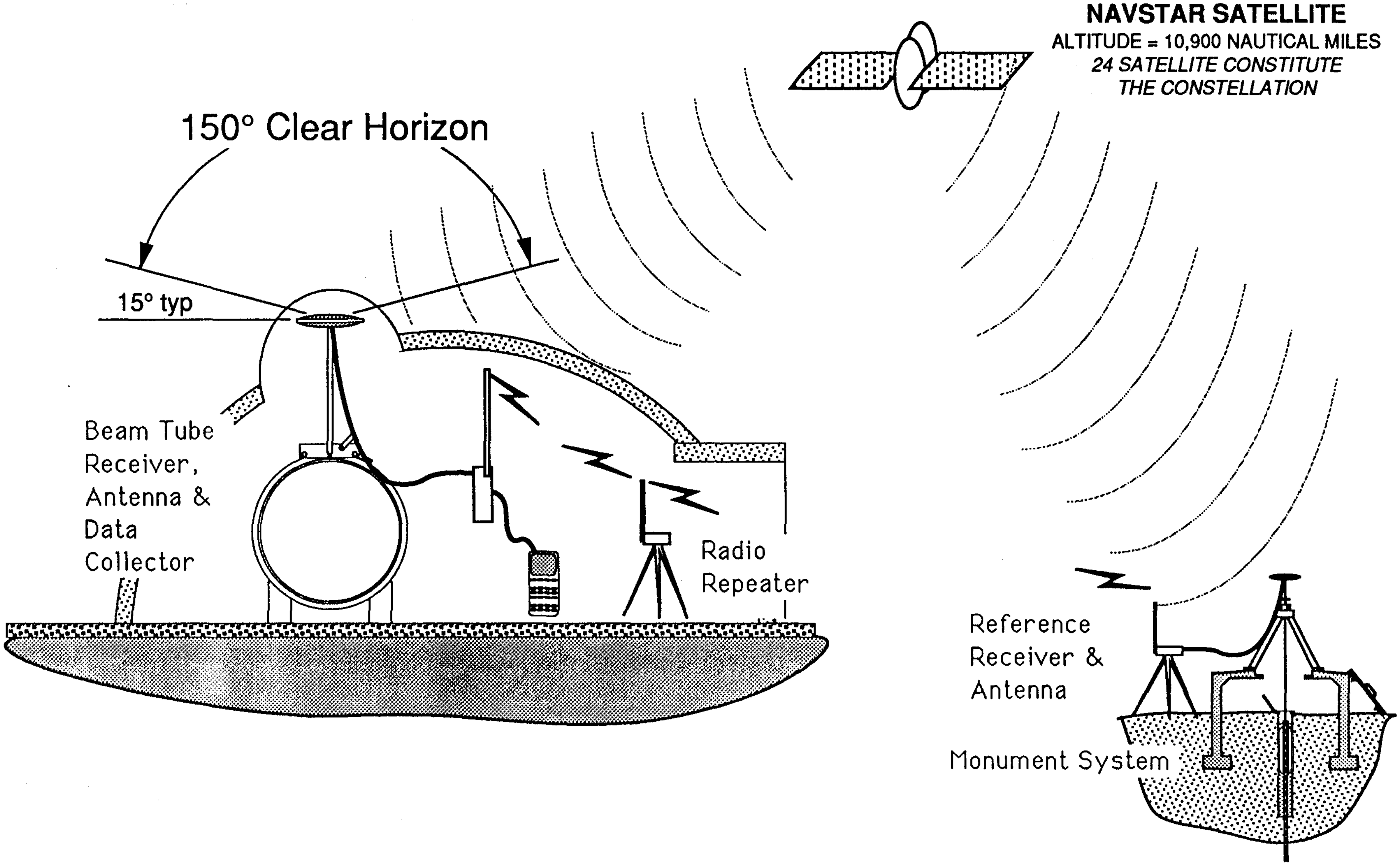


LIGO TYPICAL
COORDIANTE SYSTEM

GPS ALIGNMENT TECHNIQUES



GPS ALIGNMENT TECHNIQUES



NAVSTAR SATELLITE
ALTITUDE = 10,900 NAUTICAL MILES
24 SATELLITE CONSTITUTE THE CONSTELLATION

150° Clear Horizon

15° typ

Beam Tube Receiver, Antenna & Data Collector

Radio Repeater

Reference Receiver & Antenna

Monument System

CLEANING

1. CRITICAL PARAMETERS

a. Effective execution and control of the cleaning process.
b. Safe handling and disposal of cleaning solvents and liquids.
c. Automated process execution with limited spot and hand cleaning to minimize cost. (Strictly controlled by limited entry into the clean room controlled environment)
d. Limit contamination after "final" cleaning to limit rework and degrade cleanliness.
e. Effective final inspection.

2. SPECIFICATION REQUIREMENTS

a. Before leak testing can sections, only solvent wipe them to remove all visible contaminants.
b. Cleaning of can sections after fabrication (which includes leak testing) to be in accordance with the Caltech specified "steam" cleaning process with Oakite 33 (a mild phosphoric acid solution) which consists of the following steps.

- Remove hydrocarbons with a solvent wipe.
- Spray rinse with hot water at 60°C (140°F).
- Spray at 60°C (140°F) with a 2% by volume Oakite 33 in water cleaning solution (or equivalent).
- Hold for five (5) minutes.
- Spray at 60°C (140°F) with a 2% by volume Oakite 33 in water solution (or equal).
- Hold for five (5) minutes again.
- Spray rinse with hot water at 60°C (140°F) to remove all traces of Oakite 33 solution.

CLEANING

2. SPECIFICATION REQUIREMENTS (CONT'D)

c. Maintain cleanliness during installation and construction.
d. No visible contaminants in a beam tube module before evacuation of that module.

3. CLEANING PROCEDURE OPTIONS

a. Caltech specified cleaning process:
- Apparently effective procedure with known characteristics.
- Oakite 33 potentially environmentally hazardous.
- Disposal may be costly.

b. CBI steam cleaning and mild acidic passivation procedures:
- Successfully used on high vacuum facilities.
- Known to be effective in cleaning and iron freeing.
- Unknown effects on hydrogen outgassing characteristics.

4. CLEANING PROCEDURE DEVELOPMENT

a. Caltech specified cleaning process:
- CBI developed a draft cleaning procedure CL1N which conformed to the specified Oakite 33 cleaning process.
- CBI developed a coupon cleaning procedure CLCOUP for outgassing coupons. This procedure also conformed to the specified Oakite 33 cleaning process. In addition, it included a blacklight inspection after the initial solvent wipe.

CLEANING

4. CLEANING PROCEDURE DEVELOPMENT (CONT'D)

- This coupon cleaning procedure was used to compare a series of plain and welded coupons to determine comparative outgassing rates. In the process of using this procedure was decided to pursue alternate coupon cleaning procedures to compare with the Oakite 33 procedure to determine the best and most economical procedure. CBI also determined costs of handling and neutralizing to dispose of Oakite 33 solution.

b. CBI then developed several alternate cleaning procedure based on experience. At the suggestion of Caltech, each of these procedures included an identical oil (hydrocarbon) contamination section to put them on an even basis for comparing their cleaning capabilities. In addition to an outgassing analysis of the cleaned coupons, there would also be a surface analysis performed. These procedures were labeled as CLCOUPA for OAKITE, CLCOUPAO for steam and CLCOUPA1 for Mirachem 500.

c. CBI also determined the costs of executing these alternate processes.

d. As a result of the outgassing and surface analyses of the coupons cleaned by these alternate procedures, the decision was made to proceed with using the steam cleaning alternate to produce the procedure for cleaning of the beam tube can sections.

e. This can section steam cleaning procedure is identified as CL1N.

5. PLANNED APPROACH TO CLEANING:

The approach to cleaning is identified as procedure "LIGOCP". It contains a brief description of cleaning and cleaning maintenance procedures and additional requirements.

CLEANING

6. PURCHASED ITEMS:

- a. Baffles final cleaned by fabricator in controlled environment, bagged and sealed for shipment
- b. Preliminary cleaning and protection of tube and expansion joint by the manufacturer

7. PRECLEANING OF CAN SECTIONS AT SITE:

- a. Initial black light inspect per procedure VT1
- b. Alcohol or acetone solvent wipe down to remove hydrocarbons per procedure CL1N
- c. Pre-clean can sections with the solvent wipe after attaching stiffeners and the expansion joint, when applicable, but before leak testing.

8. FINAL CLEANING OF COMPLETED AND TESTED CAN SECTIONS:

- a. Steam clean using potable tap water (softened as necessary) in accordance with CLIN.
- b. Seal tubes after cleaning in a security controlled clean room area

9. CLEANING MAINTENANCE:

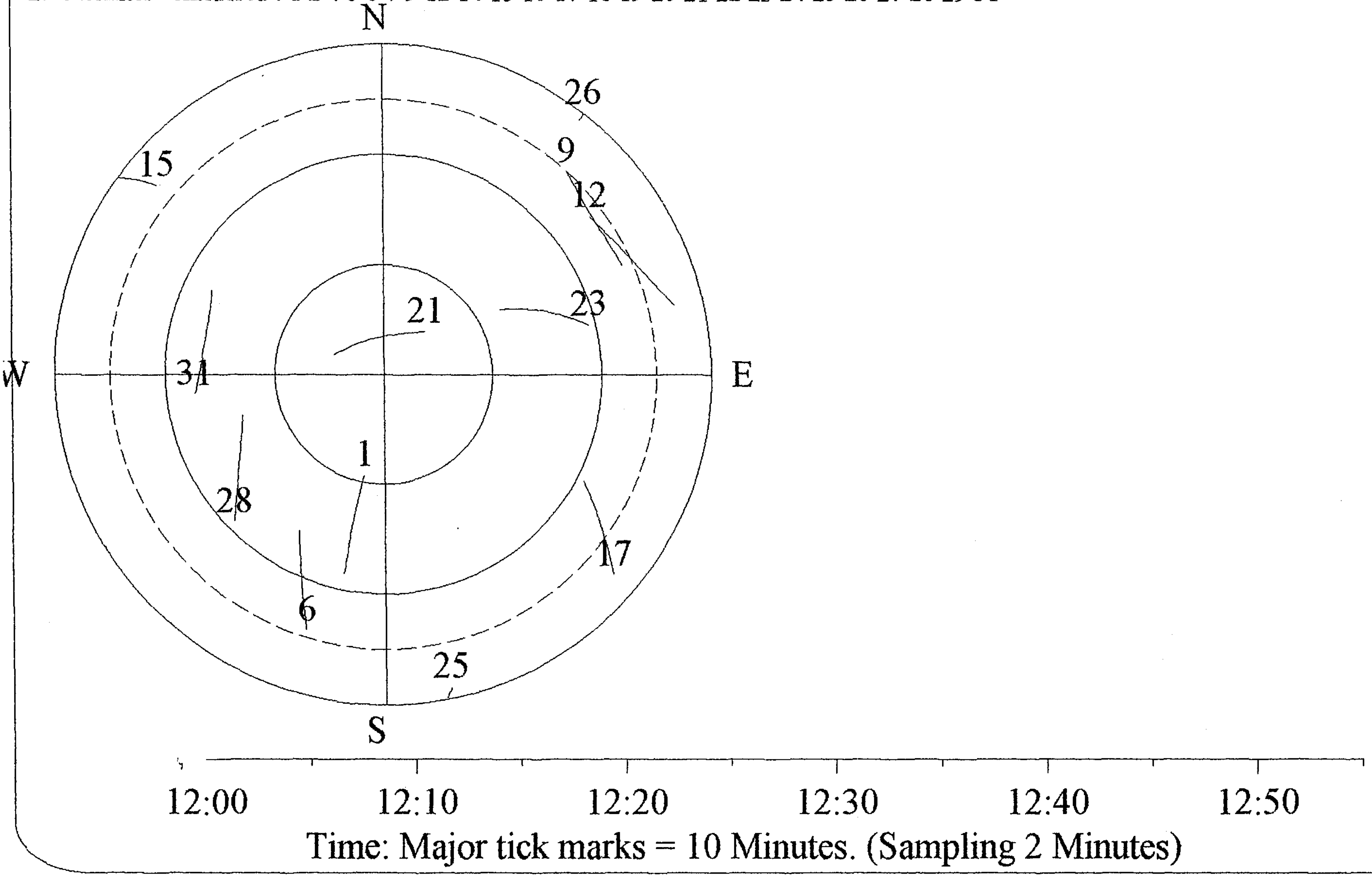
- a. Positive filtered air flow & pressure in installed tubes per procedure BDF1
- b. Filtered air to have humidity and cleanliness controls
- c. Use traveling clean room as the can sections are installed per procedure CR1TSM

SkyPlot

Point: Hanford
Date: Saturday, October 15, 1994
25 Satellites considered : 1 2 4 5 6 7 9 12 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 31

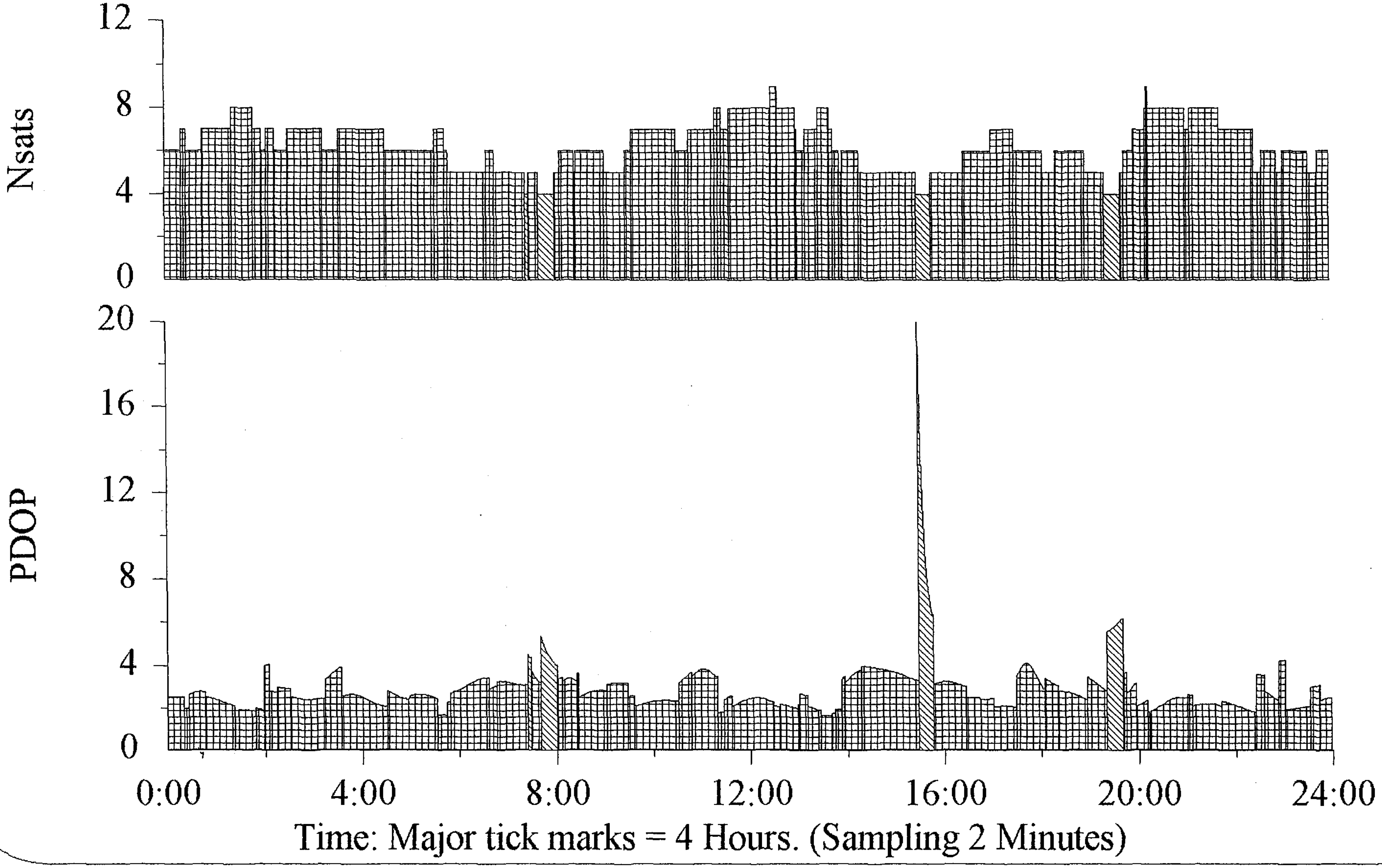
Lat 46:19:0 N Lon 119:16:0 W
Threshold Elevation 15 (deg)

Ephemeris: CURRENT.EPH 4/8/94
Time Zone 'Pacific Std USA' -8



Number SVs and PDOP

Point: Hanford
Lat 46:19:0 N Lon 119:16:0 W
Ephemeris: CURRENT.EPH 4/8/94
Date: Saturday, October 15, 1994
Threshold Elevation 15 (deg)
Time Zone 'Pacific Std USA' -8
25 Satellites considered : 1 2 4 5 6 7 9 12 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 31



New
april 27, 1997

QUALIFICATION TEST OBJECTIVES

- DEMONSTRATE FULL CONFORMANCE OF DETAILED DESIGN
  - Physical Configuration Representation
  - Dimensional Verification
  - Welding Procedures and Apparatus
  - Cleaning Procedures and Execution
  - Structural Demonstration
  - Leak Rate Requirements < 1x10^{-9} ATM CC/S into Beam Tube

- QT TEST MEASUREMENT GOALS
  - Determine outgassing rates of residual gas~~s~~es after the 140° C Bake
  - Measure outgassing rates at 30° C intervals during warmup and once a day during the bake
  - Log,in a permanent record, any leak indication and location.
  - Establish the sensitivity of air signature leak assay techniques before and
  - Record temperatures at critical locations on the QT Beam Tube Module during the I^{2}R bake. Current proposed QT bake change includes 28 thermocouples.

QUALIFICATION TEST PLAN

1. LISTING OF TEST ITEMS AND CALCULATION ITEMS
2. TEST CONFIGURATION AND PROCEDURES
3. DESIGN QT REPORT

TEST ITEMS AND CALCULATION ITEMS

- List of items requiring verification testing and items verified by calculation.

- List represents most important issues affecting design and production of complete Beam Tube Modules

  - Operation Sequence
    1. Design
    2. Material Procurement
    3. Fabrication
    4. Assembly

  - Key Issues
    1. Leak Testing
    2. Cleaning
    3. Dimensional Control

  - Discussion of tested items as well as significant differences (including significance) between QT and a Complete Module

TEST ITEMS AND CALCULATION ITEMS

ITEMS	TEST	CALCULATION	BOTH
DESIGN			
Structural Performance of Beam Tube Sections			
Dimensions and Material			X
Loadings	X		
Calculations		X	
Structural and Mechanical Performance of Expansion Joints			
Vacuum Load	X		
Axial Deflection	X		
Fatigue Performance		X	
Structural Mechanical and Thermal Performance of Beam Tube Supports			
Configuration	X		
Guided Support Range of Movement	X		
Full Gravity Load		X	
Horizontal Transverse Load		X	
Fixed Support Longitudinal		X	
Alignment Mechanical Load Performance	X		
Thermal Performance	X		
Baffle Mechanical Performance	X		
MATERIALS SUPPLIED TO CBI			
Coil Manufacture and Bake	X		
Coupon Outgas Test	X		
Beam Tube Manufacturing	X		
Beam Tube Transportation			X
Expansion Joint Manufacturing			X
Baffle Manufacturing	X		
CBI FABRICATION			
Beam Tube Handling		X	
Stiffener Attachment	X		
Pump Port Reinforcement Pad	X		
Beam Tube End Prep	X		
Pump Port	X		
Expansion Joint Attachment	X		
Work Conditions	X		

TEST ITEMS AND CALCULATION ITEMS

ITEMS	TEST	CALCULATION	BOTH
ASSEMBLY OF BEAM TUBE MODULES			
Use of Clean Room and Enclosure			X
Preliminary Alignment			X
Circumferential Welds	X		
Beam Tube Personnel Entrance	X		
Installation of Structural Supports	X		
LEAK TESTING			
Can Assemblies			X
Circumferential Beam Tube Welds	X		
10" Valve			X
Beam Tube Module			X
CLEANING OUTGAS PERFORMANCE			
Can Assembly Cleaning			X
Final Cleaning	X		
Bakeout			X
Beam Tube Outgas Performance	X		
DIMENSIONAL CONTROL			
Control of Materials and Assemblies	X		
Final Maintenance and Alignment		X	
Clear Aperture		X	

TEST ITEMS AND CALCULATION ITEMS

- DESIGN

  - Structural Performance of Beam Tube Sections

    1. Dimensions and Material: Thoroughly and realistically tested; identical beam tube material and thickness; identical stiffener material, sizes, spacing and attachments; different tube section length = 60' but identical support spacing (65').

    2. Loadings: Demonstrated by test, external pressure to design vacuum and maximum axial compression load application during bakeout.

    3. Calculations: To demonstrate structural adequacy and code conformance.

  - Structural and Mechanical Performance of Expansion Joints - Thoroughly and realistically tested, same vacuum load and maximum axial deflection as the complete module. Fatigue performance is addressed by calculation.

TEST ITEMS AND CALCULATION ITEMS

- DESIGN

  - Structural, Mechanical and Thermal Performance of Beam Tube Supports - The most critical aspects of the supports are tested. Support configuration identical. Guided support range of movement is tested. Some non-critical design elements such as full gravity load and horizontal transverse loads rely on calculations. Fixed support longitudinal load adequacy relies on calculation. Alignment mechanical performance is tested as well as thermal performance to limit local cool spots.

  - Baffle Mechanical Performance - Demonstrated by test. Identical to complete module. Installation, fit and stability are verifed by test.

TEST ITEMS AND CALCULATION ITEMS

- MATERIALS SUPPLIED TO CBI

  - Coil Manufacture + Bakeout - Fully demonstrated by test. QT processes same as planned by Option

  - Coupon Outgas Testing - Fully demonstrated by test. Equipment and methods same as planned for Option. All material within the beam outgas tube tested with the exception of pump port.

  - Beam Tube Manufacturing - Spiral welded tube manufacturing process is demonstrated by test.

  - Beam Tube Transportation - Transportation methods fully demonstrated by test. Method acceptability for fatigue concerns verified by calculation.

  - Expansion Joint Manufacturing - Manufacturing process demonstrated by test. Exceptions: QT uses flat sheets of cold rolled plats vs HRAP coil form for Option. QT uses mechanical forming vs possible hydroforming for Option.

  - Stiffener Manufacturing - Fully demonstrated by test.

  - Baffle Manufacturing - Fully demonstrated by test.

TEST ITEMS AND CALCULATION ITEMS

- CBI FABRICATION

  - Beam Tube Handling - For Option is verified by calculation. QT will use conventional handling methods and equipment.

  - Stiffener Attachment - Fully demonstrated by test. Same welding procedures and same type of equipment.

  - Pumping Port Reinforcement Pad - Fully demonstrated by test. Same welding procedures and same type of equipment.

  - Beam Tube End Final Prep Manufacture - Demonstrated by test. Evaluation made during QT of when to machine to achieve necessary end flatness.

  - Pumping Port - Demonstrated by test. Boring, fitting, purging and welding for QT is same as for Option.

  - Attach Expansion Joint - Fully demonstrated by test.

  - Work Conditions - Realistic work conditions where the QT environment will be similar to the planned Option fabrication facility environment.

TEST ITEMS AND CALCULATION ITEMS

- ASSEMBLY OF BEAM TUBE MODULES

  - Use of Clean Room and Weld Enclosures - Environment will be emulated, actual equipment and its operation will not be tested. Past experience precludes the necessity to test.

  - Preliminary Alignment of Beam Tubes - Demonstrated by test. Exception: Similar procedure with conventional surveying methods vs GPS.

  - Circumferential Welds - Fully demonstrated by test.

  - Beam Tube Personnel Entrance - Sequence of personnel entrance fully demonstrated by test.

  - Installation of Structural Supports - Fully demonstrated by test.

TEST ITEMS AND CALCULATION ITEMS

- LEAK TESTING

  - Can Assemblies - Demonstrated by test. Instead of high production Option method equipment, the QT can section is bagged for the helium surround; leaks will be localized by fine spray helium or helium bagging to isolate an area.

  - Circumferential Beam Tube Welds - Demonstrated by test. QT procedure identical to Option.

  - 10" Valve and Blind Flange Seals - Leak tightness of the 10" valve and its pump port attachment is demonstrated by test. The valve will be bagged and a Helium Mass Spectrometer Test performed.

  - Beam Tube Module - Demonstrated by test. Leak test of QT Beam Tube Module, before and after bake, uses RGA to determine air signature. If air signature indicates any leak, helium fine spray or isolation bagging will be used for location. QT uses similar procedures and the same decision process as the Option. Equipment is somewhat different.

TEST ITEMS AND CALCULATION ITEMS

- CLEANING/OUTGAS PERFORMANCE

  - Can Assembly Cleaning - Demonstrated by test. Essential parameters - temperature, pressure and flow rate of the steam, and the type of spray nozzle - are replicated. Differences: steam cleaning unit instead of a specially prepared skid, manual jet cleaning pull, versus Option power winch, no high flow fans, and QT uses softened water.

  - Final Cleaning - Done when can is in place in Beam Tube Module is demonstrated by test.

  - Bakeout - If I^2R performed - electrical current, insulation, current injection, and bakeout outgas effects are the sam as the Option. Differences: voltage, % of tube which will have auxilliary heating due to end effects, control system. If electric resistance method performed - insulation, temperature variations at supports, and effect of bakeout on outgassing rates are the same as the Option.

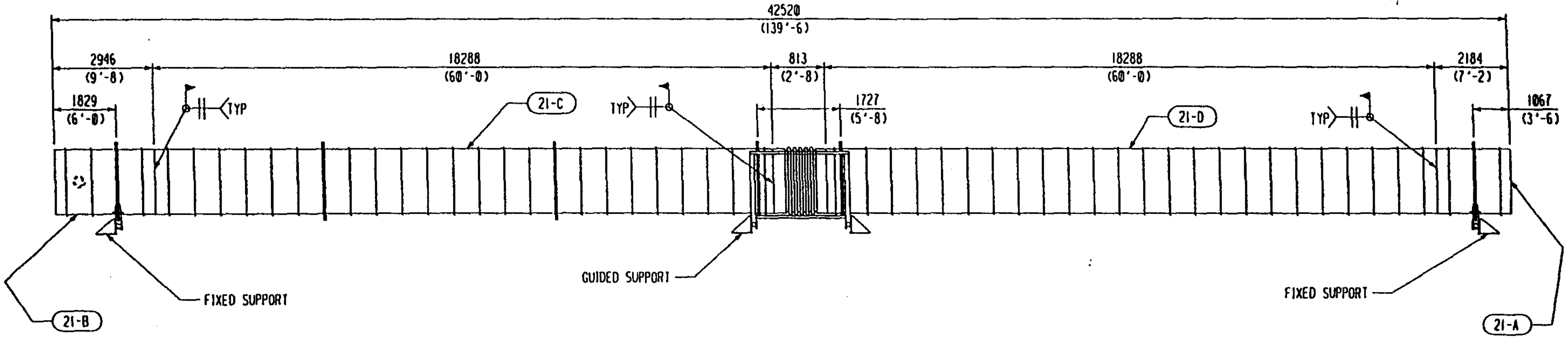
  - Outgas Performance - Outgassing rates of QT Beam Tube Module measured during all phases. Rates used by Caltech to confirm full scale facility pumping requirements.

TEST ITEMS AND CALCULATION ITEMS

- DIMENSIONAL CONTROL
  - Control of Materials and Assemblies - Fully demonstrated by test
  - Final and Maintenance Alignment - GPS adequacy for alignment is established and will not be tested. Also significant GPS improvements are anticipated.
  - Clear Aperture - Verified by calculation based on stack up of component tolerances (test measured) and GPS alignment capabilities. Clear aperture is not verified by measurement.

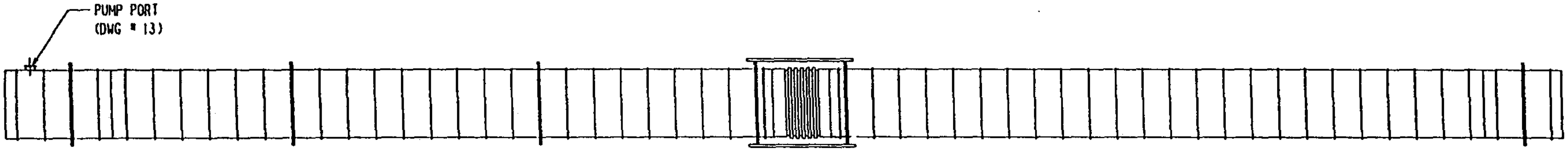
QT CONFIGURATION AND PROCEDURES FOR FABRICATION/INSTALLATION/ TESTING

- QT Beam Tube Physical Configuration
- QT Pumping and Outgas System
- QT Procedures



GENERAL CONFIGURATION
(ELEVATION)

DIRECTION OF CONSTRUCTION →



PLAN VIEW

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

BY	CHKD	DATE	BY	CHKD	DATE	BY	CHKD	DATE	REVISIONS	REMARKS

CBI

SUPPLIER'S / PURCHASER'S NO

LIGO BEAM TUBE
QUALIFICATION TEST

GENERAL CONFIGURATION

CUSTOMER'S NO ______
BY K.R CHKD ______ DATE ______
D.E. Thonn
ENGINEERING SUPERVISOR

CONTRACT NO
930212
DWG 20
SHT
REV 0

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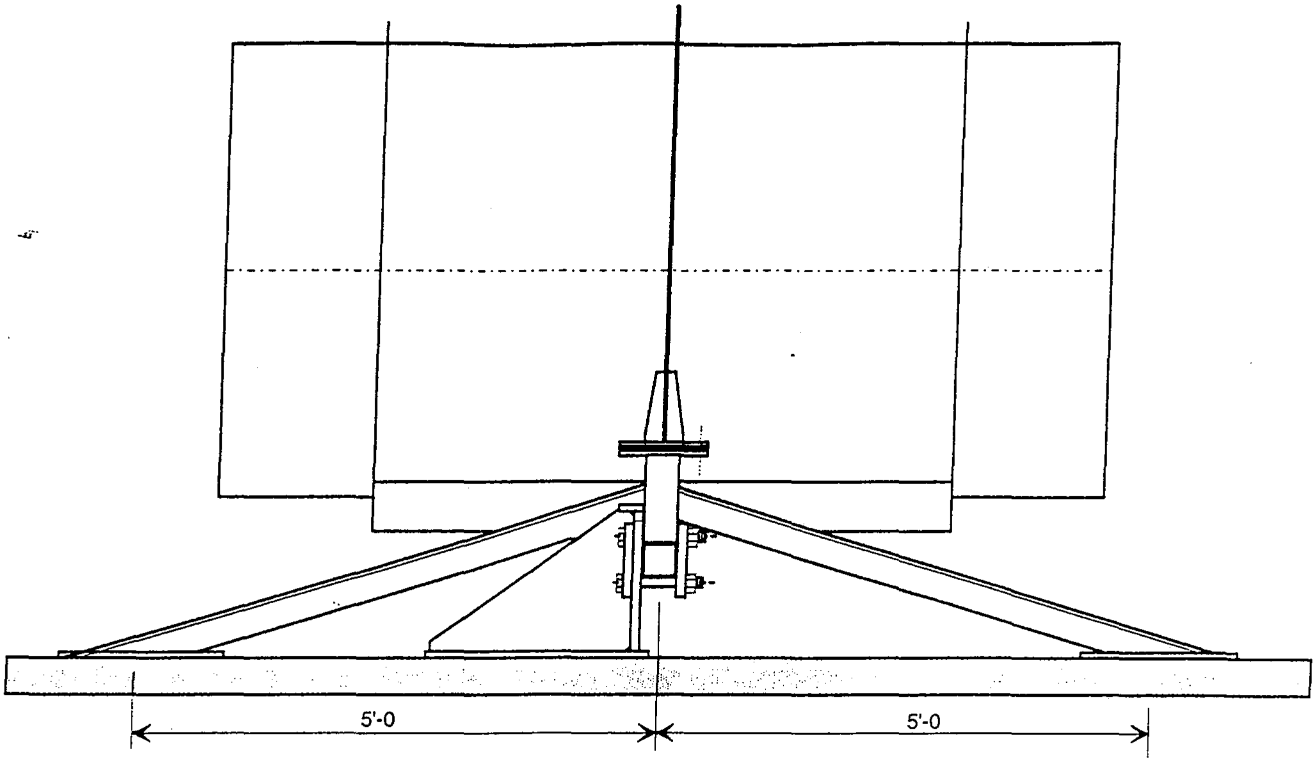
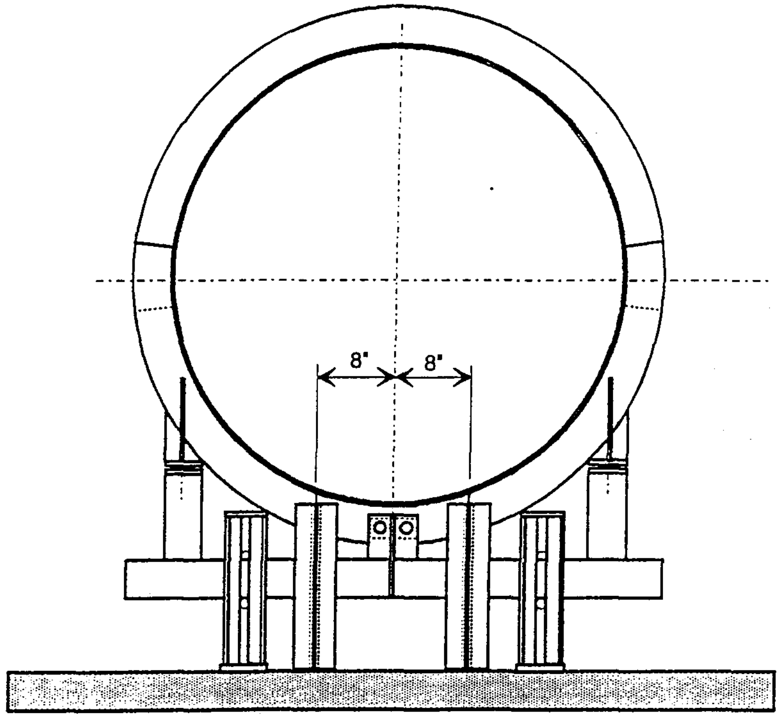




SUBJECT

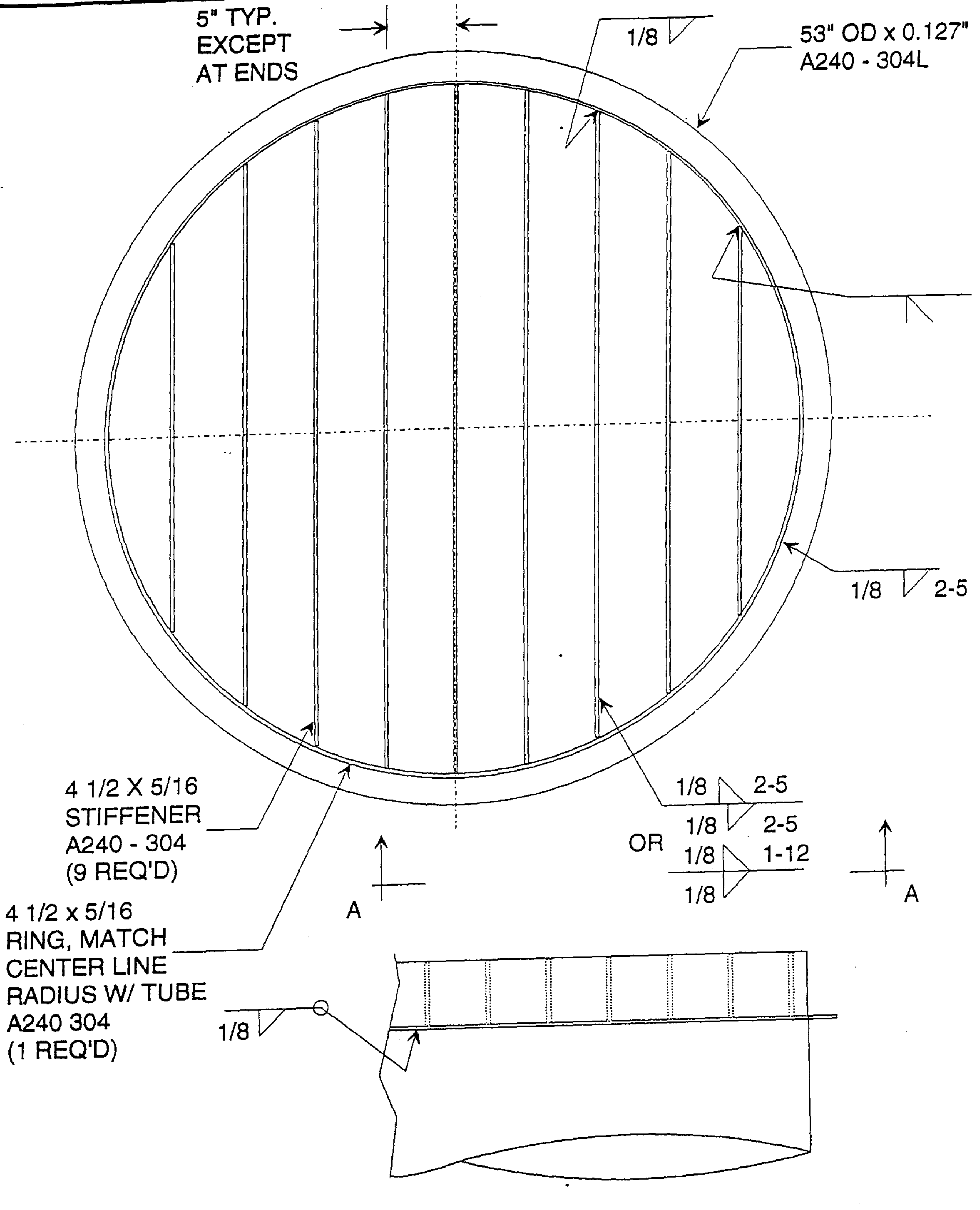
THRUST RESTRAINT
QUALIFICATION TEST
LIGO

CBI **OFFICE**

REVISION:

REFERENCE NO.

MADE MRS	**CHK'D** DDG	**MADE**	**CHK'D**	SHT___OF___
DATE 4/1/94	**DATE** 4/6/94	**DATE**	**DATE**	**SK-QT1**



SECTION A

SUBJECT QT STIFFENED END HEAD	CBI	OFFICE NOE C	REVISION 1		REFERENCE NO. 930212
	MADE BY RJW	CHKD BY TKH	MADE BY RJW	CHKD BY TKH	SHT ____ OF ____
	DATE 29MAR94	DATE 29MAR94	DATE 30MAR94	DATE 29 MARCH 94	

QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

Requirements

- Test the qualification test beam tube for hydrogen and water vapor outgassing rates.
- Provide a system to evacuate the beam tube and measure the above outgassing rates.
- The desired material outgassing rates are 1 X 10^{-13} T L/sec cm^2 for hydrogen and 1 X 10^{-16} T L/sec cm^2 for water vapor.
- Net water vapor pumping speed to be less than 600 L/sec in order to simulate the water pumping speed of the option phase pumping system.

Critical issues

- Background outgassing rate for water is critical due to low outgassing rate.
- High quality RGA is required to provide maximum measurement sensitivity.

QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

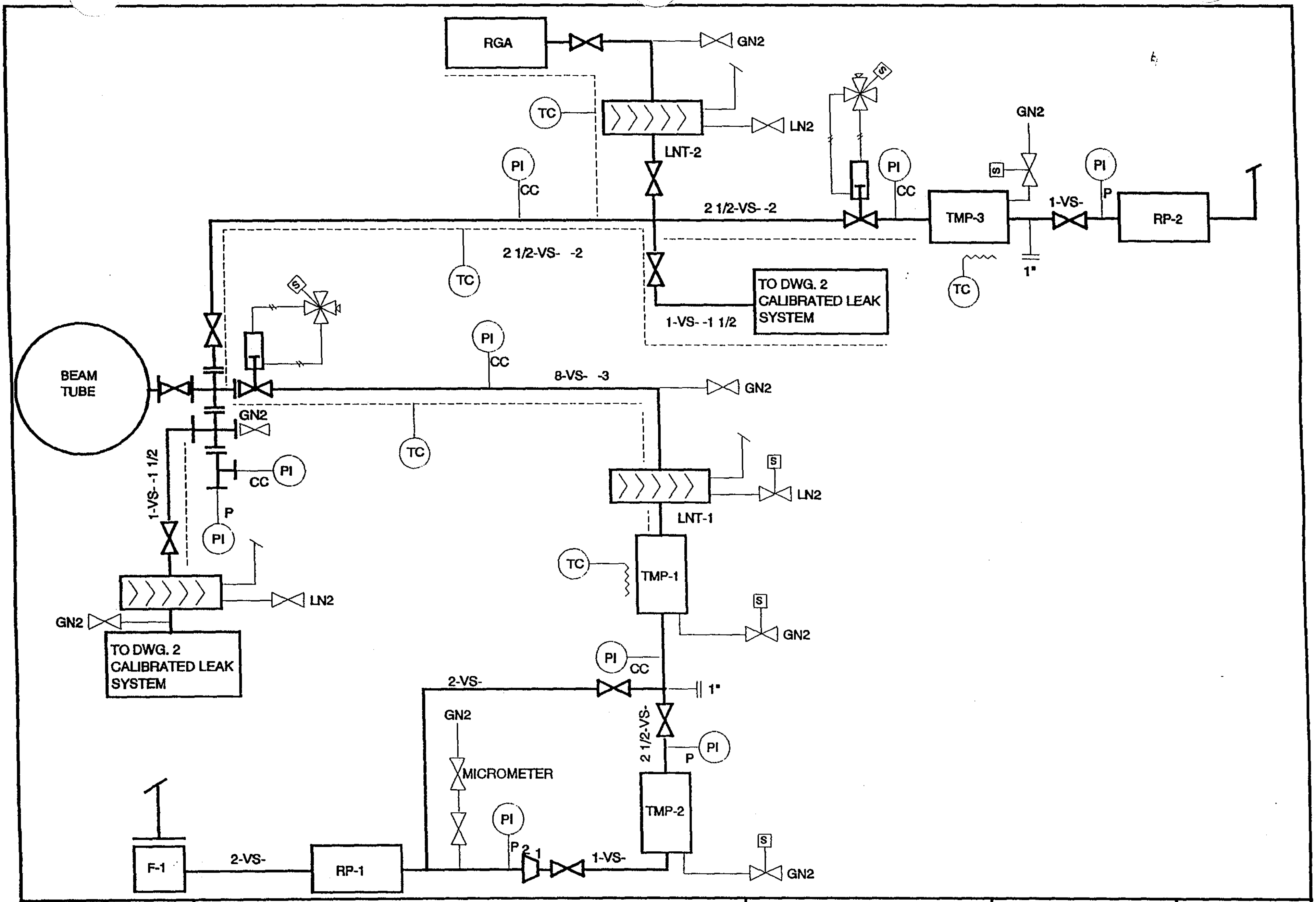
- Minimize contamination from hydrocarbons and water vapor.

Selected Configuration

- Minimize surface area to reduce background outgassing rates.
- Cold trap the RGA to reduce false hydrogen signals.
- Cold trap the pumping system to minimize contamination and as pump for H2O outgassing test.
- Ensure that the water pumping speed is less than 600 L/sec. This trap flow rate must be accurately known for the water outgassing test. Trap pumping speed limited to 600 L/S by use of orifice in the piping.
- Bake out the entire system to reduce the background outgassing rates.

QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

- Select calibrated leaks which are dry to eliminate a source of water vapor contamination.
- Use auxiliary pumping system to evacuate the RGA and calibrated leak systems to prevent contamination.
- Use two turbomolecular pumps in series to provide sufficient hydrogen compression ratio for low background outgassing rate.
- The system is capable of use for the leak test of the qualification test beam tube including the air signature test of the beam tube leak rates.

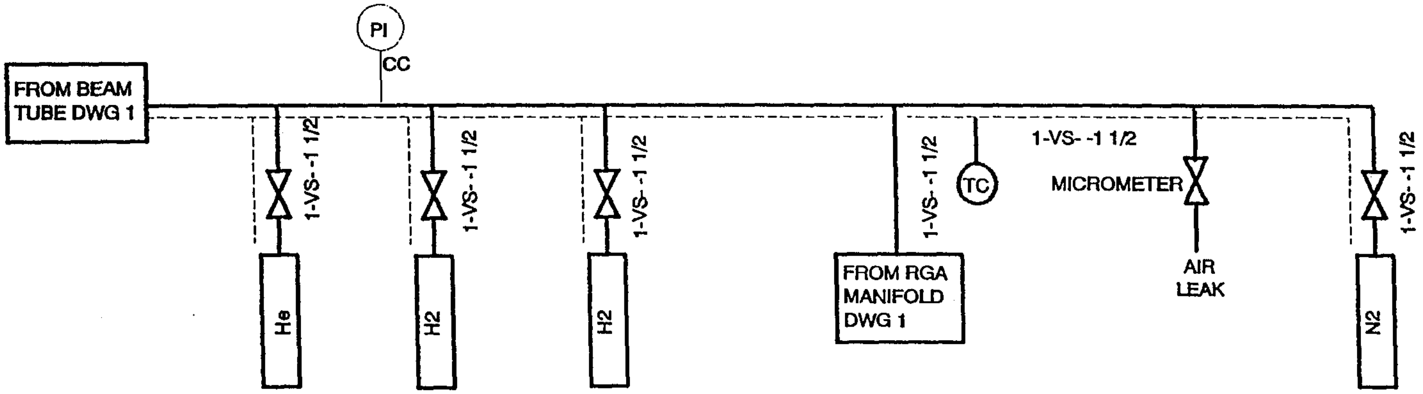


P & I DIAGRAM
VACUUM SYSTEMS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 3/11/94
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	1	REV	5
SHT	1		



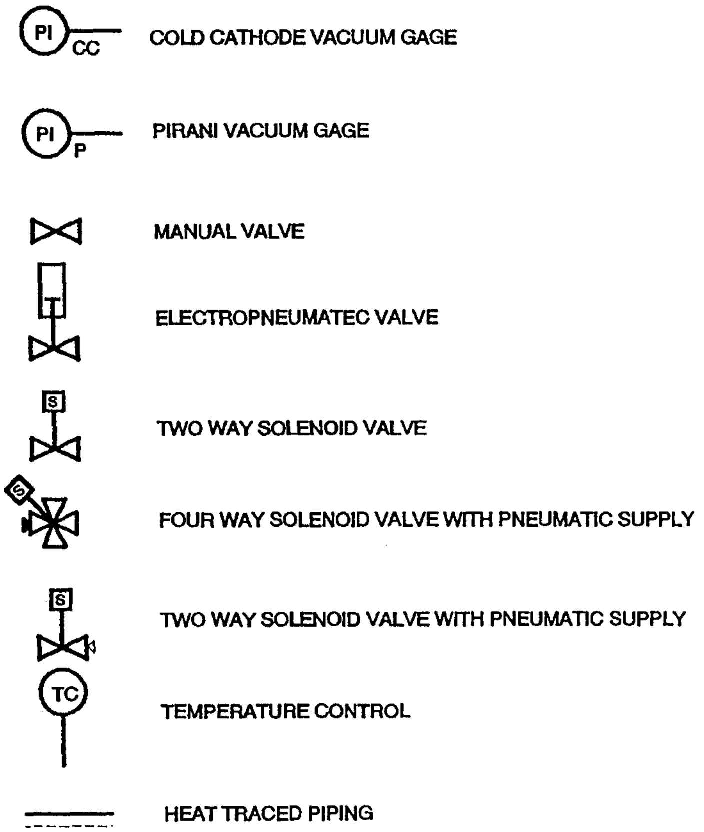
P & I DIAGRAM
CALIBRATED LEAK SYSTEM
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 11/3/93
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG 2
SHT 1
REV 3

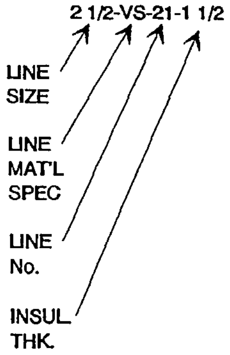
P & I SYMBOLS



PRELIMINARY EQUIPMENT SIZING

TMP -1	1100 L/S
TMP-2	60 L/S
TMP-3	60 L/S
TMP-4	60 L/S
TMP-5	60 L/S
RP-1	50 CFM
RP-2	1 CFM
RP-3	1 CFM
RP-4	1 CFM
LNT-1	6" TRAP
LNT-2	2 1/2" TRAP
LNT-3	2 1/2" TRAP

LINE DESIGNATION



CBI

P & I DIAGRAM
P & I SYMBOLS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 3/30/94
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG 3
SHT 1
REV 5

LIGO QUAL. TEST OUTGASSING CALCULATION

VACUUM VESSEL SHELL(QUAL TEST PIPE)

AREA = 1.65E+06 sq cm (140 ft long)
K-1 = 4.00E-08 T L/sq cm - s — Q-1 = 6.60E-02 T L/S
K-50 = 8.00E-10 T L/sq cm - s — Q-50 = 1.32E-03 T L/S
K-AB= 1.00E-13 T L/sq cm - s — Q-AB= 1.65E-07 TL/S

TEST HEADS

AREA = 2.50E+04 sq cm
K-1 = 4.00E-08 T L/sq cm - s — Q-1 = 1.00E-03 T L/S.
K-50 = 8.00E-10 T L/sq cm - s — Q-50 = 2.00E-05 T L/S
K-AB= 1.00E-13 T L/sq cm - s — Q-AB= 2.50E-09 TL/S

STAINLESS STEEL VALVES, FITTINGS AND PIPE

AREA = 1.00E+04 sq cm
K-1 = 4.00E-08 T L/sq cm - s — Q-1 = 4.00E-04 T L/S
K-50 = 8.00E-10 T L/sq cm - s — Q-50 = 8.00E-06 T L/S
K-AB= 1.00E-12 T L/sq cm - s — Q-AB= 1.00E-08 TL/S

ALUMINUM

AREA = 0.00E+00 sq cm
K-1 = 0.00E+00 T L/sq cm - s — Q-1 = 0.00E+00 T L/S
K-50 = 0.00E+00 T L/sq cm - s — Q-50 = 0.00E+00 T L/S
K-AB= 0.00E+00 T L/sq cm - s — Q-AB= 0.00E+00 TL/S

ELASTOMER

AREA = 0.00E+00 sq cm
K-1 = 0.00E+00 T L/sq cm - s — Q-1 = 0.00E+00 T L/S
K-50 = 0.00E+00 T L/sq cm - s — Q-50 = 0.00E+00 T L/S
K-AB= 0.00E+00 T L/sq cm - s — Q-AB= 0.00E+00 TL/S

notes:
1. K-1, Q-1 & P-1 signify properties after one hour at vacuum
2. K-50, Q-50 & P-50 signify properties after fifty hours at vacuum
3. K-AB, Q-AB & P-AB signify properties after the vacuum bake-out

TOTAL OUTGASSING FLOW

Q-1 = 6.74E-02 T L/S
Q-50 = 1.35E-03 T L/S
Q-AB = 1.78E-07 T L/S

Notes:
AB subscript denotes "after bake"
and is for hydrogen only
outgassing rates for 1 and 50 hours
represent total pressure rates (water)
shading denotes input data required

PUMPING SYSTEM EVALUATION

PUMPING SPEED (PER PUMP) = 6.00E+02 L/sec
CALCULATED PARTIAL PRESSURE P-1 = 1.12E-04 TORR
P-50 = 2.25E-06 TORR
P-AB = 2.96E-10 TORR

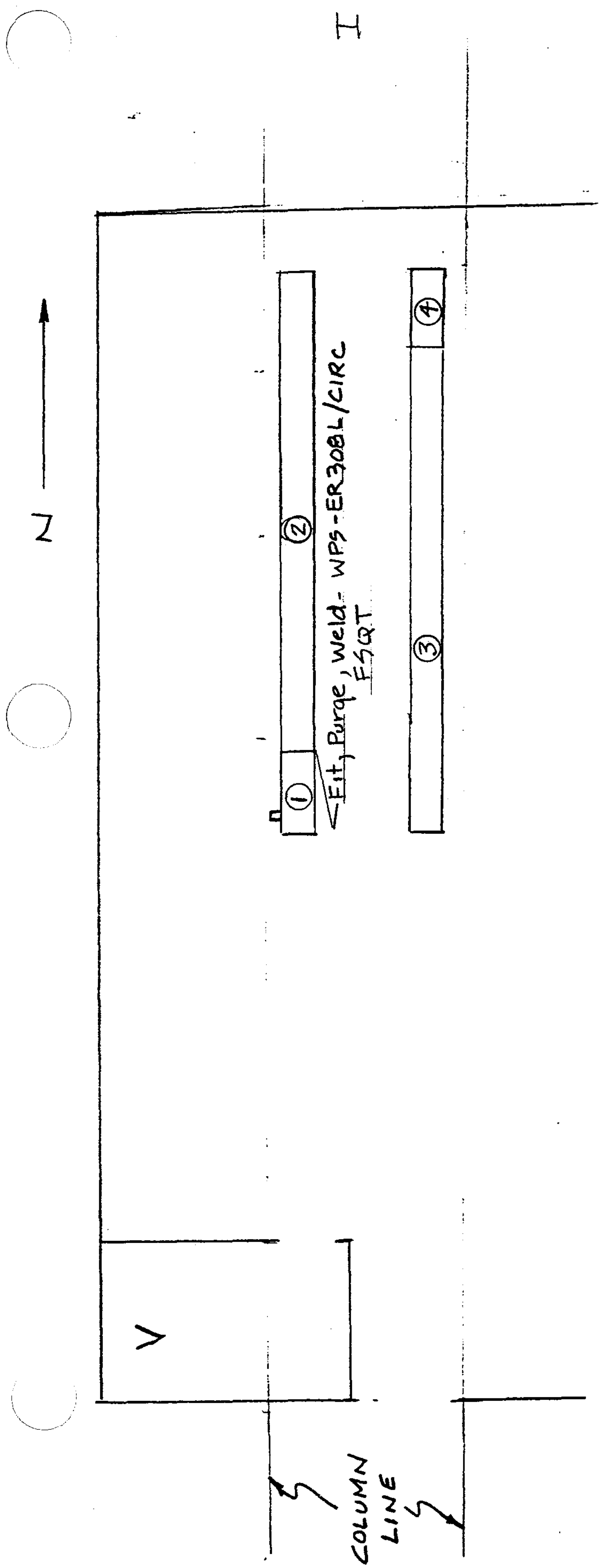
PUMPING SPEED (PER PUMP) = 9.00E+02 L/sec
CALCULATED PARTIAL PRESSURE P-1 = 7.49E-05 TORR
P-50 = 1.50E-06 TORR
P-AB = 1.97E-10 TORR

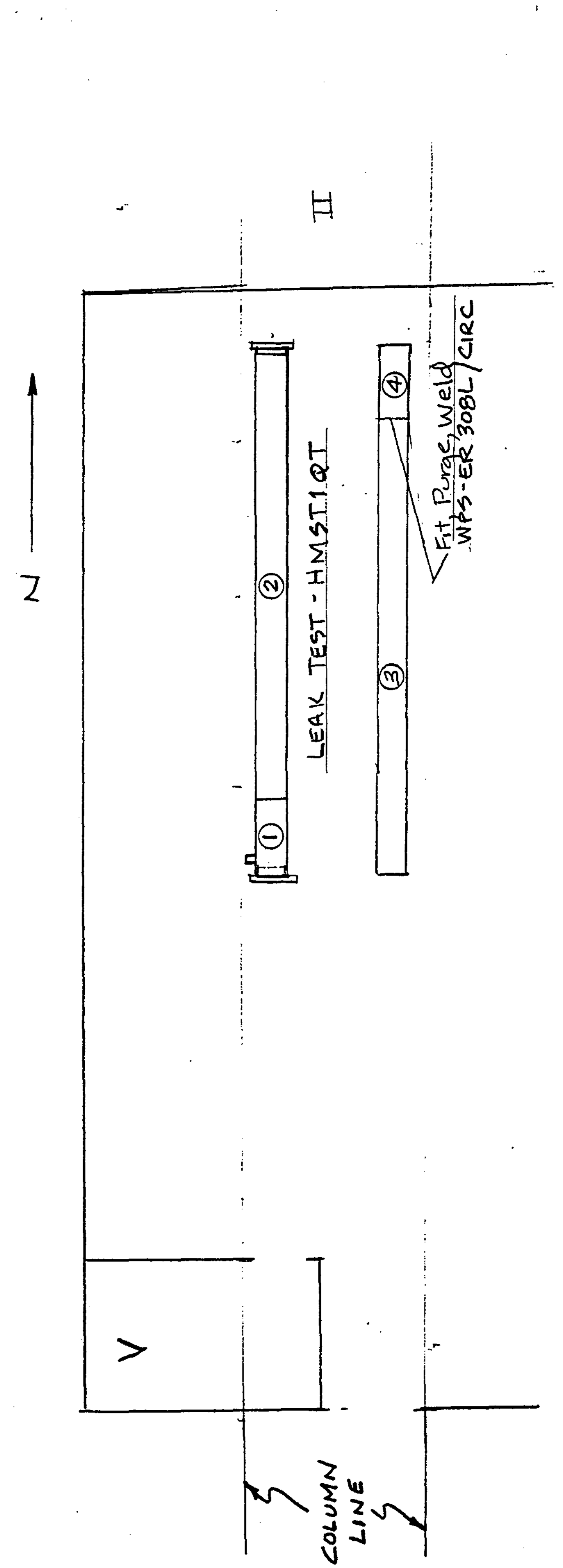
Qualification Test Procedures

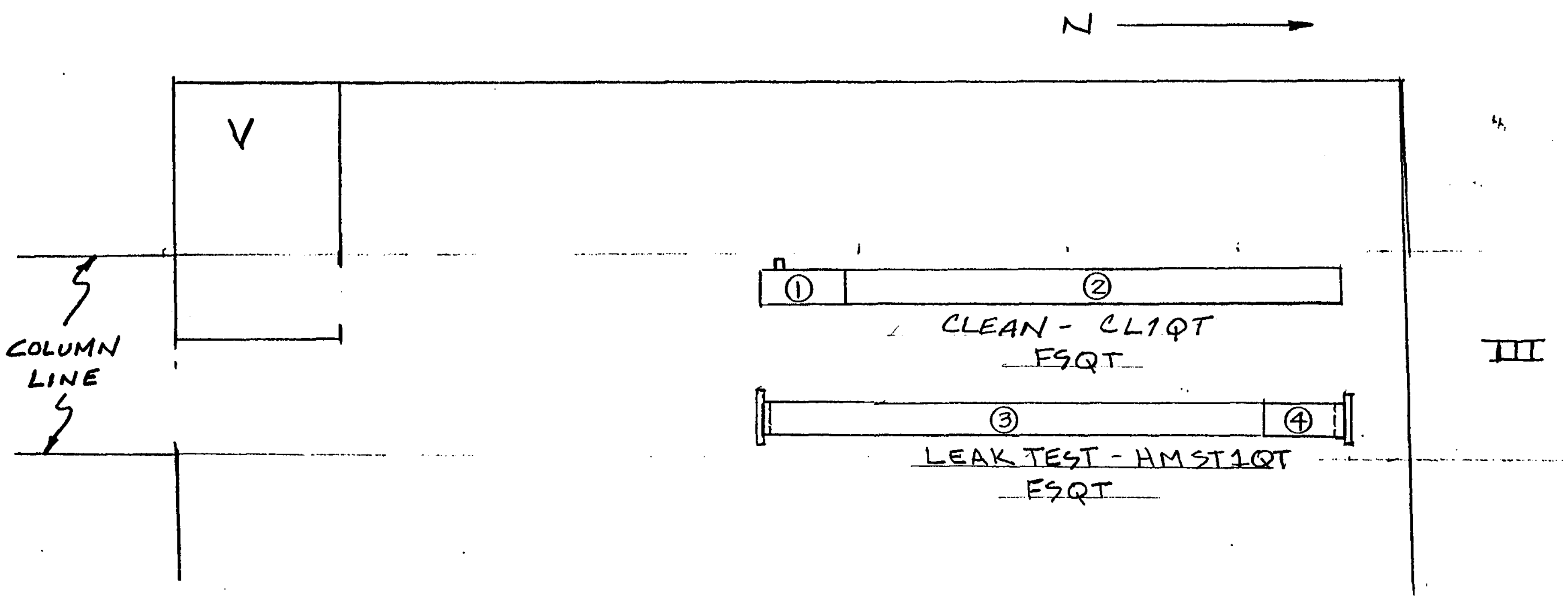
ID	Title	Directly from Detailed Design	QT Addenda to Detailed Design	QT Specific
Material Specifications				
C-240-0186	Coil Material Specification	X		
C-CMBS1	Coil Material Bake Specification	X		
WMS-ER308L	Cleaning and Bakeout Procedure of ER 308L Weld Wire	X		
C-240-0187	Baffle Material Specification	X		
C-CMBS1	Baffle Material Bake Specification	X		
C-240-0194	Expansion Joint Material Specification	X		
Purchasing Specifications				
C-BT-QT	Qualification Test Beam Tube Sections			X
C-EJ-QT	LIGO Beam tube Expansion Joints Qualification Test			X
C-SUPT-1	Beam Tube Support Specification	X		
CBAF-1	Baffle Fabrication Specification	X		
C-PORT-QT	Pump Port Specification			X
C-PORTPAD-1	Pump Port Reinforcing Pad Specification	X		
C-VAC-1	Vacuum Stiffener Specification	X		
C-SUPSTF-1	Support Ring/Baffle Ring Fabrication Specification	X		
Fabrication/Installation Procedures				
FSQT	Beam Tube Can Section Fabrication Sequence for LIGO Qualification Test Addenda		X	
ISQT	Beam Tube Can Section Installation Sequence for LIGO Qualification Test Addenda		X	
FPCircumferential	Fitting/Purge Procedure for Circumferential Butt Welds for LIGO	X		
FPStiffener	Fitting/Purge Procedure for Stiffener Attachment Welds for LIGO	X		
FPPumpPort	Fitting/Purge Procedure for Pump Port Attachment Welds for LIGO	X		
MI	Material Traceability	X		
IR	Receiving Inspection	X		
DCQT	Dimensional Control		X	
Welding Procedures				
WPS-INDEX	Weld Procedure Index	X		
WPS-ER308S/GMA (w/PQR 4858)	Weld Procedure, GMA Welding for 304L Materials	X		
WPS-ER308L/Repair (w/PQRs 10029 & 4858)	Weld procedure, GMA for Repair Welding for 304L Materials	X		

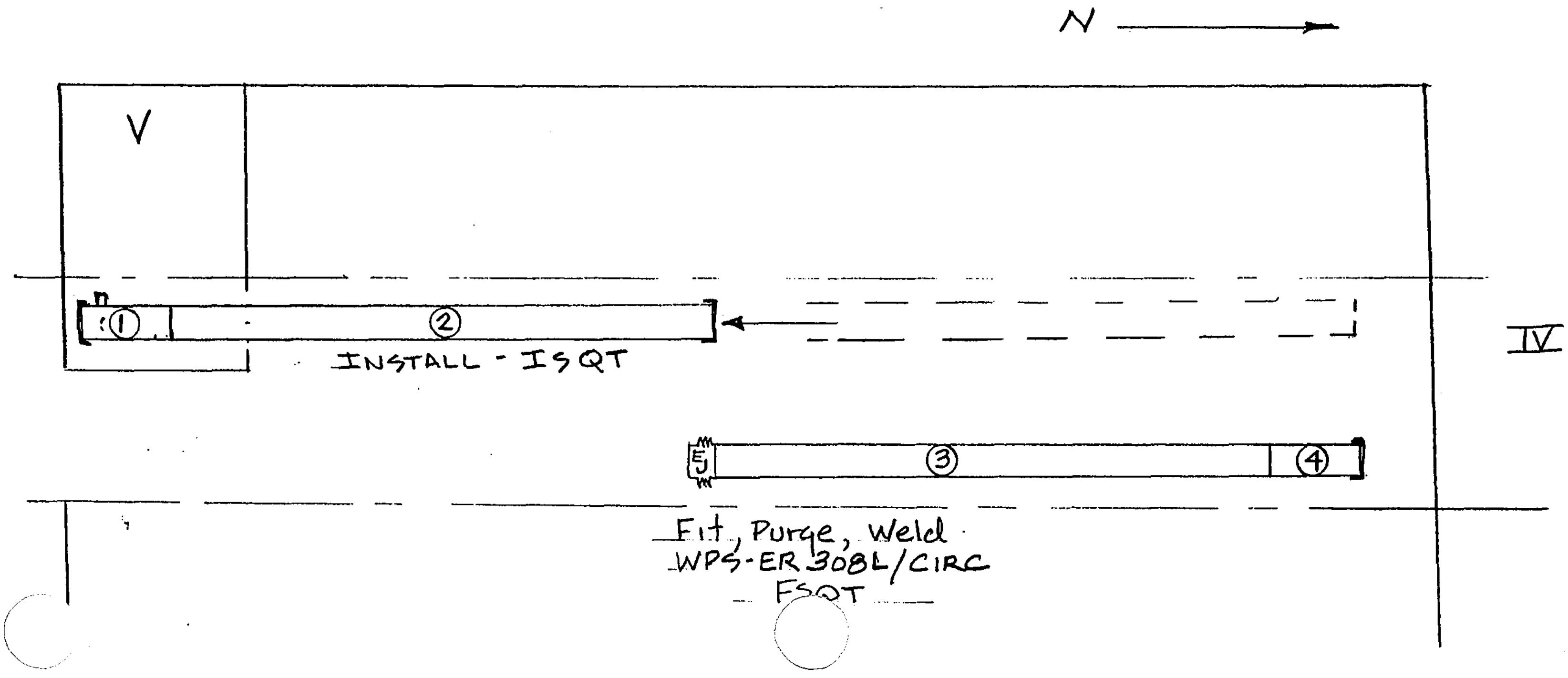
CONSTRUCTION PLAN

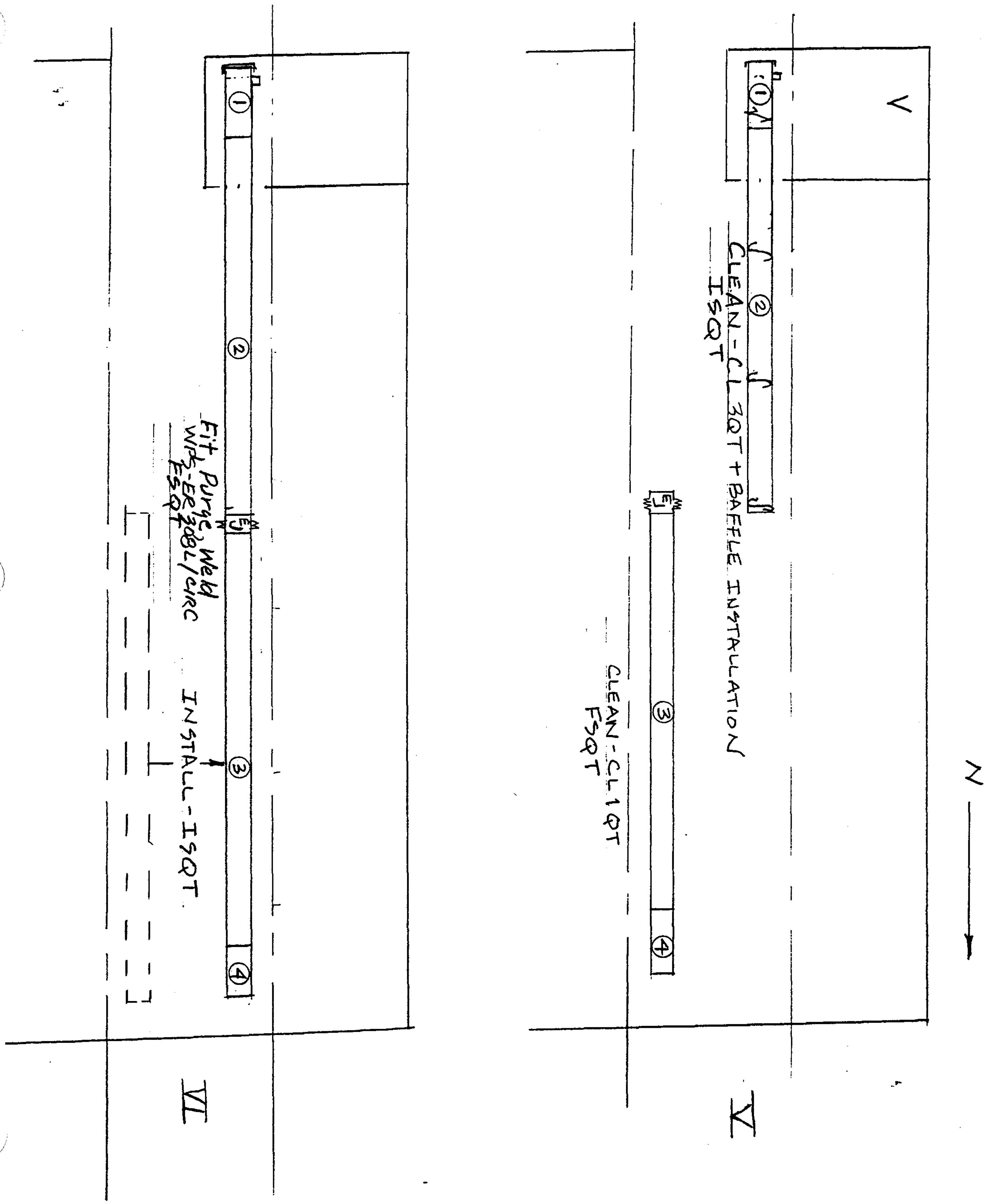
- FSQT - Fabrication Sequence
- ISQT - Installation Sequence
- LIGOCPQT Cleaning Plans
- LIGOTPQT Leak Testing

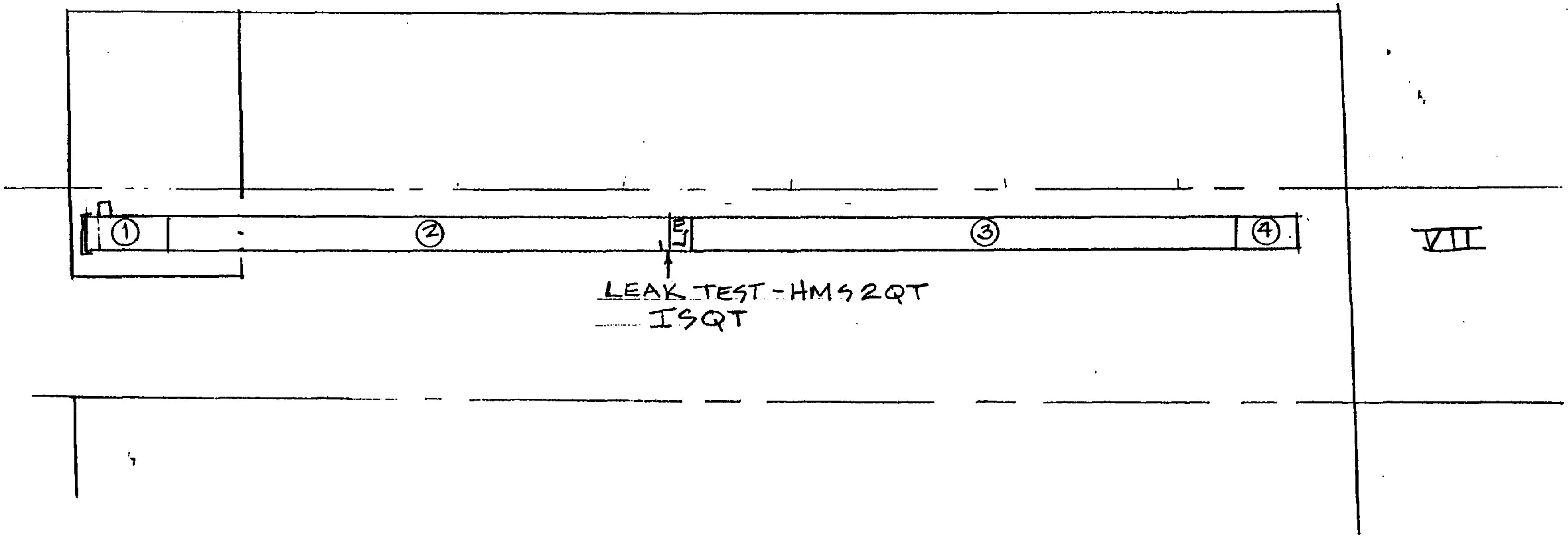

I
N
Fit, Purge, Weld - WPS-ER308L/CIRC
FSQT
①
②
③
④
V
COLUMN LINE

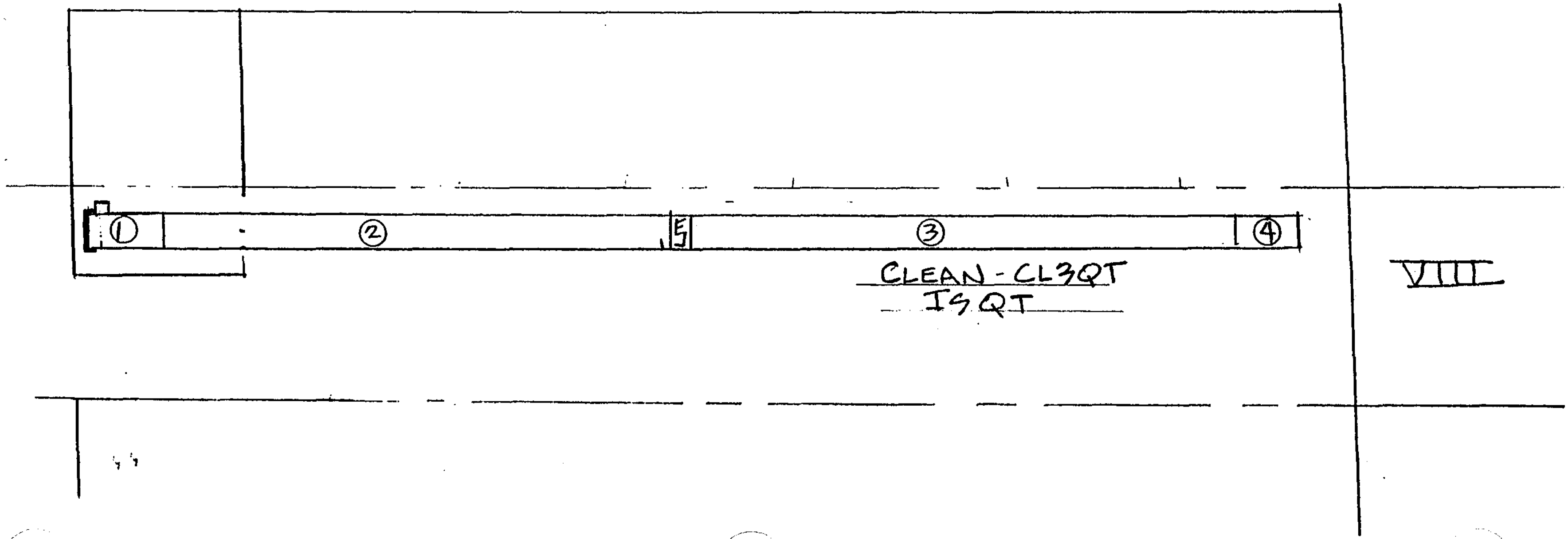

II
N
LEAK TEST - HMST1QT
Fit Purge, Weld
WPS-ER308L/CIRC
①
②
③
④
V
COLUMN LINE


N
V
COLUMN LINE
①
②
CLEAN - CL1QT
FSQT
③
④
LEAK TEST - HMST1QT
FSQT
III


N
V
①
②
INSTALL - ISQT
EJ
③
④
Fit, Purge, Weld
WPS-ER 308L/CIRC
FSQT
IV

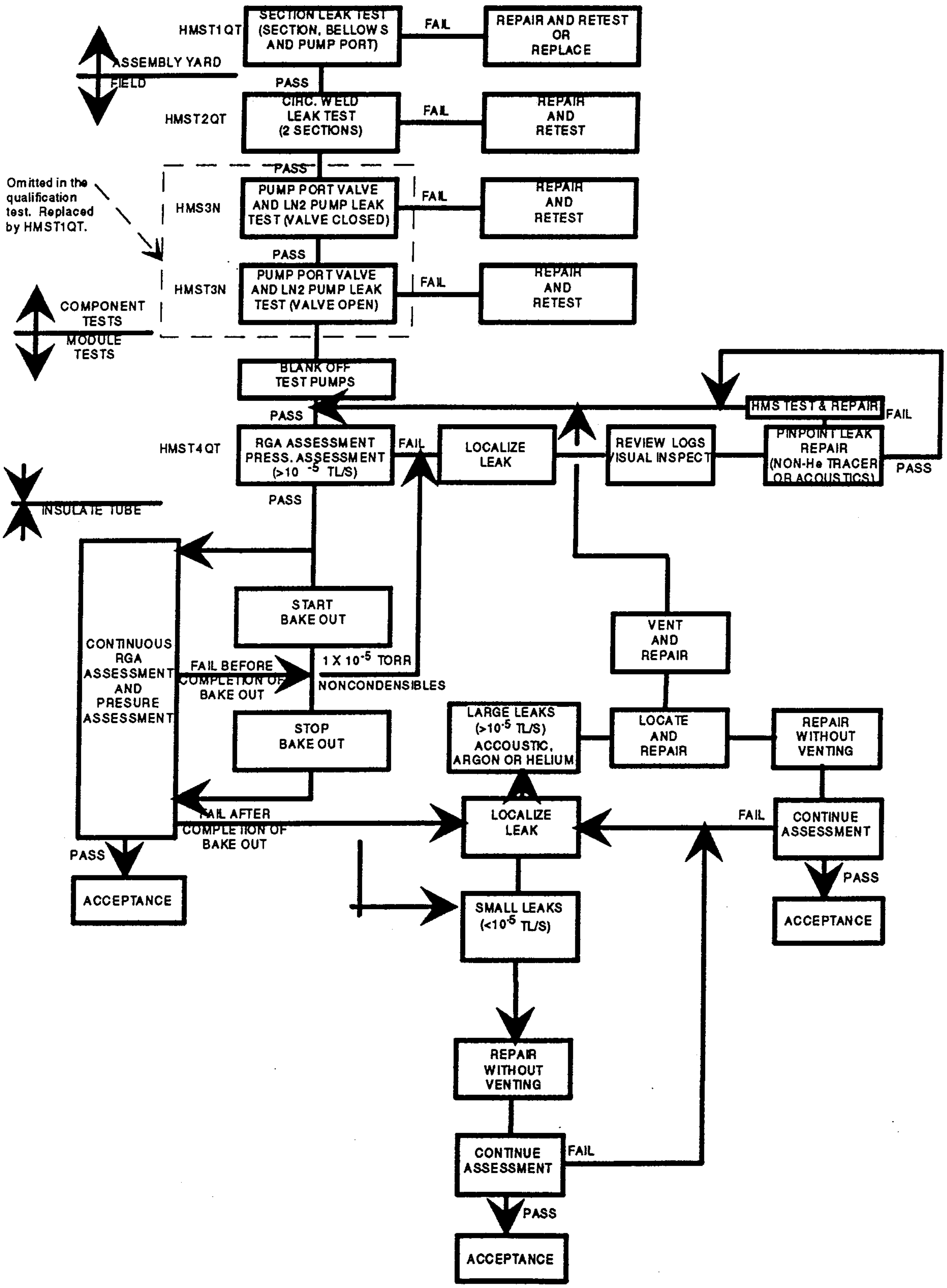

V
①
②
CLEAN-CL 3QT + BAFFLE INSTALLATION
ISQT
EJ
③
CLEAN-CL 1QT
FSQT
④
N
V
①
②
Fit Purge Weld
WPS-ER308L/CIRC
FSQT
EJ
③
INSTALL-ISQT
④
VI


①
②
③
④
LEAK TEST - HMS2QT
ISQT
VII


①
②
③
④
CLEAN - CL3QT
ISQT
VIII

LEAK TEST PROCEDURES

LEAK DETECTION DECISION TREE
QUALIFICATION TEST



BAKEOUT PROCEDURE

SPECIFIES EQUIPMENT AND PROCEDURE TO EMULATE CRITICAL BAKEOUT PARAMETERS

- Insulation
- Temperatures
- Duration

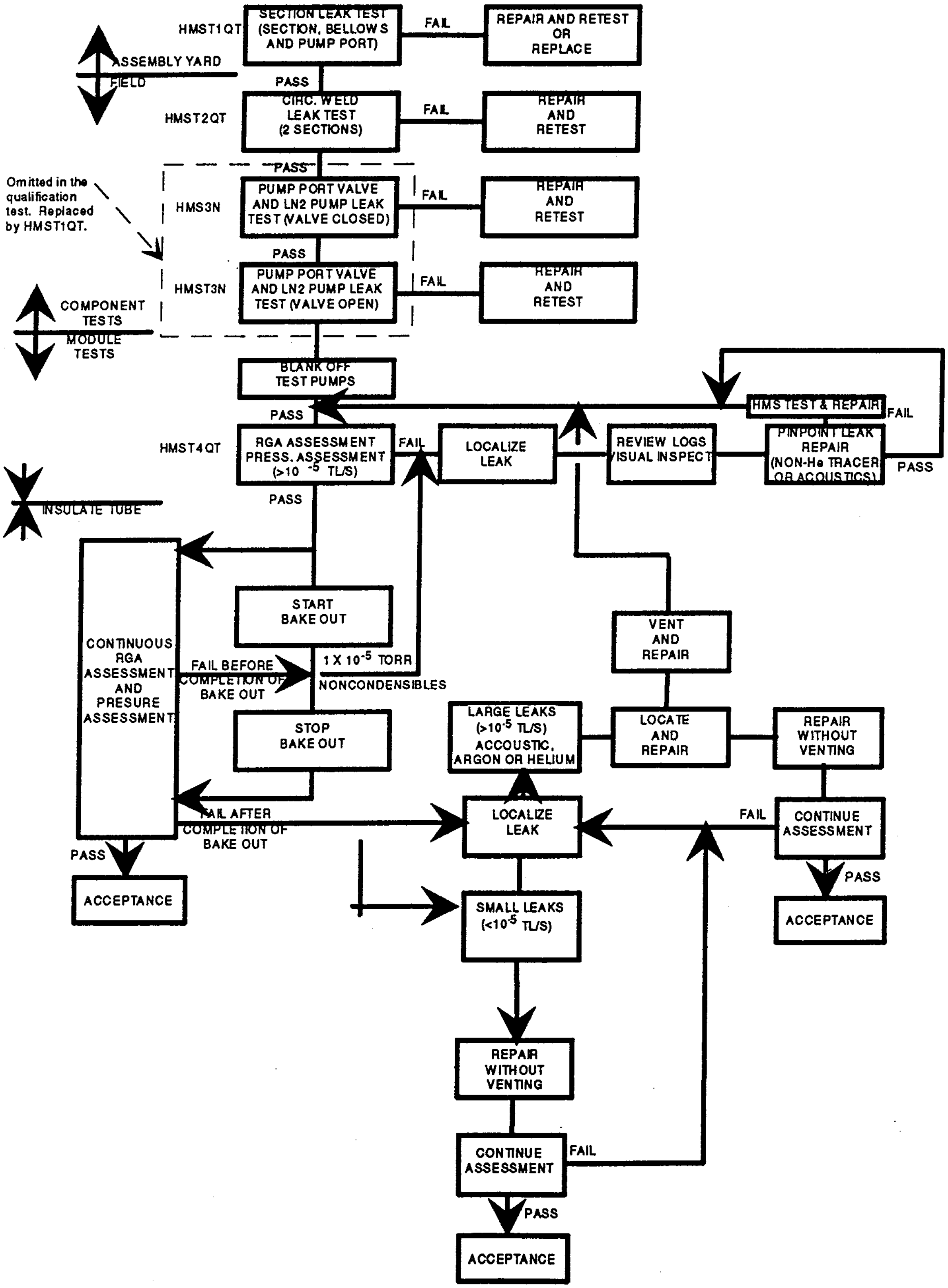
THE PROCEDURE SPECIFIES ELECTRIC RESISTANCE HEAT CABLE TO HEAT UP AND MAINTAIN TEMPERATURE

I^2R METHOD

CBI prepared basic module bakeout design and submitted RFQ for QT bakeout by I^2R. Proposal will be prepared for design of Beam Tube Module I^2R bakeout and Option performance of same.

LEAK TEST PROCEDURES

LEAK DETECTION DECISION TREE
QUALIFICATION TEST



BAKEOUT PROCEDURE

SPECIFIES EQUIPMENT AND PROCEDURE TO EMULATE CRITICAL BAKEOUT PARAMETERS

- Insulation
- Temperatures
- Duration

THE PROCEDURE SPECIFIES ELECTRIC RESISTANCE HEAT CABLE TO HEAT UP AND MAINTAIN TEMPERATURE

I^2R METHOD

CBI prepared basic module bakeout design and submitted RFQ for QT bakeout by I^2R. Proposal will be prepared for design of Beam Tube Module I^2R bakeout and Option performance of same.

QUALIFICATION TEST PUMP DOWN AND OUTGASSING TEST PROCEDURE

- Evacuate to <10^{-5} torr
- Evaluate air signature and outgassing rates
- Insulate tube
- Bake out tube and monitor outgassing rates during bake out
- Monitor outgassing rates during cooldown
- Evaluate air signature and outgassing rates at ambient temperature

DATA ACQUISITION PROCEDURE

- Written Documentation is recorded in laboratory notebooks.

- Computerized Data Acquisition for temperatures, pressures, and other analog signals, RGA data and reports, and "logbook files".

- Format - Written documentation is per procedure or recorder. Computerized data per custom analog data software, RGA software and for logbook files, which record instrument state vectors keyed to time and date, Microsoft Word document format.

- Transmission - Daily transmittal of compressed archive LIGO files via modem to Caltech designated host computer.

QUALIFICATION TEST REPORT

- Outline/Index - Report will follow outline which will incorporate all aspects of the QT Test Plan.
- Data Reporting - in same format as specified in QT procedures including Data Acquisition Procedure.
    - Test Documentation
    - Instrument Output

OLD Stuff

QUALIFICATION TEST OBJECTIVES

- Demonstrate full conformance of Detailed Design
- Identify analysis features vs tested features
- Full Scale Configuration
- QT Test execution in accordance with approved plan

QUALIFICATION TEST PLAN

1. Listing of Test Items and Calculation Items
2. Test Configuration and Procedures
3. Design QT Report

TEST ITEMS AND CALCULATION ITEMS

- Design
  - Structural Performance of Beam Tube Sections
  - Structural and Mechanical Performance of Expansion Joints
  - Structural, Mechanical and Thermal Performace of Beam Tube Supports
  - Baffle Mechanical Performance

TEST ITEMS AND CALCULATION ITEMS

- Materials Supplied to CBI
  - Coil Manufacture + Bakeout
  - Coupon Outgas Testing
  - Beam Tube Manufacturing
  - Beam Tube Transportation
  - Expansion Joint Manufacturing
  - Stiffener Manufacturing
  - Baffle Manufacturing

TEST ITEMS AND CALCULATION ITEMS

- CBI Fabrication
    - Beam Tube Handling
    - Stiffener Attachment
    - Pumping Port
    - Final Beam Tube End Prep
    - Pumping Port
    - Attach Expansion Joint
    - Work Conditions

TEST ITEMS AND CALCULATION ITEMS

- Assembly of Beam Tube Modules
    - Use of Clean Room and Weld Enclosures
    - Preliminary Alignment of Beam tube
    - Circumferential Welds
    - Beam Tube Personnel Entrance
    - Installation of Structural Supports

TEST ITEMS AND CALCULATION ITEMS

- Leak Testing
    - - Can Assemblies
    - - Circumferential Beam Tube Welds
    - - 10" Valve and Blind Flange Seals
    - - Beam Tube Module

TEST ITEMS AND CALCULATION ITEMS

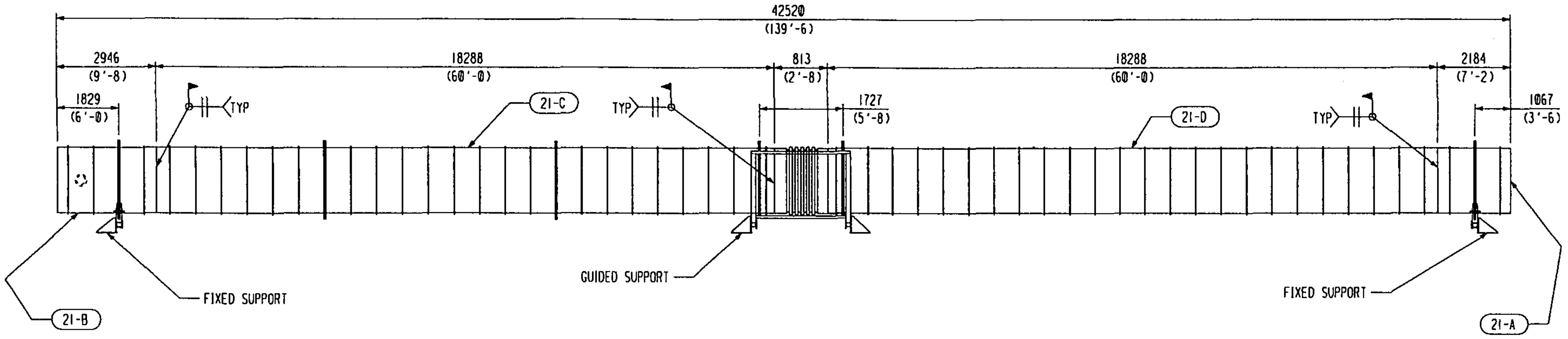
- Cleaning/Outgas Performance
    - Can Assembly Cleaning
    - Final Cleaning
    - Bakeout
    - Outgas Performance

TEST ITEMS AND CALCULATION ITEMS

- Dimensional Control
    - Control of Materials and Assemblies
    - Layout of Alignment Reference Pads
    - Installation Alignment
    - Final and Maintenance Alignment
    - Clear Aperture

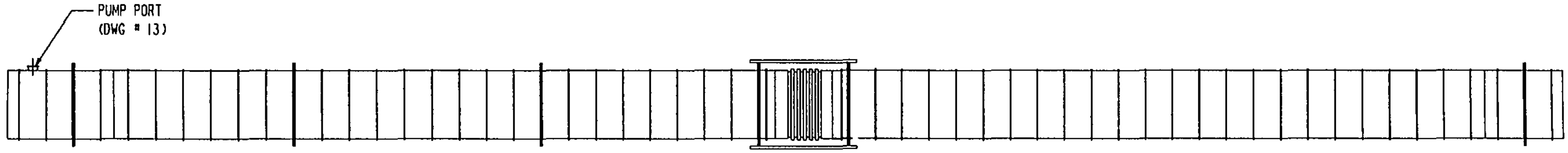
TEST CONFIGURATION AND PROCEDURES FOR FABRICATION INSTALLATION

- QT Beam Tube Physical Configuration
- QT Pumping and Outgas System
- QT Procedures



GENERAL CONFIGURATION
(ELEVATION)

DIRECTION OF CONSTRUCTION →



PLAN VIEW

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

BY	CHKD	DATE	BY	CHKD	DATE	BY	CHKD	DATE	REMARKS / REVISIONS

CBI

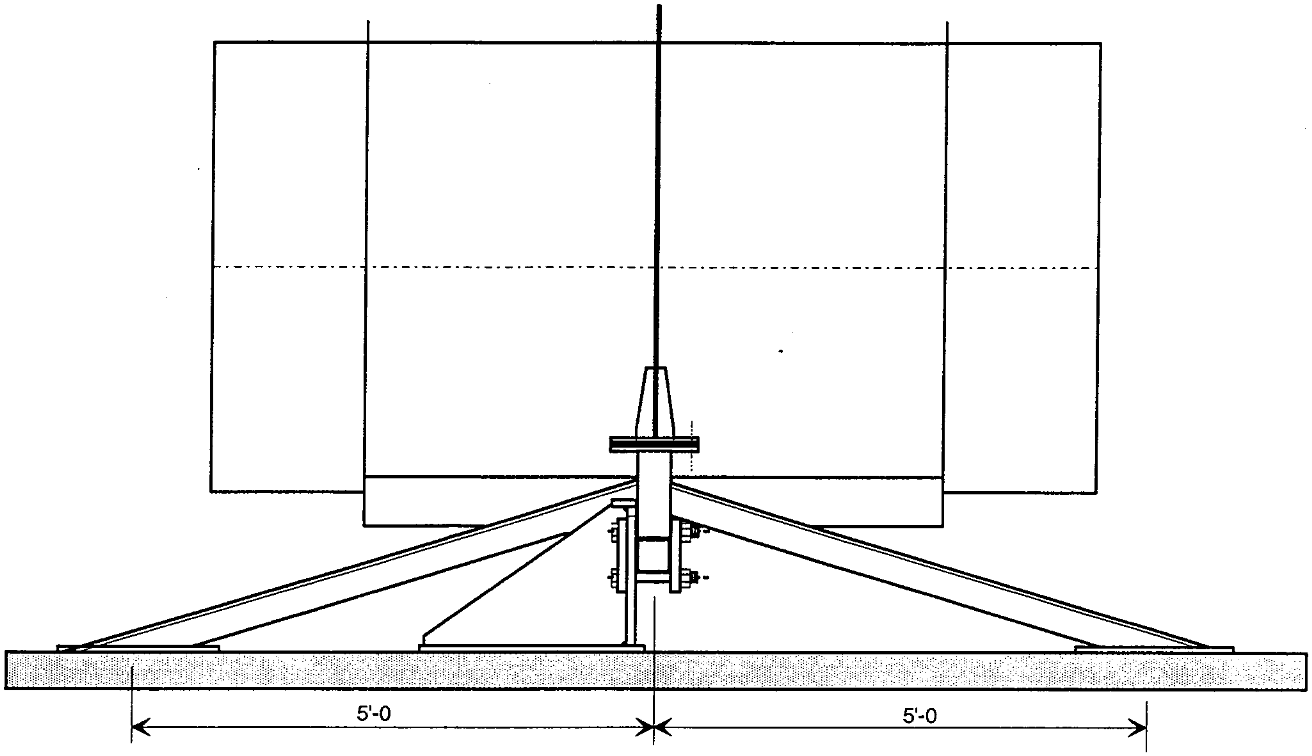
SUPPLIER'S / PURCHASER'S NO

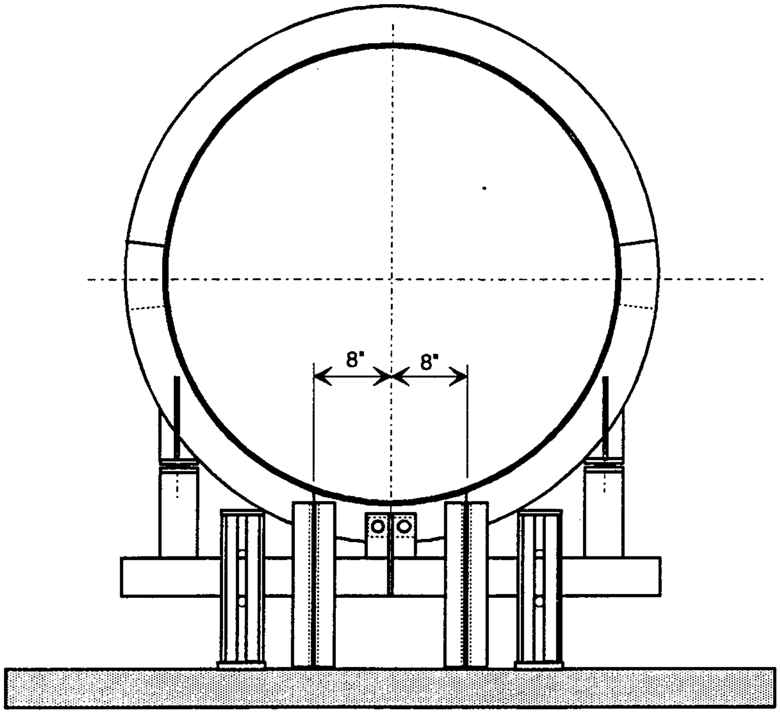
LIGO BEAM TUBE
QUALIFICATION TEST

GENERAL CONFIGURATION

CUSTOMER'S NO ______
BY KJR CHKD ____ DATE ______
D.E. Thom
ENGINEERING SUPERVISOR

CONTRACT NO 930212
DWG 20
SHT
REV 0

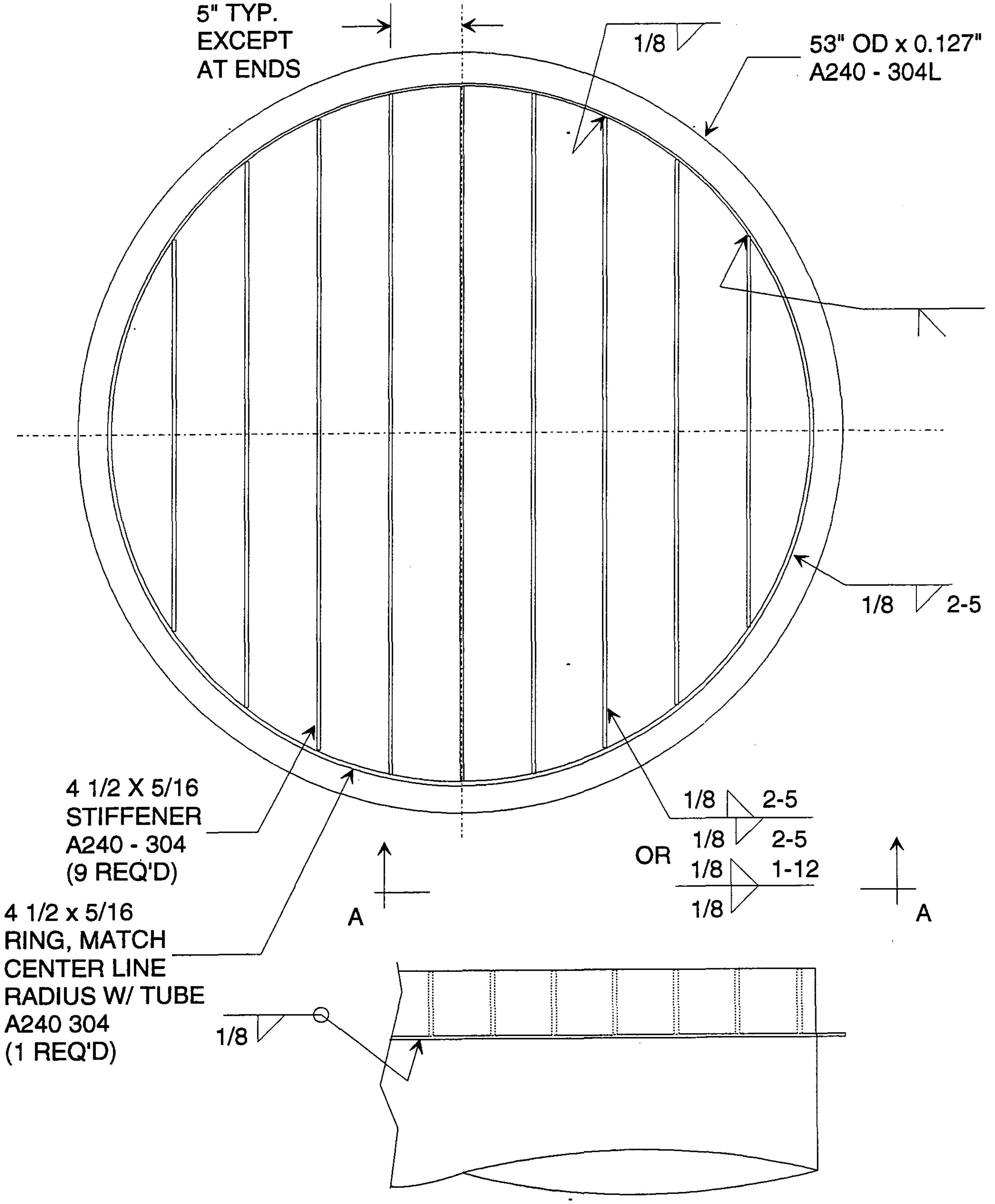




SUBJECT

THRUST RESTRAINT
QUALIFICATION TEST
LIGO

CBI	OFFICE	REVISION:		REFERENCE NO.
MADE MRS	CHK'D DDG	MADE	CHK'D	SHT___OF___
DATE 4/1/94	DATE 4/6/94	DATE	DATE	SK-QT1



SECTION A

SUBJECT QT STIFFENED END HEAD	CBI	OFFICE NOE C	REVISION 1		REFERENCE NO. 930212
	MADE BY RJW	CHKD BY TKH	MADE BY RJW	CHKD BY TKH	SHT ____ OF ____
	DATE 29MAR94	DATE 29MAR94	DATE 30MAR94	DATE 29 MARCH 94	

QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

Requirements

- Test the qualification test beam tube for hydrogen and water vapor outgassing rates.
- Provide a system to evacuate the beam tube and measure the above outgassing rates.
- The desired material outgassing rates are 1 X 10^{-13} T L/sec cm^2 for hydrogen and 1 X 10^{-16} T L/sec cm^2 for water vapor.

Net water vapor pumping speed to be less than 600 L/sec in order to simulate the water pumping speed of the option phase pumping system.

Critical Issues

- Background outgassing rate for water is critical due to low outgassing rate.
- High quality RGA is required to provide maximum measurement sensitivity.

QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

- Minimize contamination from hydrocarbons and water vapor.

Selected Configuration

- Minimize surface area to reduce background outgassing rates.
- Cold trap the RGA to reduce false hydrogen signals.
- Cold trap the pumping system to minimize contamination.
- Ensure that the water pumping speed is less than 600 L/sec. This trap flow rate must be accurately measured to provide a known pumping speed for the water outgassing test.
- Bake out the entire system to reduce the background outgassing rates.

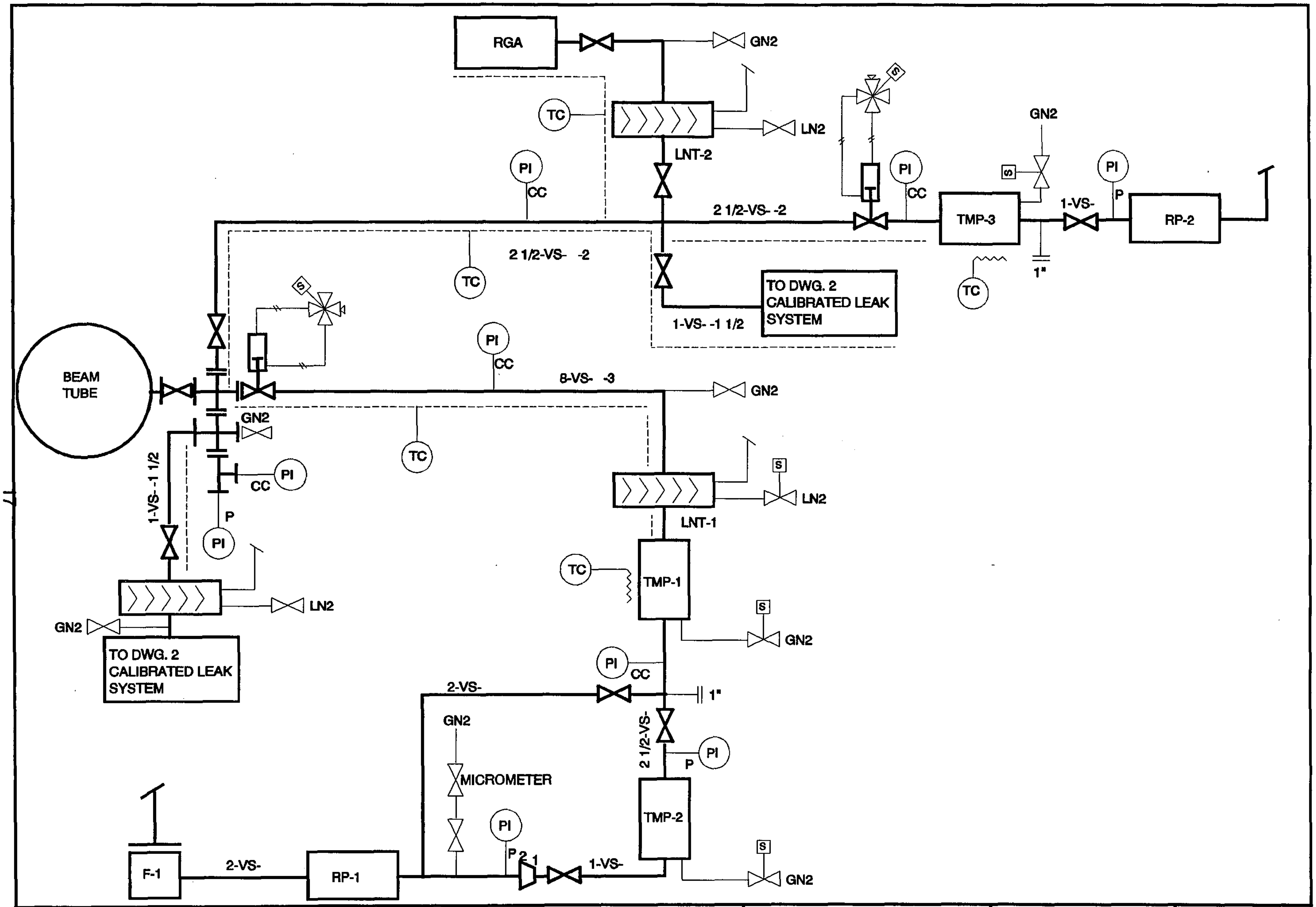
QUALIFICATION TEST PUMPING AND OUTGASSING TEST SYSTEMS

- Select calibrated leaks which are dry to eliminate a source of water vapor contamination.

- Use auxiliary pumping system to evacuate the RGA and calibrated leak systems to prevent contamination.

- Use two turbomolecular pumps in series to provide sufficient hydrogen compression ratio for low background outgassing rate.

- The system is capable of use for the leak test of the qualification test beam tube including the air signature test of the beam tube.



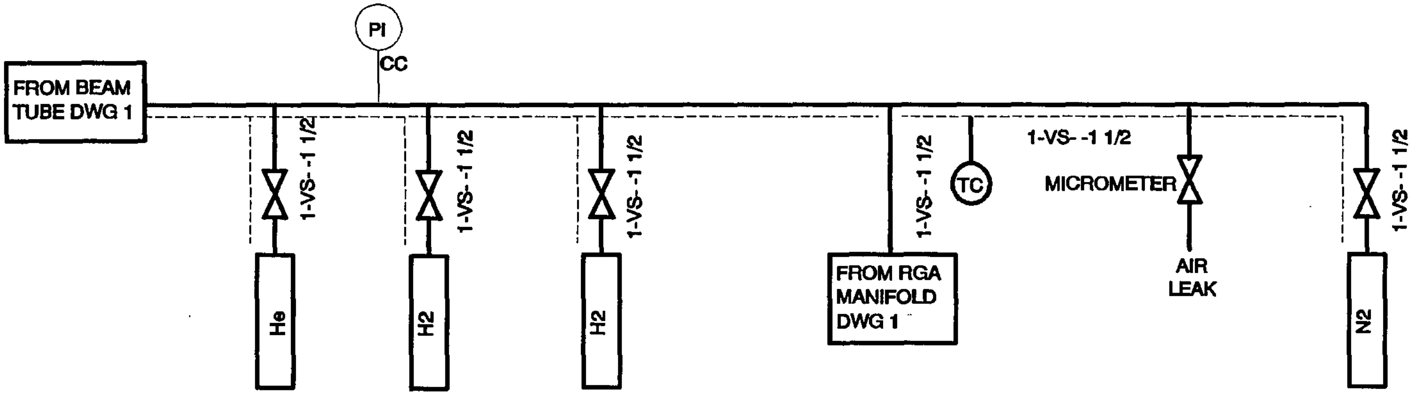
CBI

P & I DIAGRAM
VACUUM SYSTEMS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ______ DATE 3/11/94
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	1	REV
SHT	1	5



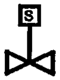
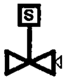
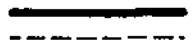
P & I DIAGRAM
CALIBRATED LEAK SYSTEM
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 11/3/93
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	2	REV	3
SHT	1		

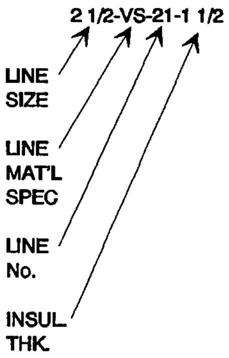
P & I SYMBOLS

	COLD CATHODE VACUUM GAGE
	PIRANI VACUUM GAGE
	MANUAL VALVE
	ELECTROPNEUMATEC VALVE
	TWO WAY SOLENOID VALVE
	FOUR WAY SOLENOID VALVE WITH PNEUMATIC SUPPLY
	TWO WAY SOLENOID VALVE WITH PNEUMATIC SUPPLY
	TEMPERATURE CONTROL
	HEAT TRACED PIPING

PRELIMINARY EQUIPMENT SIZING

TMP -1	1100 L/S
TMP-2	60 L/S
TMP-3	60 L/S
TMP-4	60 L/S
TMP-5	60 L/S
RP-1	50 CFM
RP-2	1 CFM
RP-3	1 CFM
RP-4	1 CFM
LNT-1	6" TRAP
LNT-2	2 1/2" TRAP
LNT-3	2 1/2" TRAP

LINE DESIGNATION



CBI

P & I DIAGRAM
P & I SYMBOLS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 3/30/94
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	3	REV 5
SHT	1	

LIGO QUAL. TEST OUTGASSING CALCULATION

VACUUM VESSEL SHELL(QUAL TEST PIPE)

AREA = 1.65E+06 sq cm (140 ft long)
K-1 = 4.00E-08 T L/sq cm - s   Q-1 = 6.60E-02 T L/S
K-50 = 8.00E-10 T L/sq cm - s   Q-50 = 1.32E-03 T L/S
K-AB= 1.00E-13 T L/sq cm - s   Q-AB= 1.65E-07 TL/S

TEST HEADS

AREA = 2.50E+04 sq cm
K-1 = 4.00E-08 T L/sq cm - s   Q-1 = 1.00E-03 T L/S
K-50 = 8.00E-10 T L/sq cm - s   Q-50 = 2.00E-05 T L/S
K-AB= 1.00E-13 T L/sq cm - s   Q-AB= 2.50E-09 TL/S

STAINLESS STEEL VALVES, FITTINGS AND PIPE

AREA = 1.00E+04 sq cm
K-1 = 4.00E-08 T L/sq cm - s   Q-1 = 4.00E-04 T L/S
K-50 = 8.00E-10 T L/sq cm - s   Q-50 = 8.00E-06 T L/S
K-AB= 1.00E-12 T L/sq cm - s   Q-AB= 1.00E-08 TL/S

ALUMINUM

AREA = 0.00E+00 sq cm
K-1 = 0.00E+00 T L/sq cm - s   Q-1 = 0.00E+00 T L/S
K-50 = 0.00E+00 T L/sq cm - s   Q-50 = 0.00E+00 T L/S
K-AB= 0.00E+00 T L/sq cm - s   Q-AB= 0.00E+00 TL/S

ELASTOMER

AREA = 0.00E+00 sq cm
K-1 = 0.00E+00 T L/sq cm - s   Q-1 = 0.00E+00 T L/S
K-50 = 0.00E+00 T L/sq cm - s   Q-50 = 0.00E+00 T L/S
K-AB= 0.00E+00 T L/sq cm - s   Q-AB= 0.00E+00 TL/S

notes:
1. K-1, Q-1 & P-1 signify properties after one hour at vacuum
2. K-50, Q-50 & P-50 signify properties after fifty hours at vacuum
3. K-AB, Q-AB & P-AB signify properties after the vacuum bake-out

TOTAL OUTGASSING FLOW

Q-1 = 6.74E-02 T L/S
Q-50 = 1.35E-03 T L/S
Q-AB = 1.78E-07 T L/S

Notes:
AB subscript denotes "after bake" and is for hydrogen only
outgassing rates for 1 and 50 hours represent total pressure rates (water)
shading denotes input data required

PUMPING SYSTEM EVALUATION

PUMPING SPEED (PER PUMP) = 6.00E+02 L/sec
CALCULATED PARTIAL PRESSURE P-1 = 1.12E-04 TORR
P-50 = 2.25E-06 TORR
P-AB = 2.96E-10 TORR

PUMPING SPEED (PER PUMP) = 9.00E+02 L/sec
CALCULATED PARTIAL PRESSURE P-1 = 7.49E-05 TORR
P-50 = 1.50E-06 TORR
P-AB = 1.97E-10 TORR

4/4/94

Qualification Test Procedures

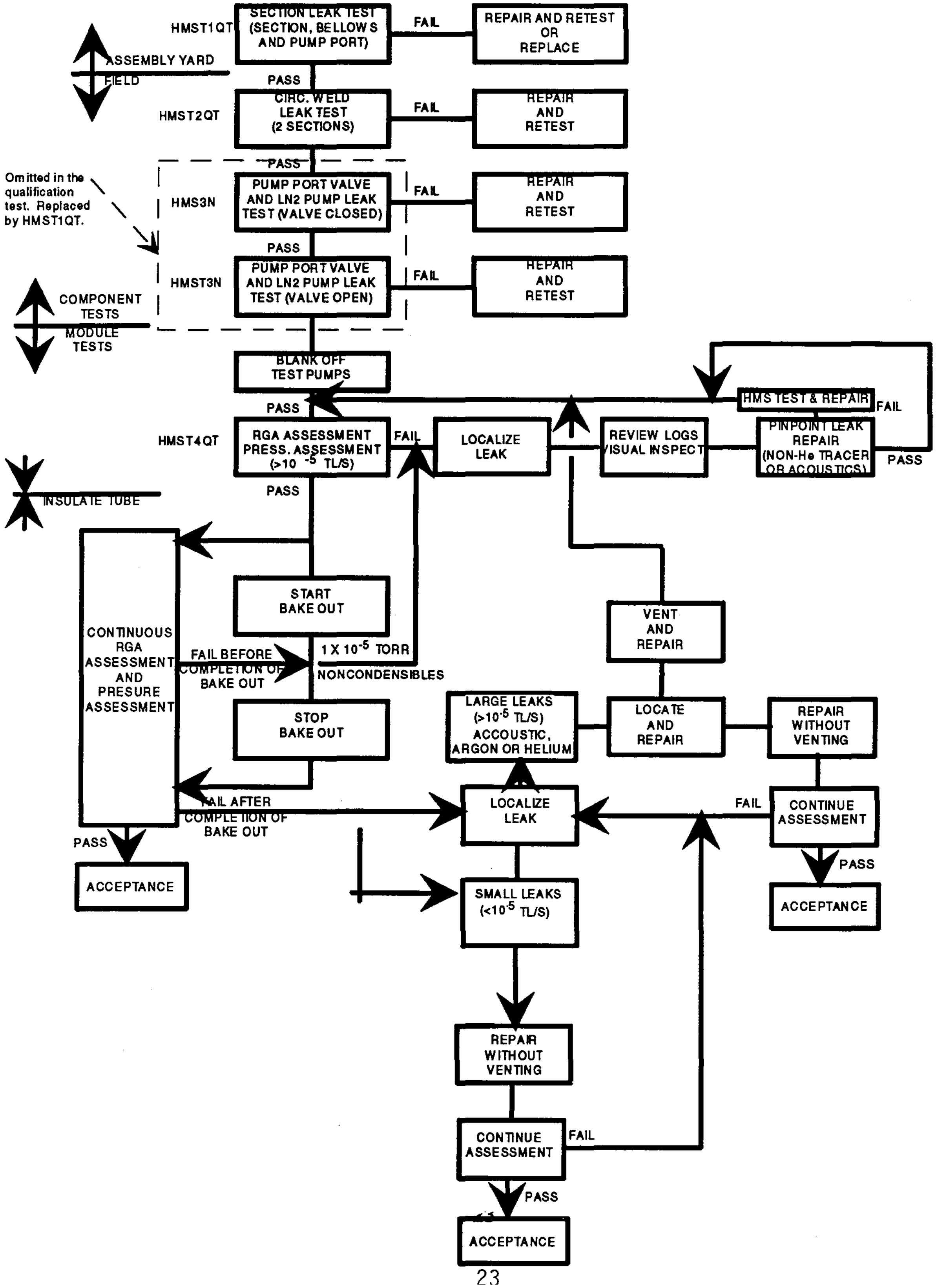
ID	Title	Directly from Detailed Design	QT Addenda to Detailed Design	QT Specific
Material Specifications				
C-240-0186	Coil Material Specification	X		
C-CMBS1	Coil Material Bake Specification	X		
WMS-ER308L	Cleaning and Bakeout Procedure of ER 308L Weld Wire	X		
C-240-0187	Baffle Material Specification	X		
C-CMBS1	Baffle Material Bake Specification	X		
C-240-0194	Expansion Joint Material Specification	X		
Purchasing Specifications				
C-BT-QT	Qualification Test Beam Tube Sections			X
C-EJ-QT	LIGO Beam tube Expansion Joints Qualification Test			X
C-SUPT-1	Beam Tube Support Specification	X		
CBAF-1	Baffle Fabrication Specification	X		
C-PORT-QT	Pump Port Specification			X
C-PORTPAD-1	Pump Port Reinforcing Pad Specification	X		
C-VAC-1	Vacuum Stiffener Specification	X		
C-SUPSTF-1	Support Ring/Baffle Ring Fabrication Specification	X		
Fabrication/Installation Procedures				
FSQT	Beam Tube Can Section Fabrication Sequence for LIGO Qualification Test Addenda		X	
ISQT	Beam Tube Can Section Installation Sequence for LIGO Qualification Test Addenda		X	
FPCircumferential	Fitting/Purge Procedure for Circumferential Butt Welds for LIGO	X		
FPStiffener	Fitting/Purge Procedure for Stiffener Attachment Welds for LIGO	X		
FPPumpPort	Fitting/Purge Procedure for Pump Port Attachment Welds for LIGO	X		
MI	Material Traceability	X		
IR	Receiving Inspection	X		
DCQT	Dimensional Control		X	
Welding Procedures				
WPS-INDEX	Weld Procedure Index	X		
WPS-ER308S/GMA (w/PQR 4858)	Weld Procedure, GMA Welding for 304L Materials	X		
WPS-ER308L/Repair (w/PQRs 10029 & 4858)	Weld procedure, GMA for Repair Welding for 304L Materials	X		

CONSTRUCTION PLAN

- FSQT - Fabrication Sequence
- ISQT - Installation Sequence
- LIGOCPQT
- LIGOTPQT

LEAK TEST PROCEDURES

LEAK DETECTION DECISION TREE
QUALIFICATION TEST



QUALIFICATION TEST PUMP DOWN AND OUTGASSING TEST PROCEDURE

- Evacuate to $<10^{-5}$ torr
- Evaluate air signature and outgassing rates
- Insulate tube
- Bake out tube and monitor outgassing rates during bake out
- Monitor outgassing rates during cooldown
- Evaluate air signature and outgassing rates at ambient temperature

BAKEOUT PROCEDURE

- Insulation
- Temperatures
- Duration
- Electric Resistance Heat Cable
- I^2R Method

DATA ACQUISITION PROCEDURE

- Written Documentation
- Computerized Data Acquisition
- Format
- Transmission

QUALIFICATION TEST REPORT

- Outline/Index
- Data Reporting
    - Test Documentation
    - Instrument Output

file:rwcbidoc050894.txt
to: Larry Jones and Gerry Stapfer
from: R. Weiss May 7, 1994
concerning: comments on CBI design documents

Note: The comments below concentrate on various parts of the CBI documents, in particular: the leak detection, cleaning, alignment and the qualification test (QT). The comments on other aspects come from a casual reading. The general impression I have of the documentation is that it is appropriate for the level after a conceptual design but not yet at the detailed final design level. The weakest part is the plan for the QT.

A misunderstanding in the entire document are the allowed leak rates:
For components (tube sections, expansion joints, fittings) 10^-10 required 10^-11 goal tl/s

For beam tube module 10^-9 required 10^-10 goal.

BOOK 1

Section 1

LIGOTP: Not consistent with the leak detecting tree. 1.4 does not involve helium leak hunting, it is the leak asessment and localization followed by other than helium leak detecting methods until all leaks are found at 10^-5 tl/s. Listing of equipment required should include air leaks and rga

Section 2

C-CMB21: 5.1 Which end of the coil will the hydrgen test coupons be taken from? Would recommend the inner end.

C-BMBS1: Overall policy question. There may be some advantages to anneal the steel for the baffles after they have been fabricated. The technical reason is that the surface will be more uniformally oxidized and not have bright patches from the welding.

C-BT-CO: 4.0 Tolerances, the .010" perpendicularity of the tube end must be explained. Is this .010" height from a plane that is perpendicular to the tube axis measured at a radius?

C-EJ-CO: 5.0 Leak rate requirements and goals not specified properly.

C-BAF-1: 0.1 Misunderstand function of the baffles. Purpose of the baffles is to attenuate grazing rays. 5.3 Should consider annealing baffles after fabrication. No mention of baffle serrations.

C-SUPSTF-1: The baffle rings have the tube mounting holes to the supports. How will these be phased correctly before welding the rings?

C-PORT-OP: 6.0 Confusion about leak specification

Section 3

General comments:

The weld torch central electrode polarity should be fixed
and the option as well as the QT should use the same polarity as the weld tests that were performed to establish the hydrogen outgassing by filler wire.

The weld inspection procedures are not spelled out adequately. Expected that there would periodic tests performed on sections of weld to determine the degree of overlap of the various passes for the vacuum welds. The tube fabrication will use microphotography on cut sections with etching to visualize the inner parts of the welds (much as was done by Sandia in the btd test). Is CBI so confident in the process and training of welders that they can assume that they can get away without periodic qualification of the welds in the field?

Section 4

FABSEQ: 2.6 How are markings put on the tubes for permanent identification from the manufacturing right through installation? 2.32 Are cutting fluids used in boring out the 10" pump ports. If so are they compatible with the cleaning techniques?

INSTALLSEQ: 2.X Will need technique to keep dirt and dust from being moved from outside walls of the tubes into the various clean areas. The whole business of maintaining a clean environment is primarily a matter of attenuation per stage of dirt isolation. The attenuation per stage is probably no more than a factor of 100. So one has to think carefully of dirt brought in from transitions in the assembly and from outside the clean areas into the clean areas.
This may require wind screens and other secondary movable structures around the sensitive assembly area. Recent calculations also show that direct solar illumination of the tube during the assembly will cause too much distortion, so a sun screen is also indicated.

FPCIRCUMFERENTIAL: 3.4 Taping the weld joint runs the risk for the tape adhesive to get lodged on the weld surface before welding.

CR1TSM: Comment under INSTALLSEQ 2.X really belongs here.

DC: 5.X The go/no go gauge shown for the baffle height measurement has a peak to peak tolerance of 0.16" (4 mm). What is the current best estimate for the fluctuation in the baffle height using the adopted procedures for fabrication and installation? LIGO project should look at this variability. First guess is that it is ok but marginal, would like to make further estimates.
8.X The final values for all mensuration on the tubes should be maintained in computer accessible formats.

MODSEQ: Overall procedure is much too sketchy. 2.3 does not involve Helium test
2.6 not consistent with leak detecting tree.

VI5 and VI8: Do not include microphotometric techniques to establish weld pass overlap.

Section 5

CLCOUP, CLCOUPA, CLCOUPA0, CLCOUPA1: Has nothing to do with option or QT. If these included flow rate and scaling to cleaning for QT or option, they would have relevance.

CLALT: Also is not relevant to QT or option. For the record it should say hydrogen outgassing not outgassing since hydrocarbons were not measured.

CL2N: Same comment for attenuation of dirt as for INSTALLSEQ

Section 6

Overall: Misunderstanding of component and module leak size requirements and goals.

HMST1N: Does the leak detecting casket accomodate the tubes with pumpout ports. Even after the analysis presented at the FDR am not persuaded of the need for the time of flight measurement. Sequential bagging will probably do as well on the, hopefully, few tubes requiring additional leak hunting.

HMST2N: 3.6 How to avoid covering possible leaks on the circumferential welds by applying Apiezon Q or electrical putty to the seal as it crosses the weld?

HMSTN3: Not clear in my mind anymore. If HMSTN1 will test the pump port weld then the technique presented here will test whether the flanges and the valve leaks. If HMSTN1 does not test the weld, the procedure as described will also not test the weld.

HMST4N: Is not consistent with the leak detection tree. The techniques to be used involve different tracer gases depending on the leak size and the stage of the process. Also the air signature assay and leak localization will require a calibrated air leak at a mid point of the module to set up the rga. The data should be recorded in the same manner as in the QT with state vectors and instrumentation vectors as well as continous computer recorded files of pressure vs time. The description still assigns the responsibility of the bake to the project.

The leak assessment and localization techniques using the rga must be rewritten.

HMST5N: 1.2.5 The expectation is that HMST5N will be used after leak assay and localization techniques have required it. The localization will provide section lengths that are suspect. The procedure HMST5N will begin in these regions of the module. 3.23 For leaks less then 10^-5 tl/s we could contemplate repair by other than air release and rewelding. This may be important in saving time and money to avoid rebake. CBI has not addressed this type of repair in HMST5N.

COUP-01: The test does not require measurment of amu values other than 2. CBI has mixed up the requirementes for the QT and the coupon hydrgen evaluation.

Section 7

ALI-1: 5.3 Attention should be given to minimize dust and dirt entering the covered space while cutting out the radom in the concrete cover.

Assume that the procedure marks the beam tube position at the support before a new section is put in place. After the section is placed and before welding, it is positioned by GPS referenced optical methods. Then when the cover is put in place, the radom is cut above the support so that the GPS position of the tube center can be established. I got lost in the description of the procedure.

QP-GPS-1: The procedure looks like a method to layout the tube supports but not to set up the alignment of the tubes once in the supports.

How long will CBI carry the alternate alignment procedures given in ALI-A, ALM-A,ALI-C,ALM-C. How will the decision be made to use ALI-1?

BOOK 2

Section 5

Many of the figures are in the state of preliminary design drawings. In the old days before computer cad systems, they would be ready for the design draftsman to make the detailed design - placement of holes, tolerances, structural element dimensions, etc. Looks like there is still much to be done before these drawings can be turned over to machinists or fabricators.

BOOK 3 QT TEST PROCEDURES

General Comments

The QT needs a time ordered layout of the steps, procedures and anticipated times. Without such a schedule and flow chart, it is hard to evaluate the planning for the QT.

The attempt to characterize the procedures in terms of their applicability to the option is partially dealt with in the index to Book 1 and in section 1 of Book 3. Once a time ordered layout is made for the QT, the evaluation of whether a specific step is a direct test, or a test by similarity and analytic extension to the option will be easier to make.

With such a sequence of steps and schedule in hand, a review of the QT makes sense. It is not ready given the state of the current planning.

Introduction

Some corrections: Air signature tests will be made both before and after bake. A major goal of the QT is to measure the outgassing spectrum after the bake. Thought that only one baffle would be involved in the QT.

Section 1.0 LISTING OF TEST ITEMS AND CALCULATION ITEMS

Structural Performance of the Beam Tube Sections

Environmental thermal gradients will not be the same in the QT and in the option.

Expansion joints

The expansion joints in QT may not be the same as in option (hydroformed vs welded section). No fatigue testing will be done in the QT

Supports

Will the option adjustment jigs be tried in the QT.

Baffles

How will possible motions of the baffle(s) before to after bake be measured?

Coupon outgas testing

Is the plan to make tube, expansion joints, baffles and 10" pump port from different materials for the QT?

Beam Tube Manufacturing

What is being planned to qualify tubes made of different sheet width or by different fabricators?

Work Conditions

The wind, sun and dirt of a field assembly will not be experienced in the QT.

Leak testing

The air signature tests in the QT and the option are not equivalent. The air signature tests should be much easier in the QT since the gas load for a given leak size will be the same but the outgassing load will be different in the ratio of the tube surface areas. The leak localization techniques using the air signature will not be tested in the QT.

Bakeout

Question the technique for injecting the current into the direct heating of the tubes by using a stiffening ring as the electrode. The spreading resistance has to be calculated and the heat leak through the supply leads has to be determined. The scheme used in the btd tests should not be rejected out of hand. Direct heating is required, not an option.

Dimensional control

The longitudinal motion at the bellows should be measured during the bake. The transverse motions of the tubes should also be measured during the bake to establish isotropy of the expansion joints.

Section 2

Figure SK-QT1 Thrust restraint on fixed supports. Has a thermal analysis been carried out for this support? What is the anticipated heat leak during bake?

QT Stiffened end head: How is the weld to the tube to be made? The end could also become the feeder for the direct heating current if an additional short section of 48" tube is used for the current clamp as was done for the btd. This serves to give the correct spreading resistance as well as offer thermal isolation for the leads.

2.2 QT Pumping and Outgassing System

The reduction in the pumping speed to 600 liters/sec is needed during bake and after. It is not a requirement during intial pump down and leak hunting. The outgassing rate for other than hydrogen is expected to be much smaller than 10^-12 tl/s/cm^2.

2.3 QT Procedures

Leak testing, coupon testing, bakeout, and data acquisition procedures are not just QT specific. In fact, the data acquisition procedure for the full module test in the option would use the same data logging scheme as the QT. I notice descriptions in the option phase reverting to log plots and notebooks.

PROCEDURES (in addition to comments already made for the same procedures in the option part.)

C-BT-QT: Same question as above concerning definition of perpendicularity. 4.0 Don't understand statement that "straightness will be critical in 10% of the tubes". 6.2.2 Do not under stand the restriction against use of water/detergent cleaning by fabricators if the the tube sections are again to be steam cleaned after leak hunting.

C-EJ-QT: Same comments on perpendicularity and cleaning as above.5.1 the same overall issue with the leak detection requirement and goal and finally a prescription should be given for keeping the belows from collapsing during leak test pump out.

C-PORT-QT: Not clear to me that the same technique for placing the hole in the

Revised sections handed out at FDR still need to be read carefully

FSQT

ISQT

DCQT

LIGOCPQT

CL1QT

CL2QT

CL3QT

CRWAQT

LIGOTPQT

HMST1QT

HMST2QT

HMST4QT

WBS #160 Beam Tube Configuration

The final beam tube configuration is based on the optimization of all the beam tube components. Considerations include the available beam tube length, baffle spacing, expansion joint spacing and support spacing. The design of each component depends on the configuration and spacing of components. This section discusses the how the components are influenced and how the optimum configuration was determined. This Section is broken down in the following headings:

- Contractual Requirements
- Beam Tube Wall Thickness
- Beam Tube Diameter
- Beam Tube Vacuum Stiffener Design
- Beam Tube Length
- Beam Tube Fatigue during Transport
- Expansion Joints
- Beam Tube Configuration
- Beam Tube Structural Analysis
- Foundation Requirements
- Grounding of the Beam Tube during Construction
- Tube to Chamber Interface
- Component Quantity Summaries of the Beam Tube Modules

Contractual Requirements

The contractual requirements of the beam tube are defined in LIGO Specification 1100004. The following items are the key requirements of the beam tube.

- The installed beam tube shall meet the clear aperture requirement of 1.07 m.
- The beam tube modules shall be field assembled from factory built sections. Lengths shall be limited by practical shipping considerations.
- The beam tube shall satisfy applicable requirements of ASME Section VIII, Division 1. The beam shall also be designed to withstand external load such as insulation, wind load & snow during construction and seismic loads.
- The expansion joints shall accommodate the expansion and contraction of the beam tube as well as aid alignment during installation and adjustment.
- The supports shall be designed to support the tube and applicable loads Thermal contraction and expansion must be allowed to occur without causing a stick-slip motion that results in impulsive mechanical or acoustic noise.

Beam Tube Wall Thickness

The LIGO beam tube modules will have an as-ordered thickness of 0.127", with a specified overtolerance and undertolerance of +0.003" and -0.007", respectively. The rationale behind this selection will be discussed shortly.

A significant limitation upon the LIGO beam tubes is that the maximum tube wall thickness cannot exceed 0.130" (for hydrogen outgassing purposes). Given the large diameter of the beam tube (48$^{3}/_{4}$" inside diameter), it is desirable from a structural standpoint to maximize the tube wall design thickness as much as possible. The ASME Code, Paragraph UG-16(c) states the following:

> "Plate material shall be ordered not thinner than design thickness. Vessels made of plate furnished with an undertolerance of not more than the smaller value of 0.01 inch or 6% of the ordered thickness may be used at the full design pressure for the thickness ordered. If the specification to which the plate is ordered allows a greater undertolerance, the ordered thickness of the material shall be sufficiently greater than the design thickness so that the thickness of the material furnished is not more than the smaller of 0.01 inch or 6% under the design thickness."

Standard mill tolerances for coil plate material is ordered thickness (+0.010", -0.010"). In order not to exceed the 0.130" maximum permissible tube wall thickness, the ordered thickness of the tube material, with standard mill tolerances, would be 0.120", resulting in tube wall thicknesses between 0.130" and 0.110". Per the provisions of Paragraph UG-16(c) above, the design thickness of the tube wall for this case will be 0.117".

Several mills can provide mill tolerances of one-half the standard mill tolerance (+0.005", -0.005") at no additional cost. In order not to exceed the 0.130" maximum permissible tube wall thickness, the ordered thickness of the tube material, with one-half standard mill tolerances, would be 0.125", resulting in tube wall thicknesses between 0.130" and 0.120". Per the provisions of Paragraph UG-16(c) above, the design thickness of the tube wall for this case will be 0.125".

However, by ordering the tube material with a thickness of 0.127", with mill tolerances of (+0.003", -0.007"), the range of tube wall thicknesses will still vary between 0.130" and 0.120" -- in essence one-half standard mill tolerances are still being obtained without additional cost. Per the provisions of Paragraph UG-16(c) above, the design thickness of the tube wall for this case will be 0.127".

.127 THICKness
48.75

Therefore, the three possible as-ordered thicknesses of the beam tube wall material are as follows:

Ordered Thickness	Specified Tolerances	Design Thickness
0.120"	+0.010", -0.010"	0.117"
0.125"	+0.005", -0.005"	0.125"
0.127"	+0.003", -0.007"	0.127"

From a design standpoint, it would be preferable to use an ordered thickness of 0.127" in order to maximize the design thickness of the tube wall. However, there is a tradeoff to consider. Using a thinner tube wall is preferable from the standpoint of reducing the material costs of the beam tubes, but will result in a higher number (and thus cost) of beam tube stiffeners.

A trade study was thus performed to investigate whether it was more advantageous to have a thin tube wall with many stiffeners, or a thick tube wall with fewer stiffeners. Refer to the attached table "Cost Comparison: Wall Thickness vs Component Costs of Tube and Stiffeners". The parameters of this trade study, as reflected in the component costs in the referenced table, are as follows:

- Total cost of beam tube material is approximately $5,000,000. This is a budget price from ARMCO, and includes costs for coil manufacturing, coil baking, outgas testing, leveling and slitting, shipping to the tube manufacturer, and the value of scrap. This value is based upon an ordered thickness of 0.127" for a 48.75" I.D beam tube, and it is an assumption of this study that this price can be scaled in proportion to both the tube diameter and the ordered plate thickness.

- Tube manufacturing cost of $36 per foot, based upon a budget price from Tubetec. The total length of beam tube assumed for this study is 51,340 feet, for a total tube manufacturing cost of $1,848,300.

- Beam tube stiffener spacing is determined per the ASME Code, with a factor of safety of 3 against buckling due to hoop (i.e., circumferential) compression.

- Beam tube stiffener cost of $41 per stiffener, based upon a budget price from Meyer Tool & Mfg. The cost of welding a stiffener to the tube is $60 per stiffener, based upon an estimate from CBI's Welding Dept.

The results of the trade study indicate that it is more cost effective, albeit slightly, to use a thicker beam tube wall with fewer beam tube stiffeners, regardless of the beam tube diameter selected.

There are, however, other very important factors unrelated to this particular trade study which make it advantageous to maximize the tube wall thickness. Foremost among these reasons:

- The manufacture of a large diameter, thin-walled tube is difficult. The fabrication tolerances that will be imposed on the tube manufacturer can more easily be obtained by using the maximum permissible wall thickness.

- Maximizing the tube wall thickness will minimize the problems associated with transportation, handling and welding of the beam tubes sections.

Therefore, the LIGO beam tube modules will have an as-ordered thickness of 0.127", with a specified overtolerance and undertolerance of +0.003" and -0.007", respectively.

Beam Tube Diameter

The diameter of the LIGO beam tubes must be large enough such that, after the effects of all deflections and tolerances of fabrication and construction are accumulated, the clear aperture of the completed modules between reference monuments, spaced at 250 meter intervals, is no less than 1.07 meters (42.13 inches). On the other hand, the diameter of the tube must not be made unnecessarily large simply in order to accomodate the required aperture, since additional material, fabrication and construction costs are naturally incurred as the tube diameter is increased. The key to selection of the "ideal" diameter is to accurately identify and quantify all associated tolerances which can be achieved with the fabrication methods and construction procedures to be prescribed. One of the functions of the Quality Assurance program which is to be implemented is to ensure compliance with these tolerances in order to eliminate the risk of interruption of the construction process to correct a failure to meet the minimum clear aperture requirement.

It has been established that the following parameters will have a direct influence on the determination of the required beam tube diameter, although all the parameters below do not necessarily interact with each other at all times. The influence of each of these parameters will be briefly discussed.

1. Required radius of clear aperture
2. Baffle radial projection
3. Baffle radial projection tolerance
4. Tube diameter tolerance
5. Tube-to-support ring fitup gap
6. Support ring diameter tolerance
7. Tube lateral offset due to end perpendicularity
8. Deflection of the beam tube

9. "Swing" of guided supports
10. Support adjustment tolerance
11. Surveying accuracy tolerance
12. Out-of-straightness of the beam tube

1. Required Radius of Clear Aperture. As stated earlier, the minimum required clear aperture between reference monuments, spaced at 250 meter intervals, is to be no less than 42.13" (1.07 meters). Therefore, the minimum required radius of the clear aperture is 21.07". This aperture is not required to be maintained during the 30 day, 300°F bakeout of the beam tube modules.

2. Baffle Radial Projection. Per LIGO Drawing 1101004 Revision A, dated 04-02-93, the internal baffles are to have a nominal radial projection of 2.36" (6.0 centimeters). The baffles, projecting from the tube wall, must not encroach upon the required aperture.

3. Baffle Radial Projection Tolerance. Per LIGO Drawing 1101004 Revision A, dated 04-02-93, there is a +/- 0.08" (+/- 0.2 centimeter) tolerance on the nominal radial projection of the baffles. Only the overtolerance of +0.08" will affect the clear aperture. This projection tolerance value of 0.08" is slightly larger than, but consistent with, the observed results of the prototype baffles fabricated by CBI.

4. Tube Inside Radius Tolerance. Based upon measurements on the 48" I.D. prequalification beam tube section supplied to CBI by Tubetec, the circumferential variation of the tube from its theoretical circumference of was +/- 0.344". If it is assumed that the 48.75" I.D. tubes (with a theoretical circumference of 153.95") will have a maximum undercircumference of 0.500", the resulting inside diameter of these tubes will be 48.59". The corresponding inside radius of these tubes will be 24.30", or 0.075" below the theoretical radius. This effect of this variation in tube radius must be taken into account.

5. Tube-to-Support Ring Fitup Gap. The inside diameter of the support ring will be machined in the field to within +/- 0.010" of the beam tube as-built outside diameter. As such, the tube-to-support ring fitup gap will be negligible and will not be considered as affecting the clear aperture.

6. Support Ring Outside Radius Tolerance. The outside diameter of the beam tube support rings is the reference point for the for the tube alignment procedure. Therefore, the outside diameter of the support ring will be machined in the shop to a diameter of 57.00" (+0.010", - 0.010") of the beam tube as-built outside diameter. As such, variation of the outside diameter of the support ring will be negligible and will not be considered as affecting the clear aperture.

7. Tube Lateral Offset Due to End Perpendicularity. The ends of the beam tubes will be fabricated such that the ends of the tubes are perpendicular to the tube axis within 0.010". This degree of perpendicularity is required in order to facilitate fitup and welding of the beam tubes to each other and to the expansion joints. However, since the ends of the beam tubes are not perfectly normal to the tube axis, when two beam tubes are welded together there will be a slight deviation from the "true" longitudinal axis of the two tubes, in effect a lateral offset of the ends of the two tube assembly. Based upon the required end perpendicularity of the tubes, the resulting lateral offset of the tube assembly ends is expected to be 0.160". Although the beam tube alignment and adjustment procedure will reduce the amount of lateral offset from the 0.160" calculated value, the full effect of this offset upon the clear aperture will be considered. This is a conservative approach.

8. Deflection of the Beam Tube. Deflection of the beam tube will affect the clear aperture in those area of the beam tube modules where internal baffles are spaced at 7 meters, nominal. In these areas, the effect of the beam tube deflection causing the baffles to encroach upon the aperture must be considered. The beam tube was modelled as a continuous system using the analysis program RISA-2D. The RISA-2D computer models are contained in the Detailed Design, and indicated that the maximum deflection of the beam tube is 0.08" and will occur under the dead weight of the beam tube, stiffeners and insulation. For aperture calculations, this value of beam tube deflection will be increased to 0.10" to account for any unforseen future dead loads on the beam tubes and material variations from those used in the analysis. This is a conservative approach, since in the field the beam tubes could be oriented such that the expected dead load deflection is partially or totally offset by the inherent out-of-straightness of the beam tube.

9. "Swing" of the Guided Supports. At the guided supports, the beam tube is supported by hangar straps which permit the longitudinal movement of the beam tube during the 30 day, 300^{o}F bakeout of the beam tube modules as well as during daily expansion and contraction of the beam tube due to daily thermal gradients. When the beam tube expands and contracts due to thermal effects, the hangars swing, permitting the "noiseless" movement of the beam tube. As the hangars swing, the center of the beam tube is raised or lowered vertically from its neutral position. Under the maximum expected daily thermal gradient, the center of the beam tube will move 0.007" vertically. The effect of this movement upon the clear aperture must be considered.

10. Support Adjustment Tolerance. It is expected that the fixed and guided supports will be adjusted to within 0.063" of their desired position. The effect of this movement upon the clear aperture must be considered.

11. Surveying Accuracy Tolerance. Trimble Navigation has stated that the Global Positioning System which will be used for alignment of the beam tubes, and determination of aperture, will provide a measurement accuracy of +/- 0.354" (+/- 9 millimeters). may be better

12. Out-of-Straightness of the Beam Tube. In those areas of the beam tube modules where the baffles are spaced at a nominal 21 meter spacing, the baffles are located only at beam tube support locations. Thus, the effects of tube out-of-straightness will not result in any infringement upon clear aperture, since there are no intermediate baffles in these areas. However, in those areas of the beam tube modules where the baffles are spaced at a nominal ~~6~~ 7 meter spacing, the effects of tube out-of-straightness must be ← considered to prevent these baffles from encroaching upon the aperture. Therefore, those beam tubes that will be placed in these regions of the beam tube modules will be required to have an out-of-straighness of no more than 0.125" to limit their effect upon aperture.

The effects of these parameters upon the required, or "ideal", beam tube diameter must be considered in two separate regions of the beam tube modules: in the area where baffles are spaced at 21 meters (nominal) and the area where baffles are spaced at 6 meters (nominal). The following table illustrates which of the parameters discussed above will affect the beam tube diameter in these area.

Parameter Number	Affects Diameter @ 21 m Baffle Spacing?	Affects Diameter @ 6 m Baffle Spacing?
1	Yes	Yes
2	Yes	Yes
3	Yes	Yes
4	Yes	Yes
5	No	No
6	No	No
7	Yes	Yes
8	No	Yes
9	Yes	Yes
10	Yes	Yes
11	Yes	Yes
12	No	Yes

The additive effect of the above parameters upon the required inside diameter of the beam tube is illustrated in the attached table, "Parameters Affecting Beam Tube Diameter". As the table shows, the "stackup" of the effects of the listed parameters indicates that a beam tube with a nominal inside diameter of 48 3/4" is necessary to provide the required clear aperture of 42.13" (1.07 meters).

Note that this inside diameter was obtained by assuming a "worst case" scenario of all of the maximum tolerances occuring simultaneously to affect the aperture. In reality, however, the upper bounds of these tolerances will most likely not be realized simultaneuously.

Use Gauss
Distribution
Function

Beam Tube Vacuum Stiffener Design

Due to the very large number of beam tube stiffeners that will be required for the 15.6 kilometers of beam tube, every effort has been made to maximize the spacing of the beam tube stiffeners without compromising the structural integrity of the beam tube given the loading conditions that can be expected.

As a starting point, the provisions and safety factors of the 1992 ASME Boiler & Pressure Vessel Code, Section VIII, Division 1, Part UG were initially used to size and space the beam tube stiffeners. In the design of vacuum vessels, the ASME Code utilizes a factor of safety of 3 against buckling of the vessel due to compressive stresses induced by vacuum. However, the ASME Code does not contain any requirements or guidelines for the maximum depth-to-thickness (d/t) ratio of stiffener rings to preclude local buckling of the stiffeners. Therefore, the local buckling criteria in Table B5.1 of the American Institute of Steel Construction (AISC) Manual of Steel Construction, 9th Edition, were utilized. The AISC criteria recommends that "plates projecting from compression members" have a d/t ratio less than $95/(Fy)^{0.5}$ to preclude local buckling.

The calculations for the design of the beam tube stiffeners per the ASME Code, with a factor of safety of 3, are contained in the Detailed Design. As the calculations show, the beam tube stiffeners, 304L stainless steel bars $^3/_{16}$" thick x $1^3/_4$" deep, must be spaced no farther than $26^1/_2$" apart to provide a factor of safety of 3 against circumferential buckling of the beam tube. The $^3/_{16}$" x $1^3/_4$" bars were selected for two reasons. First, they provided the required moment of inertia of the combined stiffener-shell section as required by ASME. Second, with a d/t ratio of 9.3, the bars were well below the AISC local buckling limitation of 21.7. Refer to the provided calculations if additional detail is required.

The LIGO beam tube modules are not ASME Code stamped. Therefore, to finalize the design of the beam tube stiffeners, a reduced factor of safety of 2.5 against buckling of the vessel due to compressive hoop stresses in an effort to increase the spacing between stiffeners beyond that required by ASME. This factor of safety will provide an adequate safety margin while, at the same time, decreasing the total number of beam tube stiffeners required. The use of a factor of safety of 2.5 is consistent with industry practice for the design of non-code stamped vacuum vessels. CBI and its competitors have, in the past, designed non-code stamped vacuum vessels using this factor of safety without encountering any operational difficulties.

The calculations for the design of the beam tube stiffeners, using a minimum factor of safety of 2.5, are contained in the Detailed Design. As the calculations show, the beam tube stiffeners, 304L stainless steel bars $^{3}/_{16}$" thick x $1^{3}/_{4}$" deep, must be spaced no farther than 30.0" apart to provide a factor of safety of 2.65 against circumferential buckling of the beam tube. This represents a stiffener spacing 13 percent greater than that permitted by ASME. Refer to the provided calculations if additional detail is required.

There is adequate justification for not pursuing an even greater spacing of the beam tube stiffeners. One of the shortcomings of the ASME code is that it contains no provisions whatsoever for investigating the adequacy of the beam tube, or any other vessel for that matter, against buckling under the combined effect of axial load, bending and external pressure. Since there are considerable longitudinal axial loads and bending moments acting on the beam tubes, in addition to the circumferential loads due to external pressure, there will be interaction between these loadings that should be considered. Therefore, as discussed in the WBS #160 section titled, "Beam Tube Structural Analysis", the beam tube was analyzed using the provisions of API Bulletin 2U, "Bulletin on Stability Design of Cylindrical Shells". The API Bulletin 2U provisions indicated that, under the combined effects of axial load, bending moment and external pressure, the 30" spacing of the beam tube stiffeners should not be increased any further. Refer to WBS #160, "Beam Tube Structural Analysis", for additional information on the API Bulletin 2U analysis of the beam tubes.

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The stiffener-to-shell attachment weld is a $^{1}/_{8}$" continuous fillet weld on one side of the stiffener only. This fillet weld terminates at, and does not cross over, the spiral weld in the beam tube. Therefore, a nomimal length of $^{1}/_{8}$" fillet weld is placed on the opposing side in the area of the spiral weld.

This fillet weld satisfies the ASME Code on the basis of strength considerations. Refer to the design calculations provided. However, this one-sided weld does not satisfy the minimum attachment weld requirements of Paragraph UG-30. Since the LIGO beam tube modules are not ASME Code stamped, there is adequate justification, both structurally and economically, to take exception to the minimum attachment weld requirements of the ASME Code.

One issue of concern is the fact the the beam tube stiffeners, welded on one side only, were found to rotate as much as 6 degrees from the vertical. As the design calculations contained in the Detailed Design indicate, the moment of inertia of the $1^{3}/_{4}$" x $^{3}/_{16}$" stiffener will be reduced approximately 1 percent, from 0.0837 in^4 in the vertical (unrotated) position to 0.0828 in^4 when rotated 6 degrees from the vertical. The moment of inertia of the combined stiffener-tube section, however, is reduced only 0.6 percent, from 0.2331 in^4 in the vertical (unrotated) position to 0.2317 in^4 when rotated 6 degrees from vertical.

The ASME Code does not contain any provisions for the degree of "tilt" that stiffeners may have. Instead, as long as the moment of inertia of the combined stiffener-tube section exceeds that required by the Code, the stiffener is adequate.

As the design calculations contained in the Detailed Design indicate, the $1^{3}/_{4}$" x $^{3}/_{16}$" beam tube stiffeners, even if rotated 6 degrees from the vertical, still provide a factor of safety of 2.65 against buckling of the beam tube due to hoop compression. Again, as mentioned in preceding paragraphs, note that this factor of safety is not in accordance with the ASME Code factor of safety of 3 for hoop compression, but still exceeds the minimum factor of safety of 2.5 that was used for design.

The rationale behind the fabrication procedure for the beam tube stiffeners is provided in WBS #260, "Stiffener Fabrication Process".

Beam Tube Length

The overall cost of the beam tube modules can be reduced by maximizing, within the limits of practicality, the length of the individual beam tube sections. These savings are realized through a reduction in the total number of tube-to-tube circumferential butt welds and associated fitup costs, as well as a reduction in the total number of shipments from the tube manufacturing facility to the Hanford, Washington and Livingston, Louisiana construction sites.

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There are, however, practical limitations that must be considered in determining the maximum length of the beam tube sections. Primary among these limitations is constructability. Once delivered to the construction site, the individual tube sections should be of a length that is not difficult for the field personnel to handle. Individual tube sections that are too long will be difficult to handle, thereby increasing the risk of damage to the tube sections and interruption of the construction process. Based upon CBI's extensive construction experience, it is expected that the maximum beam tube section length that can be handled in the field without impacting the overall construction process is 70'.

From the standpoint of the overall beam tube module configuration, a maximum tube length of 65' is desirable for a several reasons. First, and most important, a maximum tube length of 65' permits the internal baffles to be located at points of support having a controlled diameter, with baffle spacings such that additional baffle stiffener rings (i.e., above and beyond those already present for the support of the beam tubes) are unnecessary. Second, longer spans add more bending moment into the beam tubes, decrease the allowable compressive stress of the tubes, and reduce the amount of differential settlement that the beam tube can be subjected to, without compromising the structural integrity of the beam tube, between adjacent supports (Explanation: the added compressive stress in the longer beam tube, caused by the increased bending moment, causes the total tube compressive stress to approach the allowable tube stress. This decreases the stress "reserve" that is available to withstand differential settlement).

Another limitation to be considered is the costs associated with transportation of the beam tube sections from the tube manufacturing facility to the constuction sites. For beam tube sections beyond 65' in length, a premium of approximately $1.15 per mile above regular transportation costs would be imposed by the trucking companies in order to provide a required escort. This additional premium of $1.15 per mile for tube sections longer than 65' represents, on average, a 52 percent increase in transportation costs (on a per-mile basis) over those for tube sections with a maximum length of 65'. Therefore, even though using beam tube sections longer than 65' would result in a lesser number of truck loads, total transportation costs increase nonetheless for lengths in excess of 65' due to the added $1.15 per mile premium on transportation rates.

A trade study was conducted to determine the impact of various lengths of beam tube sections against the overall transportation costs of the beam tube sections. Refer to the attached table, "LIGO Cost Summary -- Tube Length Impact", for a more detailed breakdown of costs. The results of this trade study are summarized in the attached chart, "LIGO Project Trucking Cost Summary".

This table and chart shows transportation cost summaries based on three different tube suppliers (Split Suppliers, Tubetec and Northwest Pipe). However, as will be discussed in WBS #220, "Tube Manufacturing Process Study", the preferred tube supplier is Tubetec. The trade study, therefore, limits itself only to the costs associated with using Tubetec as the tube supplier. The chart indicates that trucking costs increase substantially when the length of the beam tube sections exceed 65'.

Therefore, the longest length of beam tube that will be used is 65'-0". Refer to the WBS #160 section titled, "Beam Tube Configuration", for a discussion of the lengths of specific beam tube sections.

Beam Tube Fatigue during Transport

The 65 foot long beam tube sections were investigated for loads induced during transport of the tubes from the manufacturer to the construction sites. A 1g acceleration was assumed to act on the tube sections in any one direction. These transport loadings can cause longitudinal stresses in the tube due to beam-type bending and circumferential surface stresses due to ovaling of the tube.

Detailed calculations for the analysis of the beam tube sections during transportation can be found in the Detailed Design. These calculations assumed that the beam tubes were transported by a truck averaging 40 miles per hour between Tubetec in Florida and the construction site in Hanford, Washington. It was also assumed that the tubes were subjected to the 1g loading once a second during transportation, resulting in approximately 2,500,000 applications of this load. The results and conclusions of the analysis will be briefly discussed.

The beam bending mode was investigated by assuming the tube to be a simple beam supported at it's ends. The longitudinal stresses for this case were found to be very low (3,600 psi).

Fatigue under longitudinal stress was also considered. The first mode of vibration was investigated since this mode gives the highest stress levels in the tube. It was determined that the longitudinal membrane stress levels were below the endurance limit of the material. Thus, the beam tube sections could theoretically be subjected to an infinite number of 1g loadings during transport without any adverse effect upon the beam tube from fatigue.

The fatigue investigation was carried further by using simplified fracture mechanics methods. A 0.06" deep, 0.13" long flaw in the tube wall was assumed based on what could be detected using normal nondestructive examination procedures. An estimated cycle life was then determined. The stress level was assumed to cycle from 0 psi to yield (25,000 psi) at the flaw. Under these conditions, the cycle life of the tube was calculated to be 7,000,000 cycles. As stated earlier, the number of cycles of application of the 1g load during transport was determined to be 2,500,000 cycles. Thus, the beam tube sections will be adequate during transportation even in the unlikely event of a significant flaw being present in the tube.

Even though the estimated number of load cycles is less than the estimated cycle life of the beam tube sections, more than two points of support will be used during transportion of the tubes to further reduce the risks of fatigue failure.

Ovaling of the tube was also investigated. It was determined that, under dead load and a 1g transportation acceleration, the tube wall surface stresses approach the material yield strength. Therefore at each point of support the beam tube sections will be held round by the shipping supports. This will eliminate any concern of the tube forming cracks during shipment.

Expansion Joints

Since the expansion joints are an integral part of the beam tube, the requirements of Specification 1100004 apply. From the specification, there are three functional requirements of the expansion joint.

- Maintain The Vacuum Envelop

  The high level of vacuum required for LIGO requires the expansion joints to maintain leak tightness throughout the design life and design cycles.

- Accommodate Thermal Growth and Shrinkage

  During the operating condition, the design temperature range is -27° to 38° C (-16° to 100° F), which is the ambient temperature range for both sites. The number of complete thermal cycles (-27° to 38° C) has conservatively been taken as 7300, one cycle per day for 20 years. On the basis of the vendors' design per the EJMA sixth edition (Expansion Joint Manufacturers Association), the 7300 cycles do not control the expansion joint design.

  The bake out condition imposes the most severe condition on the expansion joint. The specified bake out temperature is 140° C ± 10. The expansion joints are designed to accommodate the thermal growth from 21° C to 150° C (70° to 302° F) for 20 complete cycles.

- Provide Flexibility Due to Differential Settlement

  To protect the beam tube from excessive differential settlement the expansion joint provides sufficient flexibility. By providing some degree of flexibility, the stresses in the beam tube, the forces in the supports and foundation are reduced. Sufficient flexibility is provided to insure that structural components are not over stressed before the clear aperture tolerance is violated.

There are two different expansion joint types that can be used. The two types are based on the thickness of the material used to make the expansion joint convolutions. One type uses a thin wall design for the convolutions and requires weld ends. The second type is a near full thickness design that uses one thickness for the entire expansion joint. The thin wall design uses material which is too thin to field weld directly to the 3.23 mm (0.127") thick beam tube. The factors that dictate the thinnest material that can be field welded to the beam tubes are weldability and ASME limitations. In this situation the material is considered too thin if it is thinner than 12 gauge material (2.67mm 0.105"). For the near full thickness design, material including 12 gauge and thicker will be used.

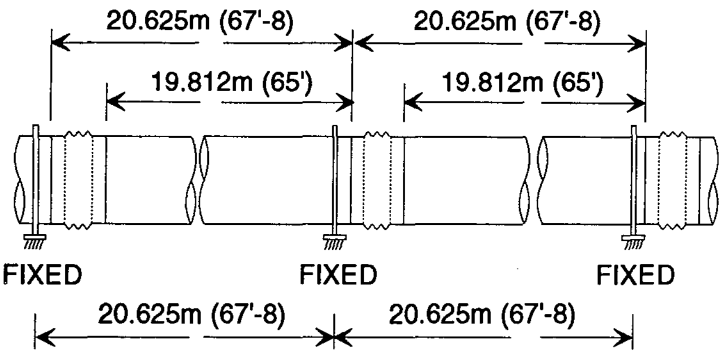
The trade off study between the two designs is discussed in WBS 230. On the basis of the cost and performance advantages, the near full thickness expansion joint will be used. The near full thickness design costs 20% less than the thin wall expansion joint. The near full thickness expansion joint does not impact the cost of the beam or supports. Eliminating the circumferential welds for the weld ends significantly reduces the risk of leaks and the associated difficulty in repairing these welds. The added longitudinal stresses on the tube during bake out is not a significant issue. The beam tube will be aligned before the bake out occurs. During bake out, the beam tube has sufficient capacity to handle a differential settlement of 14.7mm (0.579"). During operating conditions, the axial spring rate has very little influence on the beam tube capacity. The axial force due to temperature variation is only 1% (0.48 MPa, 69psi) of the beam tube capacity. The beam tube has sufficient capacity to handle a differential settlement of 25.7 mm (1.012) which is beyond the limit of violating the beam tube clear aperture. Thus, the clear aperture will be lost before the capacity of the beam tube is reached. The added loads to the supports are also insignificant. The longitudinal seismic loads are similar in magnitude compared to the bake out loads. Therefore, the near full thickness expansion joints are the obvious choice.

The expansion joint spacing is dictated by the support spacing, baffle spacing and the optimum beam tube section length. Various configurations were investigated using various expansion joint spacings. The results of this investigation are discussed later in this section (Beam Tube Configuration). The budget designs, budget prices and vendor selection for the expansion joints are all discussed in WBS 230.

Beam Tube Configuration

The initial configuration used a support spacing and an expansion joint spacing of 12.192m (40'-0). However, the optimum beam tube length was determined to be 19.812m (65'-0). On the basis of the 19.812m beam tube length, the expansion joint must have a spacing equal to a multiple of the beam tube length. To maintain this optimization, six beam tube configurations were investigated. Each beam tube configuration has special requirements for the supports and expansion joints.

Configuration #1 - Unguided expansion joint @ 20.625 m (67'-8)



This configuration is based on the initial configuration provided by Caltech. The expansion joint spacing (or support spacing) is based on a 19.812m (65') plus the length of the expansion joint. The helium leak test apparatus would be set up to test one tube section with one expansion joint. Thus, the expansion joint spacing and support spacing is 20.625m (67'-8). With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 43mm (1.7") axially during bake out. During normal operating conditions the expansion joint will contract 6.4mm (0.25") and extend 16.5mm (0.65"). This amount of movement can easily be obtained from a thin walled or near full thickness expansion joint.
- 768 Expansion joints are required, total for both sites.
- 768 Fixed Supports are required.
- 1540 circumferential weld seams are required. 1532 will be tube to expansion joint welds. Eight will be tube to tube welds.

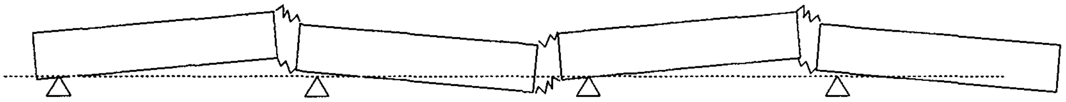
This configuration has the following advantages:

- One type of fixed support is required. Guide supports are not required.
- Large amounts of differential settlement can occur without damage to the beam tube.

This configuration has the following disadvantages:

- On the basis of overall beam tube costs, this is not the most cost effective configuration.
- This configuration does not meet EJMA or B31.3 guide requirements. A guide should not be located further than four diameters of the tube on both sides of the expansion joint. Four diameters is approximately 5m (16'). The closest support is much further away at 20.625m (67'-8).

- This configuration is not recommended by all expansion joint vendors and by a third party consultant. Some of the expansion joint vendors would supply expansion joints. However, they would not stand behind or provide a warranty on the expansion joint.
- Without properly guiding the beam tube, there is a significant risk of failure during the design life. Normally, the function of an expansion joint is to provide a pressure boundary and to accommodate thermal variation. The expansion joint life is determined by the number of cycles through a fatigue analysis. Configuration #1, imposes a third requirement on the expansion joint. It requires the expansion joint to act as a structural element, resisting shear and to provide stability. The expansion joint has some instability due to its flexible nature. A pattern of instability is illustrated in the figure below.



Given these new loadings, unknowns enter into the design of the expansion joint. The system would be allowed to oscillate. The amount of offset and rotations depends on the following:

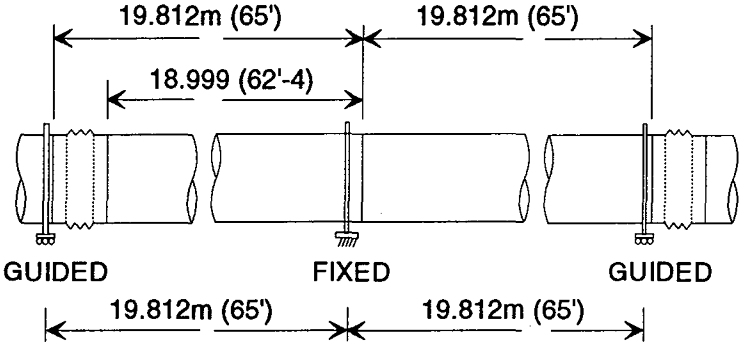
- Varying axial load due to thermal variations.
- Error in concentricity of the expansion joint.
- Amount of misalignment and differential settlement.
- Varying stiffness around the circumference of the expansion joint.
- The amount of added moment and rotation is amplified depending on the magnitude of items listed above.

Since the magnitude and the quantity of these load cycles are unknown, the life of the expansion joint can not be estimated.

It will also be noted that adding guides to the unguided side of the expansion was considered. However, this doubles the number of supports. Besides adding several technical problems, the cost is higher. As shown in the cost trade off, the cost of configuration #1 without additional guides already costs more than configuration #3.

In conclusion, since the behavior of the expansion joints is not acceptable, and this configuration is not the most cost effective, configuration #1 will not be used.

Configuration #2 - Unguided expansion joint @ 39.624 m (130 Ft)



This configuration is a modification of configuration #1. The spacing of the expansion joint is almost doubled. The helium leak test apparatus can only test one length. Thus, a tube without an expansion joint can be 19.812m (65') and a tube with an expansion joint must also be 19.812m (65'). Thus, a shorter tube section, 18.999m (62'-4) is joined with the expansion joint to make up the 19.812m length. With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 41mm (3.26") axially during bake out. During normal operating conditions the expansion joint will contract 10.9 mm (0.43") and extend 30.7 mm (1.21). This amount of movement can easily be obtained from a thin walled or near full thickness expansion joint.
- 400 expansion joints are required (total for both sites). This is 368 less than what is required for configuration #1.
- A total of 792 supports will be required. 400 will be fixed supports and 392 will be guide supports.
- 1208 Circumferential Weld Seams are required. 800 will be tube to expansion joint welds and 408 will be tube to tube welds. Overall, there are 332 less circumferential welds compared to configuration #1.

This configuration has the following advantages:

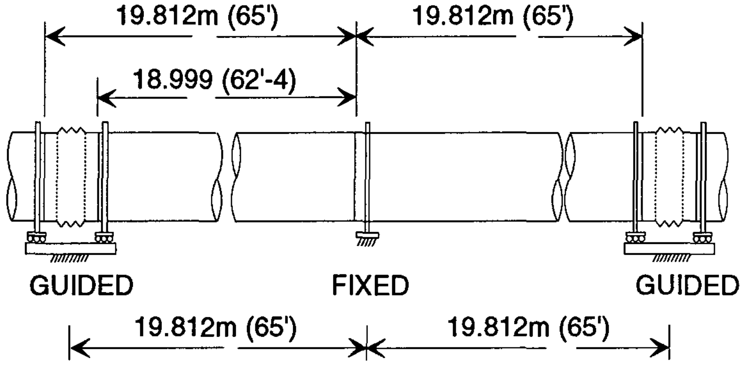
- One type of fixed support is required. Guide supports are not required.
- The number of expansion joints and circumferential seams are reduced.

This configuration has the following disadvantages:

- As in configuration #1, this configuration does not meet EJMA or B31.3 guide requirements. A guide should not be located further than four diameters of the tube on both sides of the expansion joint. Four diameters is approximately 5m (16'). The closest support is much further away at 19.812m (65').
- This configuration is not recommended by all expansion joint vendors and by a third party consultant.
- Without properly guiding the beam tube, there is a significant risk of failure during the design life. The situation is similar to configuration #1.

In conclusion, since the behavior of the expansion joints is not acceptable, configuration #2 will not be used.

Configuration #3 - Guided expansion joint @ 39.624 m (130 Ft)



This configuration is a modification of configuration #2. A guide support is added to properly guide the expansion joint The spacing of the expansion joint is at 39.624 m (130 Ft). This is nearly double the spacing of configuration #1. To helium leak test a consistent length, a shorter tube section is joined with the expansion joint to make a total length of 19.812m (65'). With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 41mm (3.26") axially during bake out. During normal operating conditions the expansion joint will contract 10.9 mm (0.43") and extend 30.7 mm (1.21). This amount of movement can easily be obtained from a thin walled or near full thickness expansion joint.
- 400 expansion joints are required (total for both sites). This is 368 less than what is required for configuration #1.

- A total of 792 supports will be required. 400 will be fixed supports and 392 will be guide supports.
- 1208 circumferential weld seams are required. 800 will be tube to expansion joint welds and 408 will be tube to tube welds. Overall, there are 332 less circumferential welds compared to configuration #1.

This configuration has the following advantages:

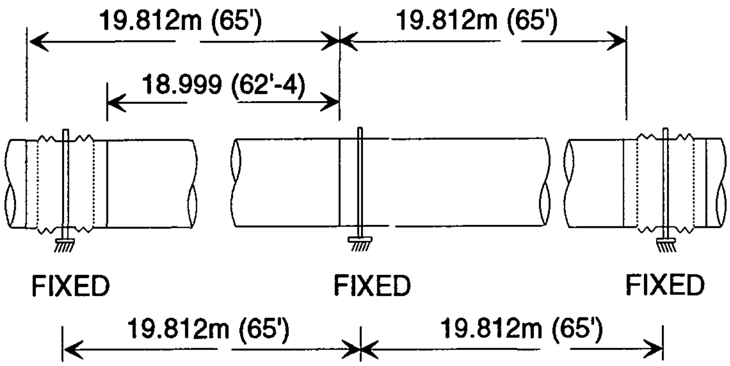
- With the guide supports, the configuration meets EJMA and B31.3 guide requirements.
- This configuration is preferred by all expansion joint vendors.
- Given the same rotational settlement or misalignment the amount of torsional rotation induced on the expansion joint is less compared to configuration #1.
- The number of expansion joints and circumferential seams are reduced.

This configuration has the following disadvantages:

- Although this configuration provides sufficient flexibility to account for differential settlement, it provides less flexibility than configuration #1
- Since there are tube to tube welds, the tolerance for squareness of the tube ends must be tighter.
- Higher foundation loads may occur by bending two tube sections straight while aligning the beam tube.

In conclusion, this is an acceptable configuration for the expansion joints.

<u>Configuration #4</u> - Double expansion joint @ 39.624 m (130 Ft)



This configuration is a modification of configuration #2. A double expansion joint is used to eliminate the need of a guided support. With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 41mm (3.26") axially during bake out. During normal operating conditions the expansion joint will contract 10.9 mm (0.43") and extend 30.7 mm (1.21). This amount of movement can easily be obtained from a thin walled or near full thickness expansion joint.
- 400 expansion joints are required (total for both sites). This is 368 less than what is required for configuration #1.
- A total of 792 supports will be required. 400 will be fixed supports that are required to resist moment and 392 will be fixed supports that are not required to resist moment.
- A total of 1208 Circumferential Weld Seams is required. 800 will be tube to expansion joint welds and 408 will be tube to tube welds. Overall, there are 332 less circumferential welds compared to configuration #1.

This configuration has the following advantages:

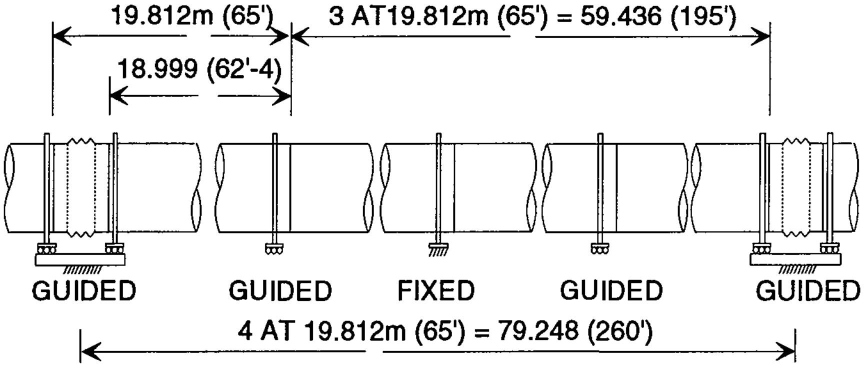
- One type of fixed support is required. Guide supports are not required.
- The number of expansion joints and circumferential seams are reduced.

This configuration has the following disadvantages:

- As in configuration #1, this configuration does not meet EJMA or B31.3 guide requirements. A guide should not be located further than four diameters of the tube on both sides of the expansion joint. Four diameters is approximately 5m (16'). The closest support is much further away at 19.812m (65').
- This configuration requires a special fixed support to resist rotation at the expansion joints. Other configurations do not require such a special support.
- This configuration is not recommended by all expansion joint vendors and by a third party consultant.
- Without properly guiding the beam tube, there is a significant risk of failure during the design life. The situation is similar to configuration #1.

In conclusion, since the behavior of the expansion joints is not acceptable, configuration #4 will not be used.

Configuration #5 - Guided expansion joint @ 79.248 m (260 Ft)



This configuration is a modification of configuration #3. The spacing of the expansion joint is doubled to 79.248 m (260 Ft). This is nearly four times the expansion joint spacing of configuration #1. To helium leak test a consistent length, a shorter tube section is joined with the expansion joint to make a total length of 19.812m (65'). With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 82mm (6.52") axially during bake out. During normal operating conditions the expansion joint will contract 21.8 mm (0.86") and extend 61.4 mm (2.42). This amount of movement can be obtained from a thin walled or near full thickness expansion joint.
- 200 Expansion joints are required (total for both sites). This is 568 less than configuration #1 and 200 less than configuration #3.
- A total of 792 supports will be required. 192 will be fixed supports, 200 will be guide supports at the expansion joints and 400 will be single hanger guide supports.
- 1208 circumferential weld seams are required. 400 will be tube to expansion joint welds, 604 will be tube to tube welds and 200 will be expansion joint to expansion joint welds. Overall, there are 332 less circumferential welds compared to configuration #1. It is the same amount of welds compared to configuration #3.

This configuration has the following advantages:

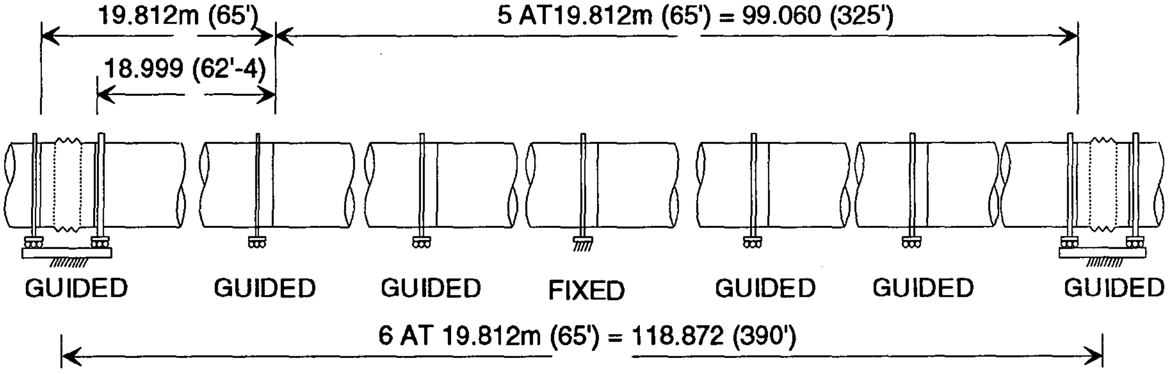
- With the guide supports, the configuration meets EJMA and B31.3 guide requirements.
- The number of expansion joints and circumferential seams are reduced.
- This configuration is the least expensive considering only the cost of the expansion joints.
- Given the same rotational settlement or misalignment the amount of torsional rotation induced on the expansion joint is less compared to configuration #1 and #3.

This configuration has the following disadvantages:

- The configuration is more difficult to align and can accommodate less differential settlement between supports.
- The expansion joint is two expansion joints welded together from configuration #3.
- Given the large axial movement, the guide supports at the expansion joints are not feasible. The movement is too large to use a hanger type of support. The hangers, made of bar or cable, need to bend too far. Another problem is, as the hanger swings, the tube lifts up. This has an effect on the clear aperture and requires a beam tube with a larger diameter.

In conclusion, although this is an acceptable configuration for the expansion joints, configuration #5 will not be used since the guide supports at the expansion joints are not feasible.

Configuration #6 - Guided expansion joint @ 118.87 m (390 Ft)



This configuration is a modification of configuration #3. The spacing of the expansion joint is tripled to 118.872 m (390 Ft). This is nearly six times the expansion joint spacing of configuration #1. To helium leak test a consistent length, a shorter tube section is joined with the expansion joint to make a total length of 19.812m (65'). With this configuration the following physical requirements are summarized below:

- Each expansion joint will be compressed 123mm (9.78") axially during bake out. During normal operating conditions the expansion joint will contract 32.7mm (1.29") and extend 92.1mm (3.63). This amount of movement can be obtained from a thin walled or near full thickness expansion joint.
- 100 Expansion joints are required (total for both sites). This is 668 less than configuration #1 and 300 less than configuration #3.

- A total of 792 supports will be required. 92 will be fixed supports, 100 will be guide supports at the expansion joints and 600 will be single hanger guide supports.
- 1208 circumferential weld seams are required. 200 will be tube to expansion joint welds, 604 will be tube to tube welds and 400 will be expansion joint to expansion joint welds. Overall, there are 332 less circumferential welds compared to configuration #1. It is the same amount of welds compared to configuration #3.

This configuration has the following advantages:

- With the guide supports, the configuration meets EJMA and B31.3 guide requirements.
- Given the same rotational settlement or misalignment the amount of torsional rotation induced on the expansion joint is less compared to configuration #1 and #3.

This configuration has the following disadvantages:

- The expansion joint becomes too long and will exhibit unstable behavior.
- The configuration is more difficult to align and can accommodate less differential settlement between supports.
- The expansion joint is four expansion joints welded together from configuration #3.
- Given the large axial movement, the guide supports at the expansion joints are not feasible.

In conclusion, configuration #6 will not be used since the guide supports and the expansion joints are not feasible.

The conclusion of each configuration is summarized below.

- Configuration #1, since the expansion joint is unguided, the behavior of the expansion joint is unacceptable.
- Configuration #2, since the expansion joint is unguided, the behavior of the expansion joint is unacceptable.
- Configuration #3, the expansion joint is properly guided and the behavior is acceptable. All beam tube components meet their requirements.
- Configuration #4, since the expansion joint is unguided, the behavior of the expansion joint is unacceptable.
- Configuration #5, the expansion joint is properly guided. However, the radial movements are too large for the guide supports.
- Configuration #6, the axial movement is too large for the expansion joint. The configuration is unacceptable.

Because there are limitations imposed from the expansion joint and the guide supports, there is only one alternative that is suitable. Configuration #3 is the only configuration that meets all the functional requirements. Thus, Configuration #3 is the configuration that will be used.

Beam Tube Structural Analysis

The beam tube was analyzed considering all the possible loadings and combinations. Load combinations are made from the following cases:

1. Dead load of beam tube, stiffeners and baffles. Does not include insulation.
2. Dead load of beam tube and insulation. Insulation per LIGO Specification 11000007, 24 kg/m (16.13 lbs/ft).
3. Snow load per ANSI/ASCE 7-88 (only during construction). Hanford has a snow load of 10 lbs/ft^2, which is approximately 20 lbs per foot length of beam tube.
4. Wind load per ANSI/ASCE 7-88 (only during construction). Since the concrete cover will be placed soon after the placement of beam tube sections, a wind load of 45 MPH was used.
5. Seismic, perpendicular to the axis of the tube. Per LIGO Specification 11000007, ANSI/ASCE 7-88 was specified. However, during the PDR, this was changed to UBC '91. This resulted in tripling the seismic load and has somewhat affected the beam tube supports.
6. Seismic, parallel to the axis of the tube.
7. Vacuum
8. Differential settlement at fixed or guided supports. From the analysis, it was determined that higher stresses and reactions are caused by the fixed support settling compared to the guided support settling the same amount.
9. Thermal loads caused by the 150^o C (302^o F) bake out.
10. Thermal loads caused by the maximum ambient temperature of 38^o C (100^o F).
11. Thermal loads caused by the minimum ambient temperature of -27^o C (-16^o F).

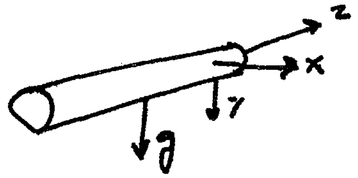
From these cases the following combinations were determined to be the severest load combinations for the beam tube. Combination #2 is your typical bake out condition with some differential settlement or misalignment. Combination #7 is the closest to a typical operational load case with some differential settlement or misalignment.

1. DL + Insulation + Vacuum + 302 F (Case 2 + 7 + 9)
2. DL + Insulation + Dif. Settlement + Vacuum + 302 F (Case 2+7+8+9)
3. DL + Insul + Seis x + Dif. Settlement + Vac + 302 F (Case 2+5+7+8+9)
4. DL + Insul + Seis z + Dif. Settlement + Vac + 302 F (Case 2+5+7+8+9)
5. DL + Wind + Dif. Settlement + 100 F (Case 1 + 4 + 8 + 10)
6. DL + Insulation + Vacuum + 100 F (Case 2 + 7 + 10)
7. DL + Insulation + Dif. Settlement + Vacuum + 100 F (Case 2+7+8+10)

8. DL + Insul + Seis x + Dif. Settlement + Vac + 100 F (Case 2+5+7+8+10)
9. DL + Insul + Seis z + Dif. Settlement + Vac + 100 F (Case 2+5+7+8+10)
10. DL + Snow + Dif. Settlement + -16 F (Case 1 + 3 + 8 + 11)
11. DL + Wind + Dif set -16 F (Case 1 + 4 + 8 + 11)
12. DL + Insulation + Dif. Settlement + Vacuum + 100 F (Case 2+7+8+11)
13. DL + Insul + Seis x + Dif. Settlement + Vac + -16 F (Case 2+5+7+8+11)
14. DL + Insul + Seis z + Dif. Settlement + Vac + -16 F (Case 2+5+7+8+11)

To investigate all the combinations, a RISA2D analysis was performed. A model was made for the Hanford site and for the Livingston site. These two models were used to take into account the different lengths of the make up sections. Another model was created to determine the effects of differential settlement at the fixed support and at the guided support. The results of the models were then factored and superimposed to determine the total stress state of the beam tube. Similarly, all the combinations were investigated to determine the severest loads to the foundation. An excel spread sheet, LIGO-3-1.XLW, was used to superimpose the loads. ASME allowable stresses were used to determine the maximum allowable differential settlement. As a final check, selected load cases were used to determine the factor of safety per API Bulletin 2U, "Stability Design of Cylindrical Shells". All of these calculations can be found in the calculation appendix of the FDR report.

Table 1 summarizes the maximum combined differential settlement and misalignment the beam tube can withstand. The maximum combined differential settlement and misalignment is defined as the sum of the horizontal and vertical distance the beam tube is off the theoretical axis at the support. The maximum stress allowed are based on the ASME Section VIII, Division 1 allowable stresses. Per ASME, a 20% increase in the allowable stress is used for the seismic and wind combinations. The combined axial and bending stress equations from the AISC Manual of Steel Construction, ninth edition are used to determine the limiting unity value of 1.0. Per ASME, a factor of safety equaling 2.0 is provided at these maximum combined differential settlements and misalignments.



Which way are the coordinates

Transverse ↓ vertical longitudinal ↓

Combination	Fixed Supports Reactions (lbs)			Guided Support Reactions (lbs)		Dif. Settlement/ Misalignment(in)	AISC combined Stress Unity	
	Rx	Ry	Rz	Rx	Ry	x + y	Comp	Tension
1	0	7018	5959	0	4980	0	0.638	-
2	0	5601	5959	0	7810	0.579	0.999	-
3	1287	5089	5959	882	8831	0.788	0.999	-
4	0	5168	8128	0	8675	0.756	0.999	-
5	1275	3413	771	874	8697	0.965	0.999	-
6	0	7018	771	0	4834	0	0.384	-
7	0	4541	771	0	9780	1.012	0.999	-
8	1287	4010	771	882	10840	1.229	0.999	-
9	0	4093	2939	0	10674	1.195	0.999	-
10	0	6128	2209	0	11118	1.044	0.999	0.784
11	1275	2872	2209	874	9818	1.186	0.999	0.785
12	0	4023	2209	0	10856	1.224	0.999	0.817
13	1287	3499	2209	882	11902	1.438	0.999	0.789
14	0	3565	4378	0	11770	1.411	0.999	0.769

TABLE 1

Maximum Combination of
Differential Settlement and Misalignment

From Table 1, it can be seen that during bake out, the maximum combination of differential settlement and misalignment is 14.7mm (0.579", case 2). It is recommended that the beam tube is realigned before a bake out is performed. Also from Table 1, the maximum combination of differential settlement and misalignment during normal operating conditions is 25.7mm (1.012", case 2). From the same spread sheet, the maximum foundation reactions were determined. These values are tabulated later in this section.

How does one know the current alignment

Strain gauges

Depending on the axial spring rate of the expansion joint, a certain percentage of the beam tube capacity is required. The specified maximum axial spring rate specified in the expansion joint fabrication specification is 1400 N/m (8000 lbs/in) plus 20%, or 1700 N/m (9600 lbs/in). When the calculations were performed a slightly higher value of 1760 N/m (10060 lbs/in) was used. On the basis of this maximum axial spring rate the axial stresses are tabulated in Table 2. Combinations tabulated are 2 and 7, with the maximum combined differential settlement plus misalignment of 14.7 and 25.7 mm (0.579 and 1.012"). It is noteworthy, the expansion joint only requires 1% of the beam tube capacity during normal operating conditions.

Combination (from Table 1)	Axial stress from E.J. Compression MPa (psi)	Axial stress from D.L. Bending MPa (psi)	Axial stress from Max Dif Settl'mt & misalignment MPa (psi)
2 (Bake Out)	10.57 (1533) 26%	15.82 (2295) 39%	14.29 (2072) 35%
7 (Operating)	0.48 (69) 1%	15.52 (2251) 38%	24.68 (3580) 61%

TABLE 2
Axial Stress & Percentage of Capacity

Although not specifically required, API U2 was used to determine the factor of safety of the beam tube. API Bulletin 2U, "Stability Design of Cylindrical Shells". API Bulletin 2U provides stability criteria for measuring the structural adequacy against buckling of circular cylindrical members when subjected to axial load, bending and external pressure acting independently or in combination. The circular cylindrical member can be either stiffened or unstiffened. API Bulletin 2U, unlike the ASME Code, considers the interaction between compressive axial and hoop stresses in evaluating the susceptibility of a stiffened cylinder to local buckling between stiffeners. It is for this reason that the beam tube was evaluated per the API Bulletin 2U provisions. Table 3 summarizes the results of the API Bulletin 2U analyses. Given the severest load combinations, the tube has a sufficient factor of safety.

								Factor of Safety	
API BUL 2U Case #	100° F Oper'g	302° F Oper'g	Vacuum	Axial Seismic	Dif support Settl'mt	Max Axial tube stress	Tube hoop stress (psi)	Actual	Recom'd
1		Yes	Yes		0"	-3762	-2836	1.88	2.00
2		Yes	Yes	Yes	0"	-4344	-2836	1.78	1.50
3		Yes	Yes		0.579"	-5896	-2836	1.55	1.50
4	Yes		Yes		0"	-2266	-2836	2.25	2.00
5	Yes		Yes	Yes	0"	-2789	-2836	2.19	1.50
6	Yes		Yes		0.25"	-3161	-2836	2.14	2.00
7	Yes		Yes		0.579"	-4340	-2836	1.99	2.00
8	Yes		Yes	Yes	0.579"	-4681	-2836	1.91	1.50
9	Yes		Yes		1.00"	-5893	-2836	1.77	1.50

TABLE 3
Summary of API Bulletin 2U analyses

The RISA2D models were also used to determine the natural frequency and period of the beam tube. The first 12 mode shapes were determined. Plots can be found in the calculation appendix of the FDR report. Table 4 lists the frequency and period for the first 12 mode shapes.

Mode Number	Frequency (Hz)	Period (sec)
1	12.43	0.08044
2	12.65	0.07905
3	40.14	0.02492
4	40.61	0.02463
5	83.45	0.01198
6	84.4	0.01185
7	141.8	0.00705
8	143.3	0.00698
9	21303	0.00469
10	215.6	0.00464
11	293.2	0.00341
12	296.5	0.00337

TABLE 4
Beam Tube Frequencies & Period
for the First 12 Mode Shapes

Foundation Requirements

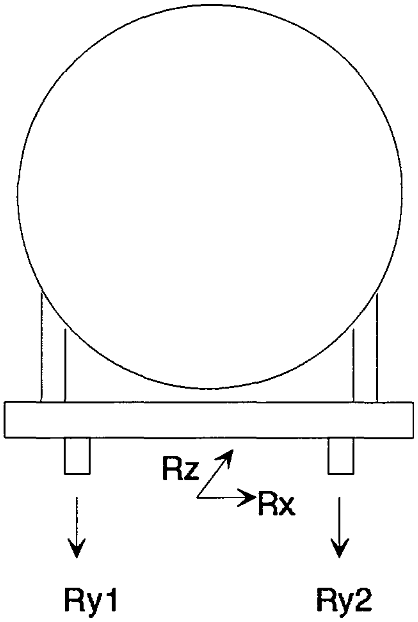
There are several requirements of the foundation for the beam tube. The supports will not be using grouted base plates. Therefore, the slab must be sufficiently flat to ensure full contact with an ungrouted base plate. The supports have been designed with a total of ± 89mm (±3 1/2") of vertical and horizontal adjustment. The additional 14mm (1/2") has been added to account for construction tolerances. This additional 14mm (1/2") is not intended to account for variation in the slab. Variation in the slab and settlement of the slab during construction must be accounted for with the specified ± 75mm (±3") adjustment of the supports.

For the beam tube and expansion joints to perform with the proper factor of safety, the following settlement limitations must be met.

- During bake out: ± 6.4 mm (±0.25")
- During normal operating conditions: ± 12.7 mm (±0.5")
- Differential slab rotation: ± 0.15 degrees
  (Any operating condition)

If the foundation imposes a settlement or rotation in excess of these amounts, the beam tube should be realigned.

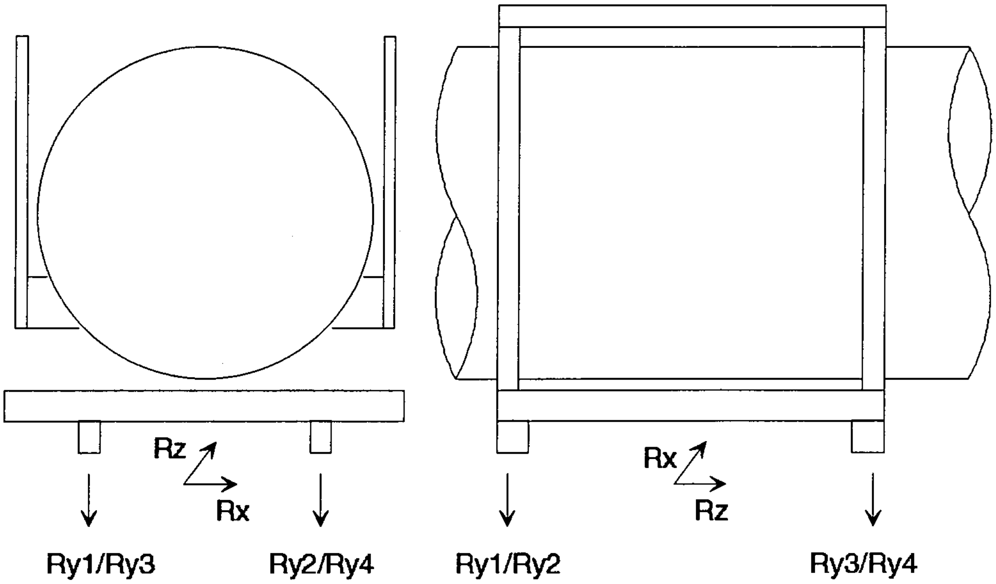
From the analysis of beam tube, the severest foundation loads were calculated. These foundation loads are the loads per pad plate. The fixed supports have two pad plates and the guided supports have four pad plates. Table 5 lists the reactions of the fixed support for each load case and the severest load combination for the fixed supports. Table 6 lists the reactions for each load case and the severest combination for the guided supports.



FIXED SUPPORT FOUNDATION LOADS	Lateral (lbs)	Vertical (lbs)			Axial (lbs)
Load Cases	Rx	Ry1	Ry2	Ry total	Rz
1. Operating	85	3870	3648	7518	771
2. Bake Out @ 302 F	656	860	-860	0	5959
3. 0.579" Dif Settlement @ Fixed Support	0	+/- 715	+/- 715	+/- 1430	0
4. 1" Dif Settlement @ Fixed Support	0	+/- 1235	+/- 1235	+/- 2470	0
5. 0.5" Horz Misalign'mt @ Fixed Support	1235	1621	-1621	0	0
6. 0.579" Dif Settl'mt @ Guided Support	0	+/- 356	+/- 356	+/- 712	0
7. 1" Dif Settlement @ Guided Support	0	+/- 615	+/- 615	+/- 1230	0
8. 0.5" Misalignment @ Guided Support	615	807	-807	0	0
9. Lateral Seismic (x direction)	1287	1689	-1689	0	0
10. Axial Seismic (z direction)	0	0	0	0	2169
11. Wind Load	1275	1673	-1673	0	0

Maximum Reactions Normal Operating Conditions	Maximum Reactions Seismic or Wind Conditions
Maximum Rx = 1320 lbs, 1+3+5	Maximum Rx = 2607 lbs, 1+3+5+9
Maximum Ry1= 6206 lbs, 1+3+5	Maximum Ry1= 7895 lbs, 1+3+5+9
Minimum Ry2= 1312 lbs, 1-3+5	Minimum Ry2= -377 lbs, 1-3+5+9
Maximum Ry= 9988 lbs, 1+4	Maximum Ry= 9988 lbs, 1+4+9
Maximum Rz = 6730 lbs, 1+2+3	Maximum Rz = 8899 lbs, 1+2+6+10

TABLE 5
Fixed Support Foundation Loads



GUIDE SUPPORT FOUNDATION LOADS	Lateral	Vertical (lbs)				
Load Case	Rx	Ry1	Ry2	Ry3	Ry4	Ry total
1. Operating	85	1664	1553	1664	1553	6434
2a. Bake Out @ 302 F	656	598	-262	598	-262	672
2b. Bake Out @ 302 F	656	262	-598	262	-598	-672
3. 0.579" Dif Settl'mt @ Fixed Support	0	+/- 715	+/- 715	-/+ 365	-/+ 365	+/- 701
4. 1" Dif Settl'mt @ Fixed Support	0	+/- 1235	+/- 1235	-/+ 630	-/+ 630	+/- 1210
5. 0.5" Horz Misalign'mt @ Fix'd Support	605	397	-397	397	-397	0
6. 0.579" Dif Settl'mt @ Guided Support	0	+/- 162	+/- 162	+/- 155	+/- 155	+/- 635
7. 1" Dif Settl'mt @ Guided Support	0	+/- 280	+/- 280	+/- 269	+/- 269	+/- 1097
8. 0.5" Misalignment @ Guided Support	549	360	-360	360	-360	0
9. Lateral Seismic (x direction)	882	579	-579	579	-579	0
10. Axial Seismic (z direction)	0	0	0	0	0	0
11. Wind Load	874	574	-574	574	-574	0

Maximum Reactions Normal Operating Conditions			Maximum Reactions Seismic or Wind Conditions		
Maximum Rx =	740	lbs, 1+2a+3	Maximum Rx =	1622	lbs, 1+2a+3+9
Maximum Ry1=	2977	lbs, 1+2a+3	Maximum Ry1=	3556	lbs, 1+2a+3+9
Minimum Ry2=	240	lbs, 1+2b-3	Minimum Ry2=	- 339	lbs, 1+2b-3+9
Maximum R3=	2627	lbs, 1+2a+3	Maximum R3=	3206	lbs, 1+2a+3+9
Minimum Ry4=	590	lbs, 1+2b-3	Minimum Ry4=	11	lbs, 1+2b-3+9
Maximum Ry =	7807	lbs, 1+2a+3	Maximum Ry =	7807	lbs, 1+2a+3+9

TABLE 6

Guided Support Foundation Loads

Grounding of the Beam Tube During Construction

While exposed to the outside environment, the beam tube needs to be electrically connected to the ground. This connection is required in order to provide protection in the event of lighting strikes during construction.

The tube shall be grounded at a maximum spacing of 250 meters. The grounding connection should be installed at every sixth beam tube fixed support. The tube may be connected to an existing grounding system or be separately grounded. If separately grounded, the grounding equipment at each location shall consist of a 10' long x 3/4" copper grounding rod, 2/0 bare copper cable, and appropriate connectors.

A 10' long grounding rod is to be driven into the ground, before the slab concrete is placed, beneath the beam tube slab at the appropriate locations along the tube centerline. A six foot long 2/0 bare copper cable shall then be connected to the ground rod, using appropriate connectors, and threaded through a one inch PVC pipe that is to run through the concrete beam tube slab at the tube centerline. The PVC pipe will act as a sleeve around the ground cable to protect the cable during concrete slab placement. The ground cable is then to be connected to the longitudinal tube gusset of the fixed support thrust connection. This connection is to be made, using appropriate connectors, outside the thickness of the tube insulation.

The grounding system must be intact as long as any part of the tube is exposed to the outside environment. The grounding connections must be disconnected before the bakeout of the beam tubes is performed. ✓

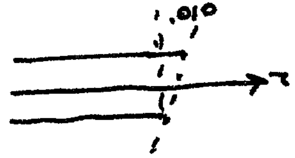
Tube-to-Chamber Interface

The tube to chamber interface is important for the beam tube. There are tolerances required so the beam tube can be properly attached. There are also physical requirements that must be met for the beam tube to perform properly.

The tolerances required at the tube to chamber interface stubs are essentially the same construction tolerances that are required on the rest of the beam tube. The required tolerances are as follows. All measurements are to be made while the temperature is between 16° and 27° C (60° and 80° F).

- The outside circumference of the ends of the chamber stubs shall be within ±1.19mm (±3/64"), of the theoretical circumference corresponding to the specified inside diameter of the beam tube.
- The ends of the chamber stubs shall be perpendicular to the cylindrical axis within 0.254mm (0.010").

Same as rings



- The ends of the chamber stubs shall be flat within 0.127mm (0.005").
- The chamber stubs projection shall be within ±3.18mm (±1/8").
- The optimum thickness of the stub ends is 3.23mm (0.127"). The thickness shall not be less than 2.67mm (0.105") and not greater than 3.81mm (0.150")

The lengths of the make up pieces that join the stub ends differ for each site. Depending on which end of the beam tube, an expansion joint must be added to maintain the pattern of expansion joints. This is illustrated in Figure 1.

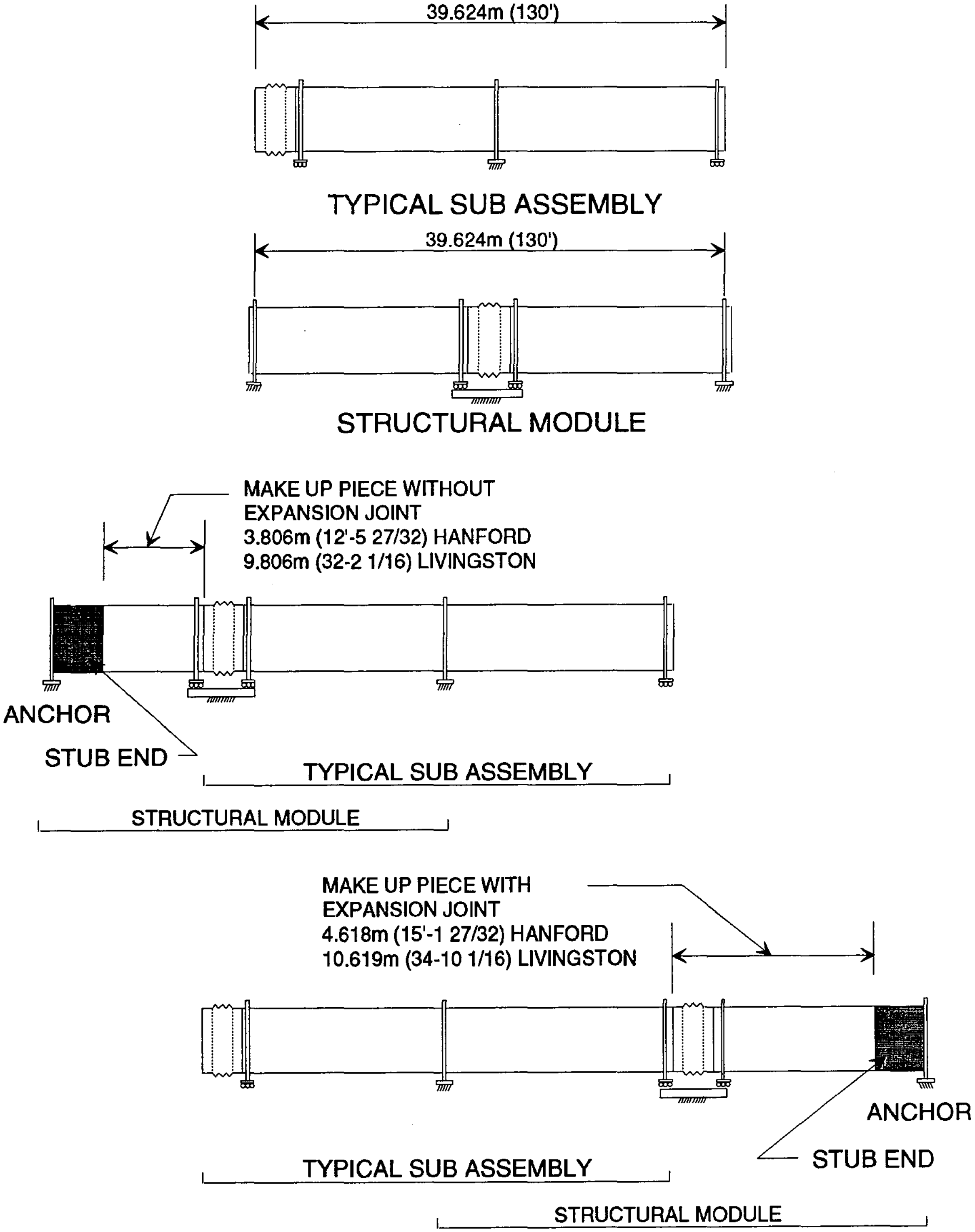
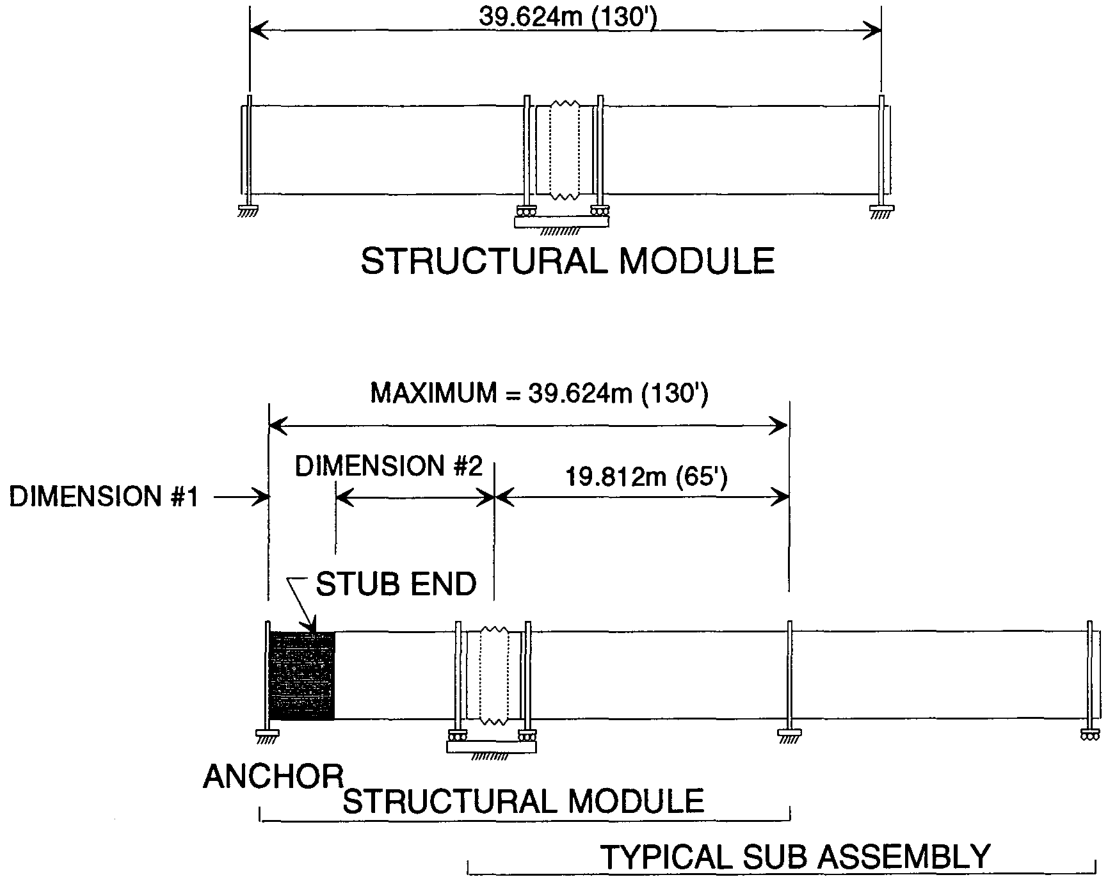


FIGURE 1
Make Up Pieces Joining Chamber Stub Ends

The chamber stub ends also must act as an anchor. The full vacuum load on the effective expansion joint area must be resisted. The effective area of the expansion joint is 1.33 m^2 (2063 sqin). Thus, the total pressure thrust which must be resisted is 135 kN (30,326 lbs).

The face of the stub end obviously will not be the point of action that is considered as the fixed support. The maximum length of tube that an expansion joint can accommodate is 39.624m (130'). Thus, there is maximum stub length. The maximum stub lengths (from end to anchor) are shown in Figure 2. The optimum length of the chamber stub ends would be these maximum lengths.

$F_{atm} \approx \pi \times 24^2 \times 15 = 30k$ lbs



DIMENSION #1
MAXIMUM STUB LENGTH:
15.600m (51'-2 5/32) HANFORD
9.600m (31'-5 15/16) LIVINGSTON

DIMENSION #2
LENGTH BETWEEN END & EXPANSION JOINT CENTER LINE::
4.212m (13'-9 5/32) HANFORD
10.212m (33'-6 1/16) LIVINGSTON

FIGURE 2
Maximum Chamber Stub End Lengths

The final requirement of the chamber stub ends is the placement of vacuum stiffeners. Given the limitation of thickness, the overall maximum vacuum stiffener spacing must be maintained. This maximum spacing is 762mm (30"). On the basis of this maximum spacing, the maximum vacuum stiffener distance from the end of the stub end can be determined. The limiting dimensions are illustrated in Figure 3. They are different for each site. To provide sufficient clearance for fit up and welding to the beam tube make up pieces, the minimum distance of 305mm (1'-0) is required. This is also illustrated in Figure 3.

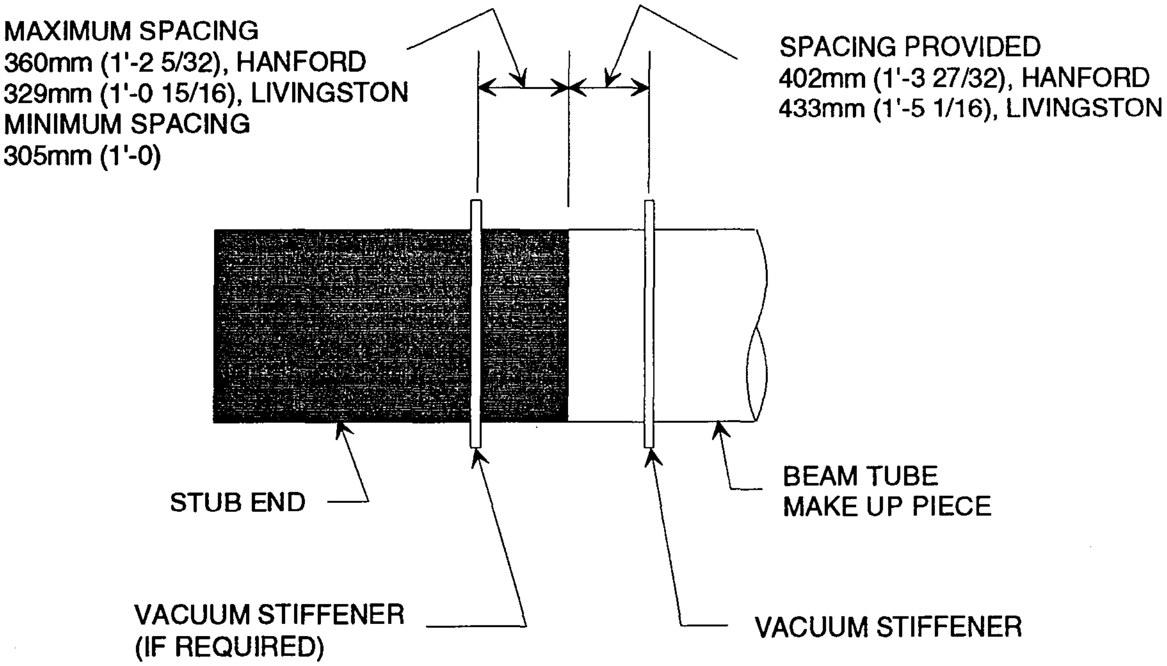


FIGURE 3
Maximum Distance from End for
Vacuum Stiffener on Chamber Stub Ends

Component Quantity Summaries of the Beam Tube Modules

Contained within the Detailed Design are drawings of the beam tube sub-modules and sub-assemblies, beam tube supports, stiffeners, baffles, and other components. Refer to these drawings for detailed information. Tabulated below is a brief summary of the beam tube module component quantities for both the Hanford, WA and Livingston, LA sites.

Component Item	Total Quantities @ Hanford, WA Site	Total Quantities @ Livingston LA Site	Total Quantities @ Both Sites
Beam Tubes, 65'-0"	196	196	392
Beam Tubes, 62'-4"	196	196	392
Beam Tubes, Ends	8	8	16
Expansion Joints	200	200	400
Supports, Fixed	196	196	392
Supports, Guided	200	200	400
Support Rings	596	596	1,192
Baffle Stiffeners	128	64	192
Beam Tube Stiffeners	9,712	9,840	19,552
Vacuum Ports	28	28	56

COST COMPARISON: WALL THICKNESS VS COMPONENT COSTS OF TUBE & STIFFENERS

							---------- Component Costs ----------		
Inside Diameter	**Ordered Thickness**	**Ordered Overtol'ce**	**Ordered Undertol'ce**	**Design Thickness**	**Approx Stiff'r Spacing**	**Approx Num of Stiff'rs**	**For Beam Tubes**	**For Stiffeners**	**For Tubes & Stiff'rs**
48.000 In	0.127 In	+0.003 In	-0.007 In	0.127 In	28.78 In	21,407	$6,767,643	$2,162,060	$8,929,703
	0.125 In	+0.005 In	-0.005 In	0.125 In	27.70 In	22,241	$6,690,172	$2,246,357	$8,936,529
	0.120 In	+0.010 In	-0.010 In	0.117 In	23.68 In	26,017	$6,496,495	$2,627,706	$9,124,201
48.250 In	0.127 In	+0.003 In	-0.007 In	0.127 In	28.58 In	21,556	$6,793,265	$2,177,190	$8,970,455
	0.125 In	+0.005 In	-0.005 In	0.125 In	27.52 In	22,387	$6,715,391	$2,261,049	$8,976,440
	0.120 In	+0.010 In	-0.010 In	0.117 In	23.50 In	26,216	$6,520,705	$2,647,833	$9,168,538
48.500 In	0.127 In	+0.003 In	-0.007 In	0.127 In	28.36 In	21,724	$6,818,887	$2,194,079	$9,012,966
	0.125 In	+0.005 In	-0.005 In	0.125 In	27.32 In	22,551	$6,740,609	$2,277,602	$9,018,211
	0.120 In	+0.010 In	-0.010 In	0.117 In	23.34 In	26,396	$6,544,914	$2,665,985	$9,210,899
48.750 In	0.127 In	+0.003 In	-0.007 In	0.127 In	28.16 In	21,878	$6,844,509	$2,209,662	$9,054,171
	0.125 In	+0.005 In	-0.005 In	0.125 In	27.12 In	22,717	$6,765,828	$2,294,398	$9,060,226
	0.120 In	+0.010 In	-0.010 In	0.117 In	23.17 In	26,590	$6,569,124	$2,685,545	$9,254,669
49.000 In	0.127 In	+0.003 In	-0.007 In	0.127 In	27.97 In	22,026	$6,870,131	$2,224,672	$9,094,803
	0.125 In	+0.005 In	-0.005 In	0.125 In	26.94 In	22,869	$6,791,046	$2,309,728	$9,100,774
	0.120 In	+0.010 In	-0.010 In	0.117 In	23.01 In	26,774	$6,593,334	$2,704,219	$9,297,553
49.250 In	0.127 In	+0.003 In	-0.007 In	0.127 In	27.78 In	22,177	$6,895,753	$2,239,888	$9,135,640
	0.125 In	+0.005 In	-0.005 In	0.125 In	26.74 In	23,040	$6,816,264	$2,327,004	$9,143,268
	0.120 In	+0.010 In	-0.010 In	0.117 In	22.84 In	26,974	$6,617,543	$2,724,347	$9,341,890
49.500 In	0.127 In	+0.003 In	-0.007 In	0.127 In	27.58 In	22,338	$6,921,375	$2,256,131	$9,177,505
	0.125 In	+0.005 In	-0.005 In	0.125 In	26.56 In	23,196	$6,841,483	$2,342,774	$9,184,257
	0.120 In	+0.010 In	-0.010 In	0.117 In	22.68 In	27,164	$6,641,753	$2,743,566	$9,385,319

CONCLUSION: ALTHOUGH TUBE WEIGHT & COST INCREASES WITH WALL THICKNESS INCREASE, COST SAVINGS DUE TO DECREASE IN NUMBER OF STIFFENERS JUSTIFIES USE OF MAXIMUM PERMISSIBLE WALL THICKNESS OF 0.127".

Notes:

1. Cost of beam tube material used is $5,000,000 based upon a budget price from ARMCO for an ordered thickness of 0.127" and a 48.75" ID tube. This item is scaled in proportion to both the beam tube diameter and the ordered plate thickness.
2. Cost of tube fabrication used is $1,848,300 based upon a budget price from Tubetec.
3. Beam tube stiffener spacing per ASME with a safety factor of 3.
4. Cost of a beam tube stiffener used is $41 based upon a budget price from Meyer Tool & Mfg.
5. Cost of welding a beam tube stiffener to the beam tube is $60 based upon an estimate by CBI's Welding Department.

PARAMETERS AFFECTING BEAM TUBE DIAMETER

Parameter Number	Parameter Description	Parameter Value	Parameter Stackup for Baffle Spacing of	
			21 meters, nominal	6 meters, nominal
1	Required Clear Aperture Radius	21.065 in	21.065 in	21.065 in
2	Baffle Radial Projection	2.360 in	2.360 in	2.360 in
3	Baffle Radial Proj'n Tolerance	0.080 in	0.080 in	0.080 in
4	Tube Inside Radius Tolerance	0.075 in	0.075 in	0.075 in
5	Tube-to-Support Ring Fitup Gap	0.000 in	----	----
6	Support Ring Outside Radius Tolerance	0.000 in	----	----
7	Tube Lateral Offset	0.160 in	0.160 in	0.160 in
8	Deflection of Beam Tube	0.080 in	----	0.100 in
9	"Swing" of Guided Support	0.007 in	0.007 in	0.007 in
10	Support Adjustment Tolerance	0.063 in	0.063 in	0.063 in
11	Surveying Accuracy Tolerance	0.354 in	0.354 in	0.354 in
12	Beam Tube Out-of-Straightness	0.125 in	----	0.125 in
		Σ =	24.164 in	24.389 in
	Required Inside Dia of Beam Tube	**2 * Σ =**	**48.328 in**	**48.778 in**

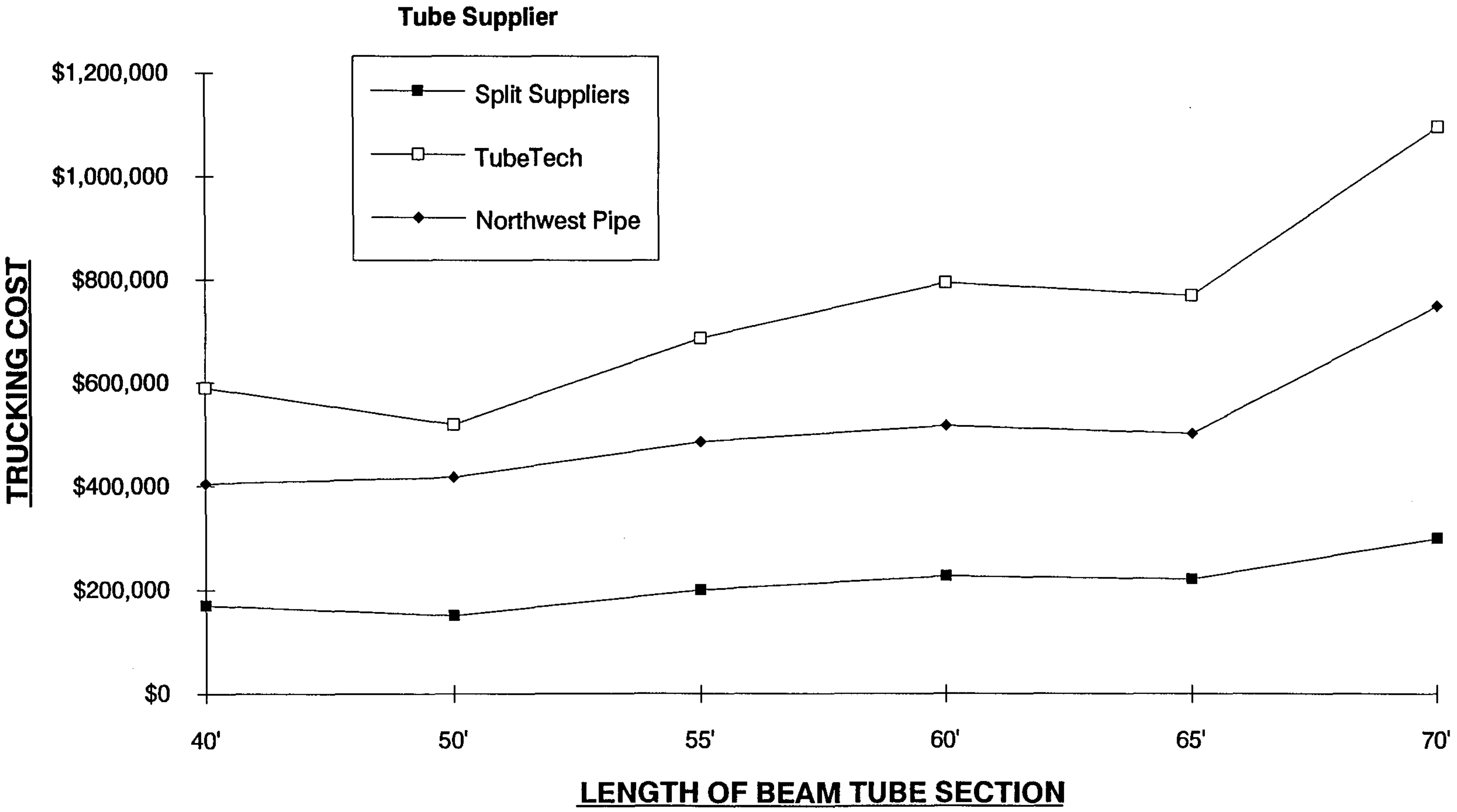
LIGO PROJECT
WBS 100
DESIGN CONFIGURATION
FINAL DESIGN REVIEW PACKAGE

just transport costs.

LIGO COST SUMMARY - TUBE LENGTH IMPACT

KHF									PER EXP. BELLOW	
4/6/94	COST PER TRUCKLOAD								INSTL'D. COST	$1,687.43
	SANFORD FL. TO LIVINGSTON, LA.			MILEAGE=	657	# TUBES	# LOADS	AVG. COST	# REQ'D PER SITE	EXT.COST
LENGTH IN FT.	CO. "A"	CO. "B"	CO. "C"	AVERAGE	COST/MILE					
40	$915.30	$886.95		$901.13	$1.37	500	125	$112,641	499	$1,684,059
50	$915.30	$886.95		$901.13	$1.37	440	110	$99,124	439	$1,481,567
55	$1,290.00	$1,152.65		$1,221.33	$1.86	436	109	$133,235	435	$1,469,295
60	$1,520.00	$1,349.75	$1,365.00	$1,411.58	$2.15	433	108	$152,922	432	$1,459,068
65	$1,520.00	$1,349.75	$1,569.00	$1,479.58	$2.25	400	100	$147,958	399	$1,346,572
(over 65 ft) 70		add $1.15/mile for escort		$2,235.13	$3.40	372	93	$207,867	371	$1,252,076
	SANFORD FL. TO HANFORD WA.			MILEAGE=	2895				PER SUPPORT	
LENGTH IN FT.	CO. "A"	CO. "B"	CO. "C"	AVERAGE	COST/MILE				INSTL'D. COST	$1,538.10
40	$3,735.00	$3,908.25		$3,821.63	$1.32	500	125	$477,703	499	$1,535,025
50	$3,735.00	$3,908.25		$3,821.63	$1.32	440	110	$420,379	439	$1,350,452
55	$5,711.00	$4,447.75		$5,079.38	$1.75	436	109	$554,114	435	$1,339,266
60	$6,295.00	$5,466.25	$6,047.00	$5,936.08	$2.05	433	108	$643,076	432	$1,329,944
65	$6,295.00	$5,466.25	$6,950.00	$6,237.08	$2.15	400	100	$623,708	399	$1,227,404
(over 65 ft) 70		add $1.15/mile for escort		$9,566.33	$3.30	372	93	$889,669	371	$1,141,271
	PORTLAND OR. TO HANFORD WA.			MILEAGE=	227				PER TUBE INST.	
LENGTH IN FT.	CO. "A"	CO. "B"	CO. "C"	AVERAGE	COST/MILE				INSTL'D. COST	$1,434.15
40	$650.00	$272.40		$461.20	$2.03	500	125	$57,650	499	$1,431,285
50	$650.00	$272.40		$461.20	$2.03	440	110	$50,732	439	$1,259,186
55	$790.00	$429.15		$609.58	$2.69	436	109	$66,499	435	$1,248,756
60	$790.00	$497.25	$775.00	$687.42	$3.03	433	108	$74,470	432	$1,240,064
65	$790.00	$497.25	$895.00	$727.42	$3.20	400	100	$72,742	399	$1,144,454
(over 65 ft) 70		add $1.15/mile for escort		$988.47	$4.35	372	93	$91,927	371	$1,064,141
	PORTLAND OR. TO LIVINGSTON LA.			MILEAGE=	2420				PER LEAK TEST	
LENGTH IN FT.	CO. "A"	CO. "B"	CO. "C"	AVERAGE	COST/MILE				INSTL'D. COST	$2,187.62
40	$2,662.70	$2,904.00		$2,783.35	$1.15	500	125	$347,919	501	$2,192,000
50	$3,760.00	$2,904.00		$3,332.00	$1.38	440	110	$366,520	441	$1,929,485
55	$4,078.00	$3,617.00		$3,847.50	$1.59	436	109	$419,727	437	$1,913,575
60	$4,205.00	$3,980.00	$4,105.00	$4,096.67	$1.69	433	108	$443,806	434	$1,900,317
65	$4,205.00	$3,980.00	$4,721.00	$4,302.00	$1.78	400	100	$430,200	401	$1,754,475
(over 65 ft) 70		add $1.15/mile for escort		$7,085.00	$2.93	372	93	$658,905	373	$1,631,968
TOTAL COST-SPLIT SUPPLIERS		40'	50'	55'	60'	65'	70'			
SANFORD/LIVINGSTON		$112,641	$99,124	$133,235	$152,922	$147,958	$207,867			
PORTLAND/HANFORD		$57,650	$50,732	$66,499	$74,470	$72,742	$91,927			
	FREIGHT	$170,291	$149,856	$199,735	$227,392	$220,700	$299,795			
	BELLOWS	$1,684,059	$1,481,567	$1,469,295	$1,459,068	$1,346,572	$1,252,076			
	SUPPORTS	$1,535,025	$1,350,452	$1,339,266	$1,329,944	$1,227,404	$1,141,271			
	TUBE INSTALL	$1,431,285	$1,259,186	$1,248,756	$1,240,064	$1,144,454	$1,064,141			
	LEAK TEST	$2,192,000	$1,929,485	$1,913,575	$1,900,317	$1,754,475	$1,631,968			
COST SUMMARIES		**$7,012,659**	**$6,170,546**	**$6,170,627**	**$6,156,785**	**$5,693,606**	**$5,389,251**			
TOTAL COST- TUBETECH										
SANFORD/LIVINGSTON		$112,641	$99,124	$133,235	$152,922	$147,958	$207,867			
SANFORD/HANFORD		$477,703	$420,379	$554,114	$643,076	$623,708	$889,669			
	FREIGHT	$590,344	$519,503	$687,349	$795,997	$771,667	$1,097,536			
	BELLOWS	$1,684,059	$1,481,567	$1,469,295	$1,459,068	$1,346,572	$1,252,076			
	SUPPORTS	$1,535,025	$1,350,452	$1,339,266	$1,329,944	$1,227,404	$1,141,271			
	TUBE INSTALL	$1,431,285	$1,259,186	$1,248,756	$1,240,064	$1,144,454	$1,064,141			
	LEAK TEST	$2,192,000	$1,929,485	$1,913,575	$1,900,317	$1,754,475	$1,631,968			
COST SUMMARIES		**$7,432,712**	**$6,540,193**	**$6,658,241**	**$6,725,390**	**$6,244,572**	**$6,186,993**			
TOTAL COST - NORTWEST PIPE								note: tubing material &		
PORTLAND/HANFORD		$57,650	$50,732	$66,499	$74,470	$72,742	$91,927	mfg cost not included		
PORTLAND/ LIVINSTON		$347,919	$366,520	$419,727	$443,806	$430,200	$658,905			
	FREIGHT	$405,569	$417,252	$486,226	$518,276	$502,942	$750,832			
	BELLOWS	$1,684,059	$1,481,567	$1,469,295	$1,459,068	$1,346,572	$1,252,076			
	SUPPORTS	$1,535,025	$1,350,452	$1,339,266	$1,329,944	$1,227,404	$1,141,271			
	TUBE INSTALL	$1,431,285	$1,259,186	$1,248,756	$1,240,064	$1,144,454	$1,064,141			
	LEAK TEST	$2,192,000	$1,929,485	$1,913,575	$1,900,317	$1,754,475	$1,631,968			
COST SUMMARIES		**$7,247,937**	**$6,437,943**	**$6,457,118**	**$6,447,669**	**$5,975,847**	**$5,840,289**			

LIGO PROJECT TRUCKING COST SUMMARY



WBS #130 Beam Tube Support Design

As discussed in WBS #160, "Beam Tube Configuration", vertical and lateral support will be provided on both sides of the LIGO beam tube expansion joints for structural, operational and performance reasons. As such, there will be two separate and distinct types of beam tube supports that will be provided:

- A "fixed", or non-guided, support that will be located in the region of the beam-tube-to-beam tube circumferential seam. This support will resist vertical, lateral and longitudinal loads from the beam tube.

- A guided support that will be located at each expansion joint. This support will resist vertical and lateral loads from the beam tube, but will not resist longitudinal loads from the tube. Rather, this support will permit the "noiseless" longitudinal movement of the beam tube caused by thermal loads.

Support Design Load Cases

The load cases that were considered for the design of the beam tube supports are as follows:

- Dead Load of Beam Tubes
- Insulation Load
- Seismic Load
- Wind Load
- Snow Load
- Thermal Loads, Daily
- Thermal Loads, Bakeout

$\Delta m / \Delta \ell \simeq 100$ lbs/ft

Dead Load of the Beam Tubes. For a 48.75" I.D. beam tube with a wall thickness of 0.127", the beam tube will weigh approximately 66 pounds per foot. The beam tube stiffeners will add another 8 pounds per foot to the weight of the tube, for a total tube metal weight of 74 pounds per foot.

Insulation Load. Per the LIGO Specifications, the weight of the beam tube insulation is to be taken as 16 pounds per foot (24 kg/m).

Seismic Load. The beam tubes at the Hanford, WA site will be designed for a Zone 2B seismic load in accordance with the 1991 Edition of the Uniform Building Code (1991 UBC). The beam tubes at the Livingston, LA site are designed for a Zone 0 seismic load in accordance with the 1991 Standard Building Code (1991 SBCCI). Refer to the design calculations contained in the Detailed Design for seismic load calculations.

Wind Load. The beam tubes will be exposed to wind loading for a short period of time, since the construction sequence calls for the placement of the concrete weather covers soon after placement of the beam tubes. As such, the beam tubes will not be designed for the full wind loading as prescribed by the relevant Building Codes. Rather, the tubes will be subjected to a construction wind load of 45 mph. Refer to the design calculations contained in the Detailed Design for wind load calculations.

Snow Load. As with the wind load, the beam tubes at the Hanford, WA site will be exposed to snow loading for only a short period of time. The beam tubes at the Livingston, LA site are not required to be designed for a snow load. Refer to the design calculations contained in the Detailed Design for snow load calculations.

Thermal Loads, Daily and Bakeout. The beam tubes will be designed for the effects thermal loads. The effects of daily thermal variations (i.e., occurring during operation, and not during bakeout) upon the beam tubes are considered, as are the more severe effects of the beam tube bakeout. Refer to the design calculations contained in the Detailed Design for thermal load magnitude calculations.

Support Design Load Combinations

The load combinations that were initially considered for the design of the beam tube supports are as follows:

1. Dead Load
2. Dead Load + Snow Load
3. Dead Load + Construction Wind Load
4. Dead Load + Insulation Load
5. Dead Load + Insulation Load + Lateral Seismic Load
6. Dead Load + Insulation Load + Longitudinal Seismic Load

FINAL QUALIFICATION TEST PLAN AND PROCEDURES

INDEX

INTRODUCTION

The qualification test plan consists of the list of items requiring verification testing and items verified by calculations; the test configuration and the procedures for fabrication, installation, and testing for that configuration; and the format for reporting the test results in the Design Qualification Test Report. This plan ensures that the Qualification Test demonstrates the critical features of the LIGO beam tube module design.

The overall test configuration, including procedures, controls the execution of the qualification test plan. The configuration has been assembled for submittal at this FDR by making conceptual plans, based on requirements, and preparing designs, drawings, and procedures on the basis of these plans. Beam tube component fabrication procedures/procurement specifications have been prepared and will be used to purchase these components for the QT. Fabrication by CBI will be accomplished in two locations, Houston Welding and Plainfield Research and Development. Houston Welding (HW) will receive the spiral welded tubes in the ordered QT lengths, the stiffeners, the baffle/support rings, and the pump port. CBI HW will perform the necessary receiving inspection including dimensional inspection and welding of stiffeners, support rings and pump port. Post welding dimensional checks of the stiffened beam tubes are also performed in Houston prior to shipment to CBI Plainfield Research and Development Center. CBI's Plainfield Research and Development (R&D) Center will receive the stiffened beam tubes from HW and the expansion joints and supports from their respective manufacturers. The R&D center will perform the circumferential welds to create each beam tube can section (one aft (contains pump port) and one forward of the expansion joint). These can sections will be individually helium mass spectrometer hood tested. The expansion joint will be attached to the forward assembly and that circumferential weld will be HMS leak tested. The aft assembly will be installed including alignment as the starting piece of the QT Beam Tube Module, locating the pump port in the high vacuum lab. Final cleaning and baffle (~ 6 M spacing) installation of this aft assembly will occur at this time. The forward assembly (including expansion joint) will then be installed, including alignment, into the QT Beam Tube Module, including fitup, purge and welding of the circumferential seam joining the aft assembly to the forward assembly. This weld will be HMS leak tested. Final cleaning and baffle installation (~ 20M spacing) will occur at this time. The closure head will be installed including fitup, purge and welding. Installation alignment checks and support adjustments will be made. Vacuum thrust restraints will be added to the supports. The QT Beam Tube Module will be pumped down, air signature evaluated, and leak tested if necessary. The QT Beam Tube Module will be baked out while taking periodic RGA measurements. When the bakeout is complete, air signature will be evaluated and the QT Beam Tube Module will be leak tested if necessary. Final outgas test will then be performed .

1.0 LISTING OF TEST ITEMS AND CALCULATION ITEMS

DRD No. 03 requires a listing of items requiring verification testing and items verified by calculations. This section provides this list.

The items that make up the list represent all of the most important issues that affect the design and production of complete beam tube modules. The first four sections of the list are ordered to chronologically follow the complete module sequence of operations, i.e. Design, Material Procurement, Fabrication, and Assembly. In addition, the key issues of Leak Testing, Cleaning/Outgas, and Dimensional Control are each addressed separately since they are affected by interrelated steps that are woven all through the option phase activities.

For each issue, a discussion is provided which covers not only whether the item is verified by test or not, but also any significant differences that exist between the Qualification Test (QT) and a Complete Module and the significance of these differences. Also, for those items that are not tested, the discussion covers how the verification is made that the plans for the Option meet specifications. This is in some cases by calculation, in other cases by analysis, by past experience etc.

- DESIGN

Structural Performance of the Beam Tube Sections

Dimensions & Material: This area will be thoroughly and realistically tested during the QT. The differences between the QT and the complete module are very few and not significant. The beam tube material and thickness will be identical to option phase modules as will the stiffener material, sizes, spacing and attachment details. The only dimensional difference will be the length of tube sections (60' in QT instead of 65' and 62'-4"). However, the spacing of supports, which is the significant parameter from a structural standpoint, will be identical.

Loadings: The QT will include external pressure to the design level of full vacuum. The maximum axial compression load will also be applied during the QT bakeout.

Calculations: In addition to the above testing, calculations have also been prepared to demonstrate structural adequacy and conformance to specified codes.

Structural and Mechanical Performance of the Expansion Joints

Like the beam tubes, this area will be thoroughly and realistically tested during the QT. The expansion joints will be identical to the expansion joints used for the complete modules. Vacuum load and maximum axial deflection will be the same as applied to the complete modules. In addition, calculations have been made to demonstrate structural adequacy. The only difference in loading will be that the full number of cycles that the modules might experience will not be applied on the QT. The fatigue performance of the expansion joints is therefore addressed by calculation only.

Structural, Mechanical and Thermal Performance of the Beam Tube Supports

Both the fixed supports and the guided supports will be tested during the QT in all of their most critical respects. The supports will be identical to those used for the complete modules. The range of movement required of the guided supports will be realistically tested during the QT bakeout.

Gravity loads applied to the supports will be somewhat different than design loads for the complete modules due to the fact that full length beam tube only extends in one direction from the QT fixed supports. This non critical element of design therefore relies on calculations. Likewise, no horizontal loads transverse to the tube will be applied. The design relies on calculations.

Longitudinal loads will exist during the QT due to unbalanced pressure end loads and expansion joint reactions which are larger than will exist in the complete modules. However, these loads will, for the most part, be carried by supplemental bracing required to carry these larger loads rather than by the fixed supports. Therefore verification of the fixed supports' adequacy for design longitudinal loads relies on calculations.

The mechanical performance of the supports needed in order to accomplish final alignment of the tube will be fully demonstrated by test.

The thermal performance required to limit the local cool spot at supports during bakeout will be demonstrated by test as well as by analysis that has been completed.

Baffle Mechanical Performance

The baffles performance will be fully and realistically tested. The baffles will be identical to those to be used for the complete modules. The QT baffles will be placed in the tube as far as 70'+ from an open end and their fit to the inside surface and their stability without attachment to that surface will be verified by test.

- MATERIALS SUPPLIED TO CBI

Coil Manufacture and Bakeout

The beam tube material manufacturing and bakeout process will be fully demonstrated during the Qualification Test. The processes for the Qualification Test will be the same as are planned for the Option.

Coupon Outgas Testing

The coupon outgas testing process will be fully demonstrated during the Qualification Test. The coupon testing done during the QT will use the same CBI coupon outgas test equipment and same methods as are planned for the Option with the exception that the Option test system will have more than one test chamber.

Coupons will be outgas tested during the QT for all materials within the beam tube with the exception of the 10" pump port. Materials that will be tested include the tube material, bellows material and the baffle material. The limited area of the pump port negates the necessity for testing that material.

Beam Tube Manufacturing

The spiral welded beam tube manufacturing process will be fully demonstrated during the Qualification Test. The manufacturing process for the Qualification Test will be the same as is planned for the Option.

Beam Tube Transportation

The beam tube transportation methods will be fully demonstrated during the Qualification Test. The transportation methods for the Qualification Test will be the same as is planned for the Option. In addition, the acceptability of these methods has been verified with respect to fatigue concerns by calculations.

Expansion Joint Manufacturing

The expansion joint manufacturing process will be fully demonstrated during the Qualification Test. The manufacturing process for the Qualification Test will be the same as is planned for the Option with the following exceptions:

- The expansion joints for the Qualification Test will be manufactured from flat sheets of SA 204 Type 304L cold rolled material. The material will be baked in the flat sheet form. For the Option the material will be purchased and baked in coil form.

- The expansion joints for the Option may be manufactured from Hot Rolled Annealed and Pickled (HRAP) Type 304L material instead of cold rolled 304L material. Although the HRAP material is less expensive than cold rolled material it is not economically available for the minimum quantities needed for the Qualification Test. Much larger quantities are required for the Option.

- The expansion joints in Qualification Test will be mechanically formed. In the Option the expansion joints may be hydroformed instead of mechanically formed.

Only one of the expansion joint manufacturers has offered hydroformed bellows. Hydroforming the expansion joints should improve the shape of the expansion joints.

Stiffener Manufacturing

The beam tube stiffener manufacturing process will be fully demonstrated during the Qualification Test. The manufacturing process for the Qualification Test will be the same as is planned for the Option.

Baffle Manufacturing

The baffle manufacturing process will be fully demonstrated during the Qualification Test. The manufacturing process for the Qualification Test will be the same as is planned for the Option.

- CBI FABRICATION

Beam Tube Handling

The beam tube handling planned for use in the Option has been verified by calculations.

The beam tube handling methods and equipment used in the Qualification Test will not be the same methods and equipment planned for use in the Option. The handling equipment and methods used for the Option are specially designed and configured for repetitive lifting at the LIGO sites. Conventional handling methods and equipment will be employed during the Qualification Test to handle the beam tubes.

Stiffener Attachment: Fit up, Purge, Weld

The stiffener attachment process will be fully demonstrated during the Qualification Test. The welding procedure specifications (WPS) used in the Qualification Test (QT) will be the same as that planned for use in the Option. The welding equipment will be generic to (i.e. same type, possibly different brand name) that planned for use in the Option. The gas metal arc wire machine with down flat fixed torch and the internally purged beam tube can section turning on rollers are the general arrangement that will be used for the QT and for the Option.

Pumping Port: Repad Attach, Purge, Weld

The process of attaching the pump port repad will be fully demonstrated during the Qualification Test. The WPS, equipment, etc., used for the QT will be the same as or generic to that planned for use in the Option.

Final Beam Tube End Preparation

The final beam tube end preparation process will be fully demonstrated during the Qualification Test. Procedures demonstrated will be the same as those which will be used for the Option.

During the QT, the beam tube end preparations will be performed before welding the stiffeners and related attachments. Measurements made during the QT of changes in tube end flatness will provide data which may justify having the beam tube supplier perform the final end preparations in the Option. If flatness is not maintained, final end preparations will be moved to after stiffener welding in both the QT and in the Option.

Pumping Port: Bore, Fit nozzle, Purge, and Weld

The pump port production process will be fully demonstrated during the Qualification Test. The WPS, equipment, etc., used for the QT will be the same as or generic to that planned for use in the Option.

Attach Expansion Joint: Fit, Purge, Weld

The expansion joint attachment process will be fully demonstrated during the Qualification Test. The WPS, equipment, etc., used for the QT will be the same as or generic to that planned for use in the Option.

Work Conditions

The procedures for beam tube can section fabrication will be tested during the QT under realistic work conditions. This fabrication for the qualification test will be performed indoors in an environment which will be very similar to the environment of the planned fabrication facility for the complete module.

- ASSEMBLY OF BEAM TUBE MODULES

Use of Clean Room and Weld Enclosures

Use of Clean Room and Weld Enclosures is an item where the environment will be emulated during the QT while the actual equipment and operation planned for the Option will not be tested. The ability to provide a protected, access controlled, quality air enclosure, to exclude the outdoor environment from a critical work space, is an industry established construction activity. Past experience in providing these types of enclosures precludes the necessity to build and test their operation for the LIGO QT.

In order to emulate the Option phase work environment, special facility controls will be implemented in the CBI Research Center basement during the QT at times of critical installation events to prevent the final cleaned beam tube assemblies from being exposed to detrimental contaminated air flow.

Preliminary Alignment of the Beam Tube

Preliminary alignment of the beam tube assemblies in the Qualification Test will be demonstrated by test. The procedure will be similar to that planned for the Option with the following exception:

Conventional surveying and layout equipment will be used in the Qualification Test to establish the centerline reference points on the concrete slab rather than the Global Positioning System proposed for use on the Option.

Circumferential Welds: Fit, Purge, Weld

The procedures to be used for these circumferential welds will be fully demonstrated during the Qualification Test. The WPS, equipment, etc., used for the QT will be the same as or generic to that planned for use in the Option.

Sequence of Personnel Entrance into Beam Tube for Cleaning and for Installation/Removal of Purge Rings and Baffles

The sequence of personnel entrance into the Beam Tube will be fully demonstrated. The QT beam tube personnel entrance sequence will be the same as is planned for the Option.

Installation of Structural Supports

The installation of structural supports will be fully demonstrated during the Qualification Test. The procedure demonstrated will be the same as is planned for the Option.

- LEAK TESTING

Leak Testing of Can Assemblies

Leak testing of can assemblies will be demonstrated during the Qualification Test. However, the procedure demonstrated will differ in some ways from that which is planned for the Option.

The major difference will be in the equipment used to supply Helium to the outside of the can section. For the Option, a high production method will be employed wherein the can section will be placed in a specially constructed casket which will contain the applied Helium. During the QT, helium will be applied in a fine spray or by isolating successive areas with plastic sheet and duct tape, and injecting these areas with helium.

Differences in procedures will be small. Modifications between the QT and the Option phase are limited to small changes or adaptations to replicate the option phase of the LIGO project. Such changes are insignificant and may be examined in documents HMST1N and HMST1QT.

Leak Testing of Circumferential Beam Tube Welds

The leak testing of circumferential beam tube welds will be fully demonstrated during the Qualification Test. The procedure demonstrated will be the same as is planned for the Option.

Leak Testing of 10" Valve and Blind Flange Seals

The valve and blind flange mounted on the 10" pump port will be tested in the qualification test by bagging the exterior of the valve and port fittings. The inside of the tube will then be evacuated and a helium mass spectrometer hood test will be used to check for leakage. The difference between the test in the option phase and the qualification test is that CBI will use a vacuum box to evacuate the valve and fittings during the option phase. CBI has no concern about fabrication of a vacuum box for testing of the valve. CBI has used custom fabricated vacuum boxes on many projects. It is therefore not a test issue which must be modeled.

Leak Testing of Beam Tube Module

Leak testing of a beam tube module will be demonstrated during the Qualification Test. The leak test of the entire qualification test beam tube module, both before and after the bake out will be accomplished using an RGA to determine an air signature. If the pre bake out air signature indicates an air leak (the RGA has been calibrated with a known air leak), the techniques of leak test procedure HMST-4QT will be utilized to find the leak. If the post bake out air signature indicates that the air leakage is less than $1X10^{-9}$ atm cc/sec, the testing will be complete. If the air signature indicates a larger leak, the tube will be releak tested in accordance with HMST-4QT.

The Option leak location procedures discussed in HMST4N have been modified for the qualification test and are shown in HMST-4QT. The location technique used with the qualification test will be spraying the seams and fittings with helium, as opposed to using multiple RGA's or vacuum gages as is proposed for the option phase leak location.

The qualification test procedure uses very similar procedures to that which will be used on the option phase of the project. The decision process used on the qualification test leak tests will be the same as the option phase, however, the equipment will be somewhat different. Pumping systems will not be accurately modeled in the qualification test.

- CLEANING / OUTGAS PERFORMANCE

Can Assembly Cleaning

Can assembly cleaning will be demonstrated during the Qualification Test. The essential parameters of the Option Phase cleaning process will be replicated such as the temperature, pressure and flow rate of the steam, and the type of spray nozzle. However, the procedure demonstrated will differ in some ways from that which is planned for the Option. One difference will be the use of a small steam cleaning unit for the QT in lieu of a specially prepared cleaning skid for the Option. Another difference will be manual pulling of the jet cleaning apparatus through the can section in the QT in lieu of a power winch for the Option. Also, high flow input and output fans at the opposite ends of the can sections will be used for the Option but not for the QT and potable water will be used for the Option while softened water will be used for the QT.

Final Cleaning

The final cleaning procedure for the beam tube which is done in place after a can is final placed and welded will be fully demonstrated during the Qualification Test. The procedure demonstrated will be the same as is planned for the Option.

Bakeout

Based on the recommendations of the Preliminary Design Review Board, Caltech issued a Technical Directive Memorandum stating "Consider using direct current (I^2R) heating for the tube sections and expansion joints (to be used during field bake out of the beam tube modules) during the qualification test. Due to the limited time available, Caltech has not yet processed this contract change request. However, the following is presented on the assumption that an I^2R bake out will ultimately be specified for the QT by Caltech.

The I^2R bake out of the qualification test beam tube will model the critical parameters of a full module bake out. These parameters are the electrical current, the insulation, the current injection details and the effect of the bake out on the outgassing rates. The current will be identical to the full scale module. The insulation will also be identical to the insulation used for the beam tube modules. This will allow an evaluation of the bellows heating, the tube cooling at the supports and the ease of insulation installation.

The current injection system will be identical to the beam tube modules. This will confirm the acceptability of current injection into a stiffener near the end of the tube instead of injecting the current into a copper bar clamped to the tube.

The pumping speed for water vapor during the QT will be set so that the pumping speed per unit of surface area during the QT will match that which will exist in the option phase. This accurate speed-per-area modeling will ensure that the water vapor outgassing rate will be realistically simulated in the qualification test.

Parameters which will not be identical to a full module bake out will be the voltage, the percentage of tube which will have to be heated with auxiliary heaters due to end effects, and the control system. These parameters are not critical in the proof of the concept.

If the I^2R bake out is not required, the qualification test will prove the insulation system, the temperature variations at the supports, and the effect of the bake out on the outgassing rates.

Beam Tube Outgas Performance

One of the major purposes of the qualification test is the measure of the outgassing rate of the beam tube. The outgassing rates will, therefore, be measured during all phases of the qualification test. These outgassing tests will be utilized by Caltech as the final data required to confirm the pumping requirements of the full scale facilities.

- DIMENSIONAL CONTROL

Control of Materials and Assemblies

The dimensional control of materials and assemblies will be fully demonstrated during the Qualification Test. The procedures demonstrated will be the same as are planned for the Option.

Final and Maintenance Alignment

The adequacy of Global Positioning System (GPS) for final and maintenance alignment of the beam tube modules is considered to be established by the equipment's proven track record. GPS will not be tested in the QT. The GPS is a tested and proven system with known accuracy. Further, significant improvements are anticipated in the GPS system before it is needed for the LIGO project.

Clear Aperture

Clear aperture through the beam tube and baffle system has been verified by calculation based on the stackup of the tolerances of the various components and the capabilities of the GPS alignment system. There will be no verification of clear aperture by test.

2.0 TEST CONFIGURATION AND PROCEDURES FOR FABRICATION, INSTALLATION, AND TESTING

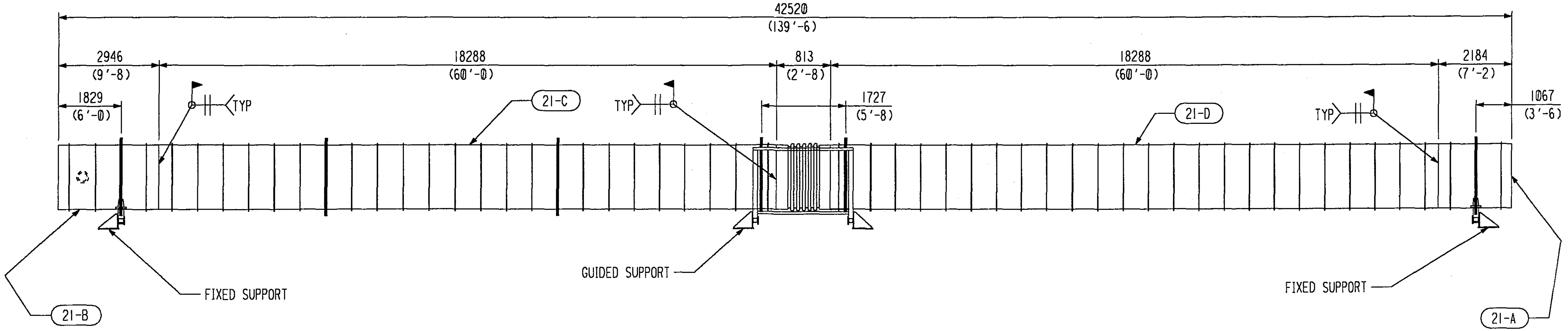
The overall test configuration, including procedures, controls the execution of the qualification test plan. The configuration has been assembled by making conceptual plans, based on requirements, and preparing designs, drawings, and procedures on the basis of these plans. Beam tube component fabrication procedures/procurement specifications have been prepared and will be used to purchase these components for the QT. Fabrication by CBI will be accomplished in two locations, Houston Welding and Plainfield Research and Development. Houston Welding (HW) will receive the spiral welded tubes in the ordered QT lengths, the stiffeners, the baffle/support rings, and the pump port. CBI HW will perform the necessary receiving inspection including dimensional inspection and welding of stiffeners, support rings and pump port. Post welding dimensional checks of the stiffened beam tubes are also performed in Houston prior to shipment to CBI Plainfield Research and Development Center. CBI's Plainfield Research and Development (R&D) Center will receive the stiffened beam tubes from HW and the expansion joints and supports from their respective manufacturers. The R&D center will perform the circumferential welds to create each beam tube can section (one aft (contains pump port) and one forward of the expansion joint). These can sections will be individually helium mass spectrometer hood tested. The expansion joint will be attached to the forward assembly and that circumferential weld will be HMS leak tested. The aft assembly will be installed including alignment as the starting piece of the QT Beam Tube Module, locating the pump port in the high vacuum lab. Final cleaning and baffle (~ 6 M spacing) installation of this aft assembly will occur at this time. The forward assembly (including expansion joint) will then be installed, including alignment, into the QT Beam Tube Module, including fitup, purge and welding of the circumferential seam joining the aft assembly to the forward assembly. This weld will be HMS leak tested. Final cleaning and baffle installation (~ 20M spacing) will occur at this time. The closure head will be installed including fitup, purge and welding. Installation alignment checks and support adjustments will be made. Vacuum thrust restraints will be added to the supports. The QT Beam Tube Module will be pumped down, air signature evaluated, and leak tested if necessary. The QT Beam Tube Module will be baked out while taking periodic RGA measurements. When the bakeout is complete, air signature will be evaluated and the QT Beam Tube Module will be leak tested if necessary. Final outgas test will then be performed .

2.1 Qualification Test Beam Tube Module Physical Configuration

The qualification test beam tube module will be composed of primarily one subassembly and has an overall length of over 130' with support centerlines of 65'. This configuration represents a current design configuration which consists of repeating subassemblies with consistent distance between support centerlines of 65' throughout the Beam Tube Module length. As shown in Drawing 20, the general configuration for the Qualification Test consists of two sections of beam tube and one expansion joint. Additional representative design details include a pump port; size and spacing of vacuum stiffeners and baffle/support rings; fixed and guided support details and location; and baffle details and location for both the ~ 20 meter spacing and ~ 6 meter spacing.

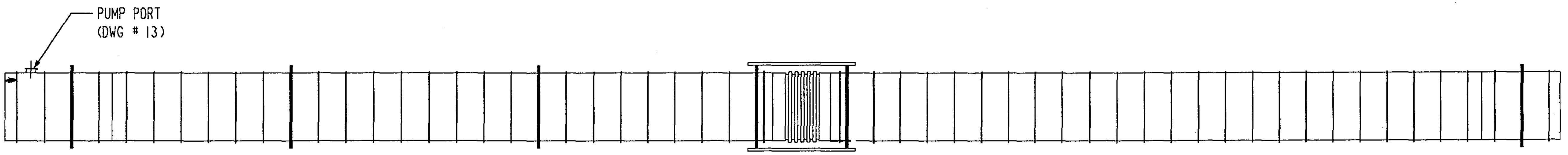
Several items, shown on sketches at the end of this section, are specific to the Qualification Test and are not used in the Beam Tube Module Detailed Design. These items are the end test/closure heads and the thrust restraint supports. Both of these items provide closure, support and restraint for the vacuum end loads on the Qualification Test Beam Tube Module. Calculations for these items are included in the Qualification Test Plan Appendices.

The qualification test will be conducted in the basement of the Research and Development Center. The QT Beam Tube Module vacuum and outgassing system will be located in the LIGO Qualification Test Vacuum Lab. the vacuum and outgassing system will be connected to the QT Beam Tube Module at the pump port.



GENERAL CONFIGURATION
(ELEVATION)

DIRECTION OF CONSTRUCTION →



PLAN VIEW

▶ INDICATES CHANGE FROM PREVIOUS ISSUE

BY	CHKD	DATE	BY	CHKD	DATE	BY	CHKD	DATE	REVISIONS

REMARKS

CBI

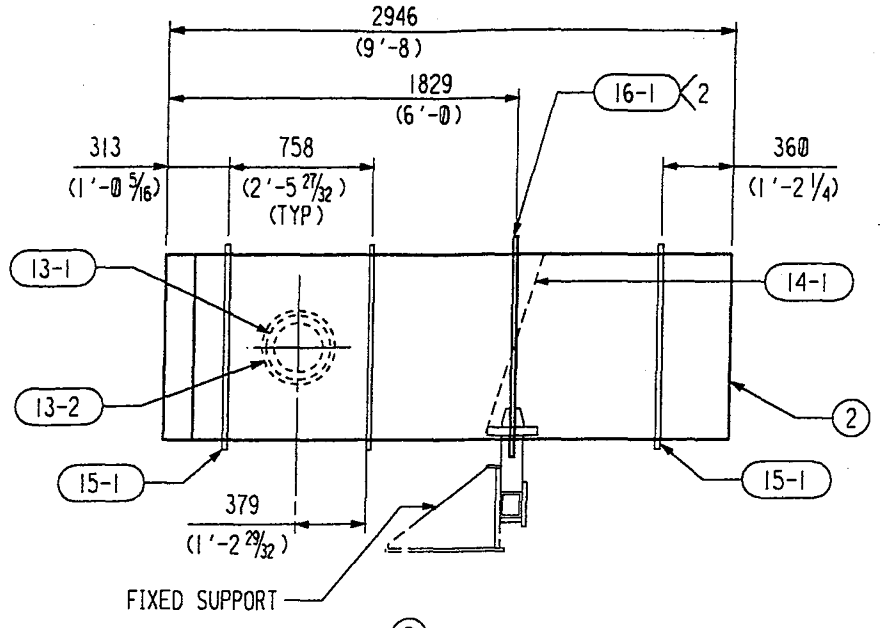
SUPPLIER'S / PURCHASER'S NO

LIGO BEAM TUBE
QUALIFICATION TEST

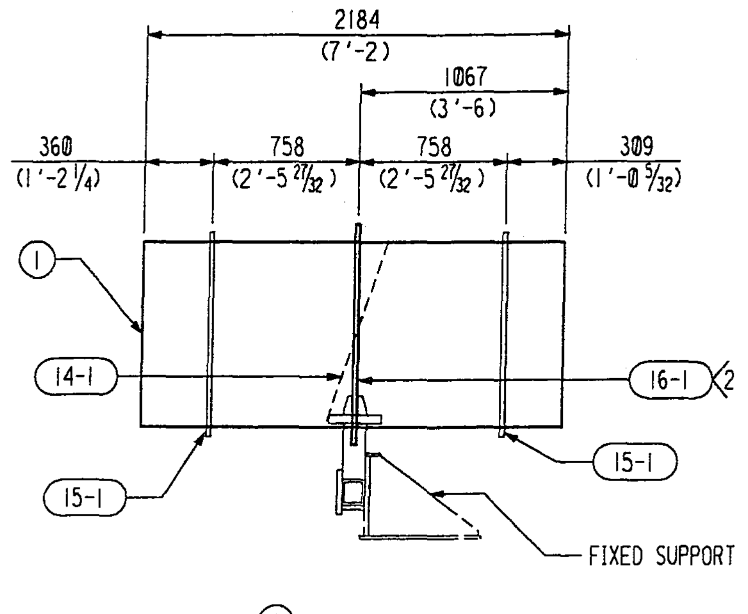
GENERAL CONFIGURATION

CUSTOMER'S NO ______
BY KJR CHKD ______ DATE ______
D.E. Thonn
ENGINEERING SUPERVISOR

CONTRACT NO
930212
DWG 20
SHT
REV 0

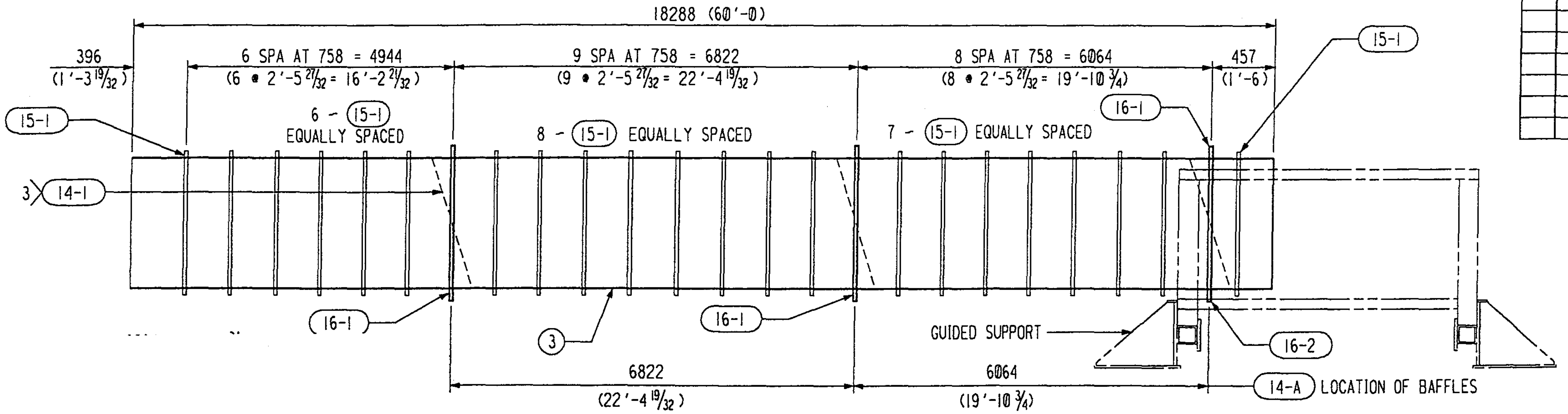


B

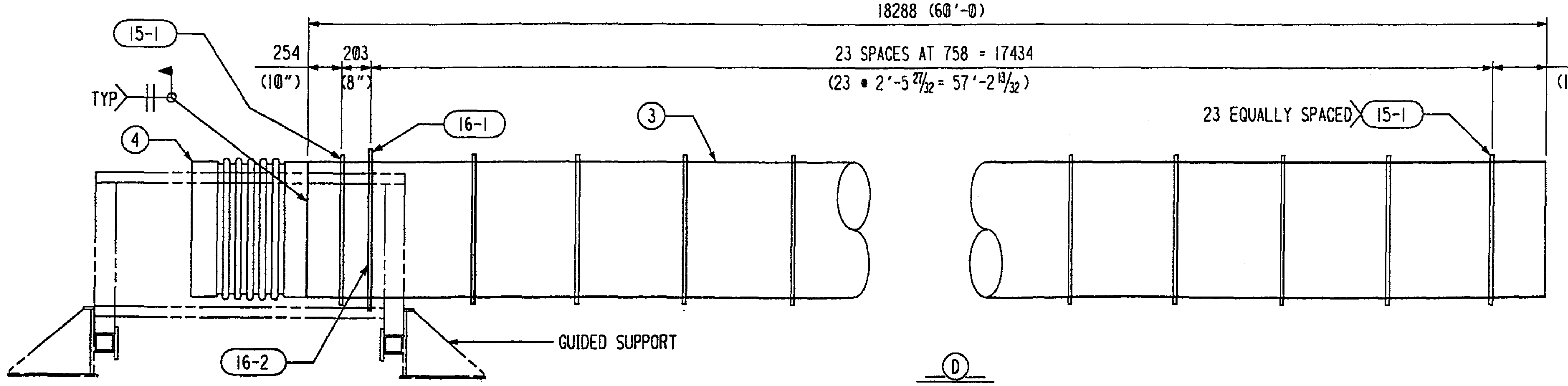


A

SHIP PC	MARK	ASSM PC	DESCRIPTION	LENGTH MM	SPEC
1	21-A		- BEAM ASSEMBLY -		
	21-1	1	BEAM TUBE 1245 x 3.2	2184	
			(49.00 OD x 0.127" THK x 7'-2 LG)		
	14-1	1	BAFFLE		
	15-1	2	VACUUM STIFFENERS		
	16-1	2	SUPPORT RING/BAFFLE STIFFENER HALF		
1	21-B		- BEAM ASSEMBLY -		
	21-2	1	BEAM TUBE 1245 x 3.2	3556	
			(49.00 OD x 0.127" THK x 11'-8 LG)		
	14-1	1	BAFFLE		
	15-1	4	VACUUM STIFFENERS		
	16-1	2	SUPPORT RING/BAFFLE STIFFENER HALF		
1	21-C		- BEAM ASSEMBLY -		
	21-3	1	BEAM TUBE 1245 x 3.2	18288	
			(49.00 OD x 0.127" THK x 60'-0 LG)		
	14-1	3	BAFFLES		
	15-1	22	VACUUM STIFFENERS		
	16-1	5	SUPPORT RING/BAFFLE STIFFENER HALF		
	16-2	1	SUPPORT RING HALF		
1	21-D		- BEAM ASSEMBLY -		
	21-3	1	BEAM TUBE 1245 x 3.2	18288	
			(49.00 OD x 0.127" THK x 60'-0 LG)		
	21-4	1	EXPANSION JOINT	813	
	15-1	24	VACUUM STIFFENERS		
	16-1	1	SUPPORT RING/BAFFLE STIFFENER HALF		
	16-2	1	SUPPORT RING HALF		



C



D

INDICATES CHANGE FROM PREVIOUS ISSUE

BY	CHKD	DATE	BY	CHKD	DATE	BY	CHKD	DATE	REVISIONS

REMARKS

CBI

SUPPLIER'S / PURCHASER'S NO

LIGO BEAM TUBE
QUALIFICATION TEST

SUB-ASSEMBLIES
A B & C

CUSTOMER'S NO ______
BY KJR CHKD ______ DATE ______
D.E. Thorn
ENGINEERING SUPERVISOR

CONTRACT NO

DWG 21
SHT
REV 0

3212A021

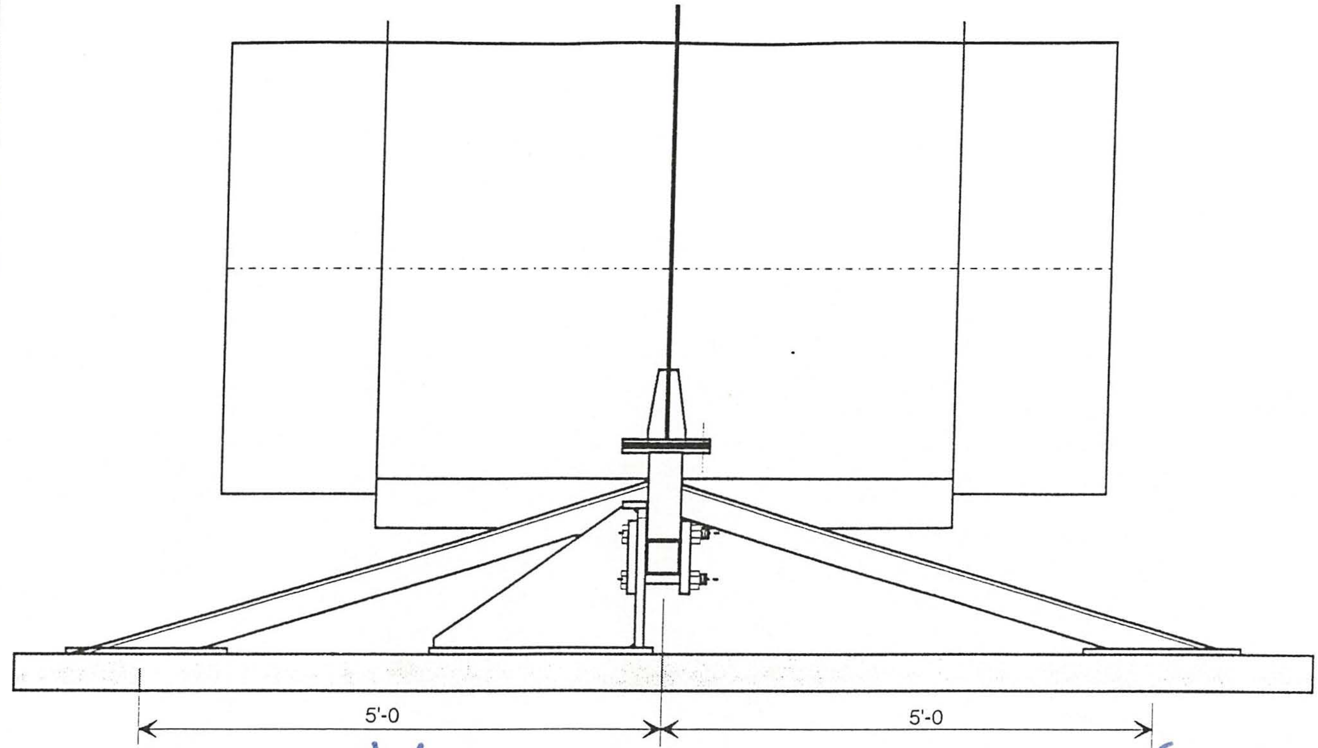
Pull the stud out !

75 ft lbs of torque on each bolt

~~Up~~ Up until it

Bellows

Spring Rate 5700 lbs/INCH

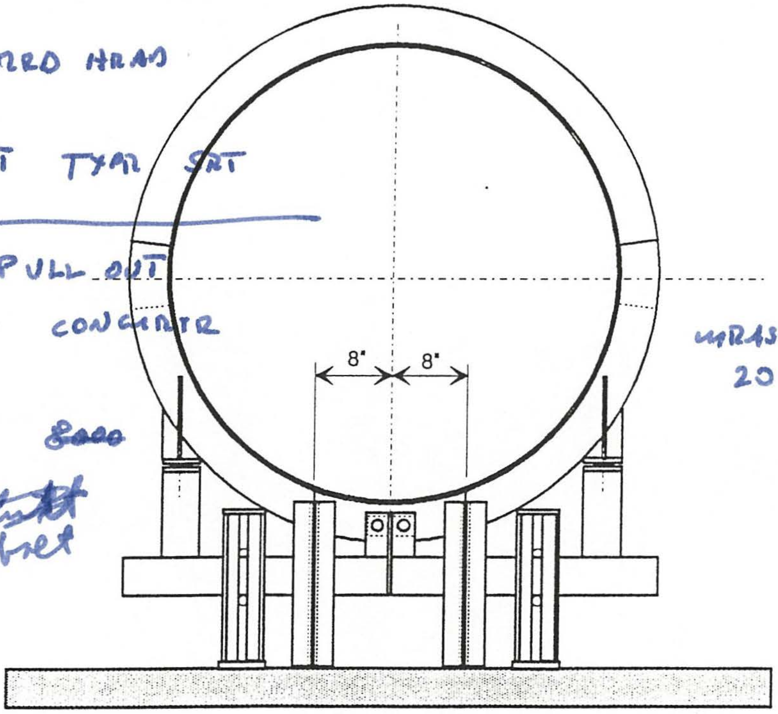


5/8 BOLTS 4/plts
6/plate 4 Plts

Course
24 ea × 5/8 - 10 tpi
COARSE

RAMSET RED HEAD
ANCHOR

TRUE BOLT TYPE SET



ULTIMATE PULL OUT
ASSUME 4000 PSI CONCRETE

MEASURED
2000 psi CONCRETE

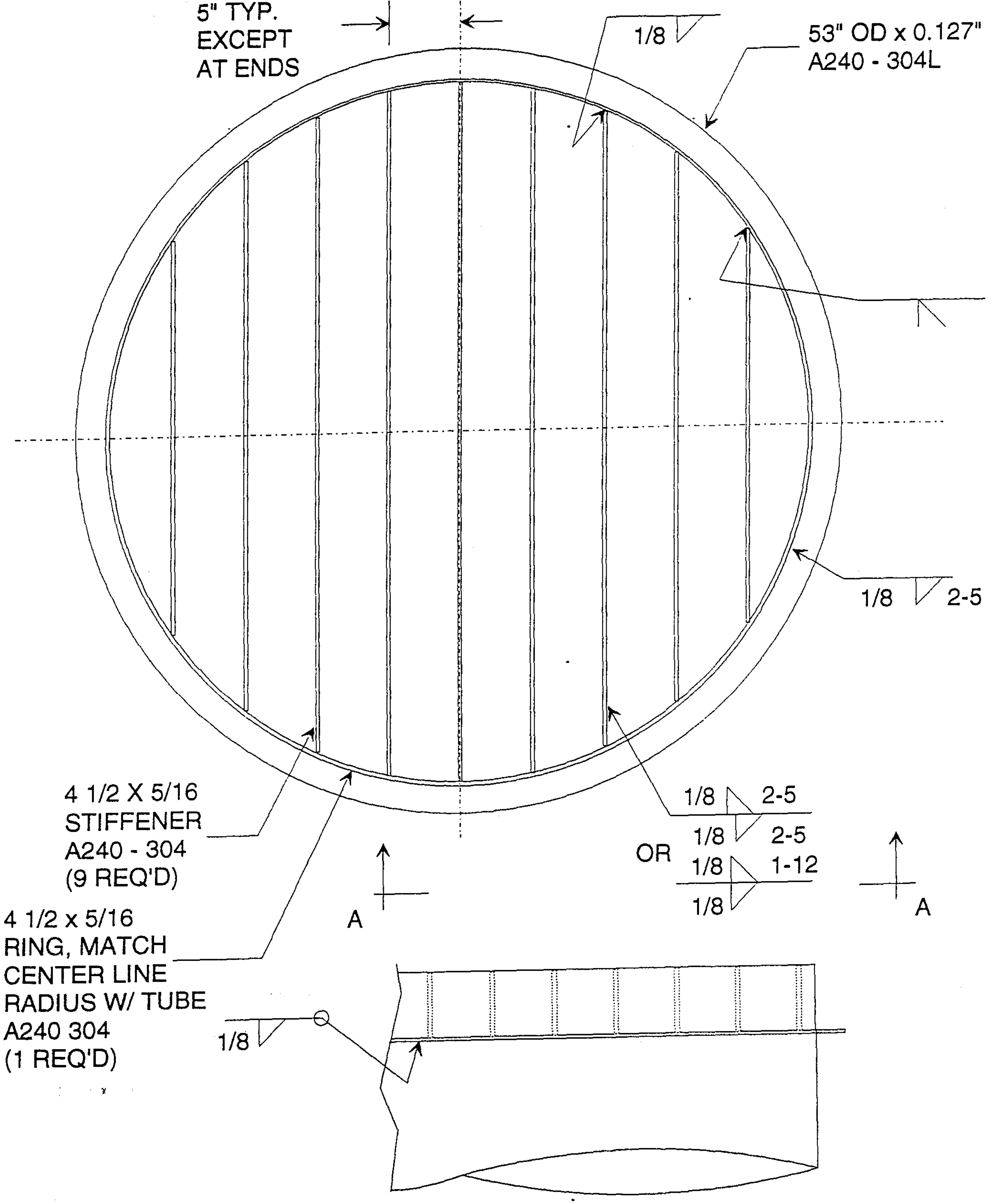
EMBEDMENT
2 3/4"
~~8000~~

8000 lb / ~~[illegible]~~ feet
~~4000 p~~

FOR
Design:
750 lb / feet

PARTONQURING (?)

SUBJECT	CBI OFFICE	REVISION:		REFERENCE NO.
THRUST RESTRAINT QUALIFICATION TEST LIGO	MADE MRS	CHK'D DDG	MADE	CHK'D	SHT___OF___
	DATE 4/1/94	DATE 4/6/94	DATE	DATE	SK-QT1



SECTION A

SUBJECT QT STIFFENED END HEAD	CBI OFFICE NOE C		REVISION 1	REFERENCE NO. 930212
MADE BY RJW	CHKD BY TKH	MADE BY RJW	CHKD BY TKH	SHT ____ OF ____
DATE 29MAR94	DATE 29MAR94	DATE 30MAR94	DATE 29 March 94	

2.2 Qualification Test Pumping and Outgassing System

The pumping and outgassing system for the Qualification test is shown in the P & I Diagrams which are located at the end of this section. The system will utilize a 1100 L/S turbomolecular pump backed by a smaller wide range turbomolecular pump and again backed by a mechanical pump. The two turbomolecular pumps in series are provided to effectively evacuate the chamber and provide the hydrogen compression ratio necessary to minimize the hydrogen background in the system. The large turbomolecular pump has a hydrogen compression ratio of 2200. The small, wide range turbomolecular pump used to back the large pump has a hydrogen compression ratio of 3 X 10^6. The combination, along with the roughing pump which will be operated at approximately 200 micron, in order to maintain the flow in the viscous regime, will provide a compression ratio in the range of 10^{12}. This will allow the system to be evacuated into the 10^{-9} torr range.

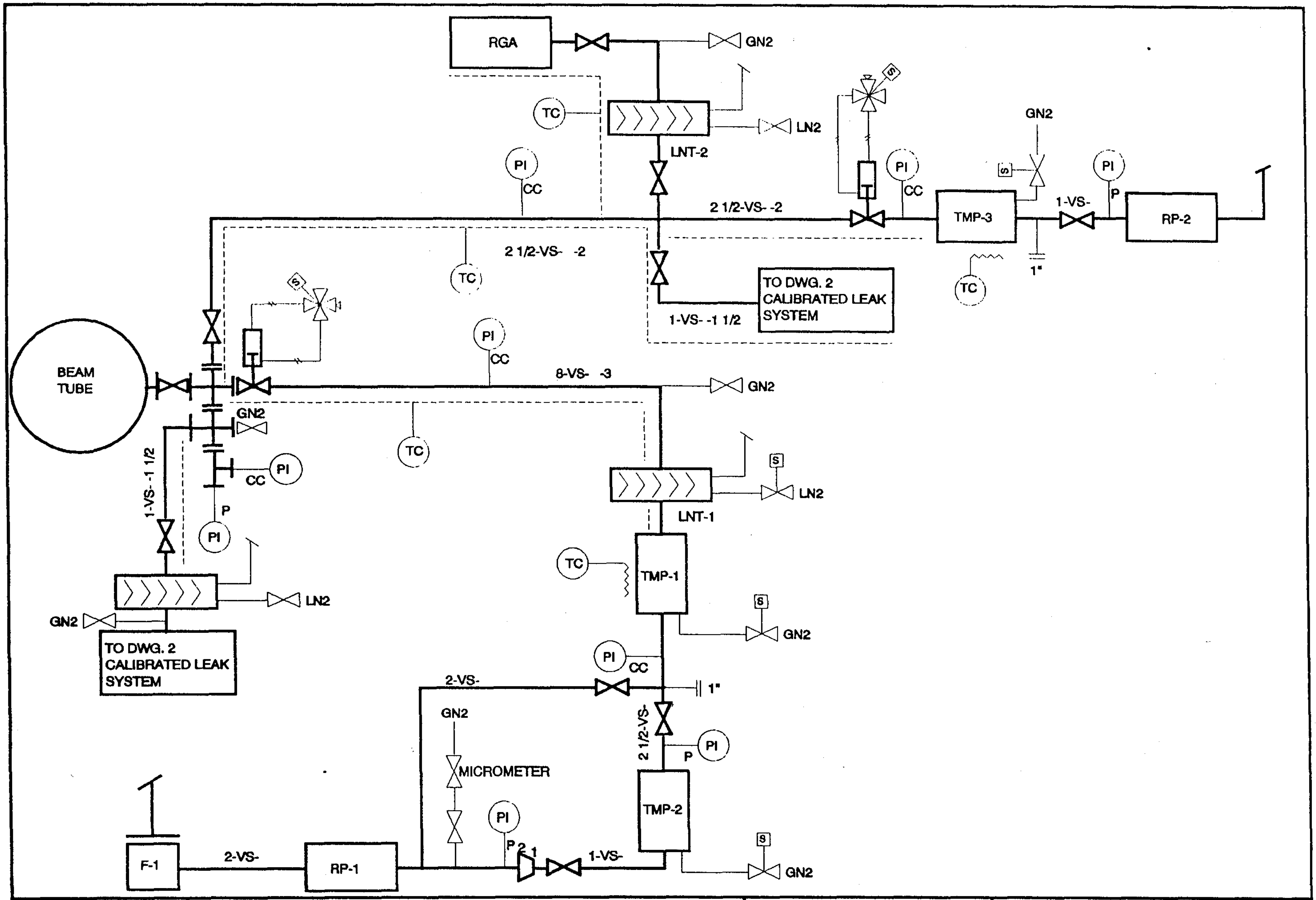
Caltech has required a maximum water vapor speed of 600 L/s in order to simulate the water pumping speed which will be present in the full size modules. CBI will therefore provide an orifice in the pumping system piping in order to limit the speed to the specified 600 L/s.

The pumping system is provided with a cold trap to prevent back streaming and to provide a known water vapor pump speed for the water vapor outgassing test. The pumping systems are also provided with a pneumatically operated valve which will shut upon equipment or electrical failure. These two features along with a viscous flow inbleed in the roughing line will prevent any hydrocarbon back streaming into the beam tube.

The outgassing test will be accomplished using a steady state outgassing technique. The partial pressure of hydrogen in the system should be in the 10^{-9} torr range and the water vapor should be in the 10^{-12} torr range, if the outgassing rates are as experienced by Caltech. The Qualification test will utilize a Balzers RGA with a detection limit in the 10^{-15} torr range. The hydrogen outgassing rate for the pumping and outgassing test system will be an order of magnitude less than the outgassing from the beam tube so the test accuracy should be sufficient for the test purposes. Spurious hydrogen from fractionation of water and hydrocarbons will be minimized because of the cold trap located in front of the RGA. The line length between the cold trap and the RGA will be minimized to minimize contamination.

The entire pumping and outgas test system will be heat traced and insulated in order to bake out the equipment up to the maximum temperature limitations provided by the equipment manufacturers. The pumping and outgas test systems are predicted to have an initial outgassing rate of approximately 1 X 10^{-12} torr liter/sec cm^2after bake out.

Calibrated leaks will be provided for nitrogen, hydrogen, helium and air leakage. These leaks will be provided in the proper ranges to accommodate calibration of the RGA and the Helium Mass Spectrometer.



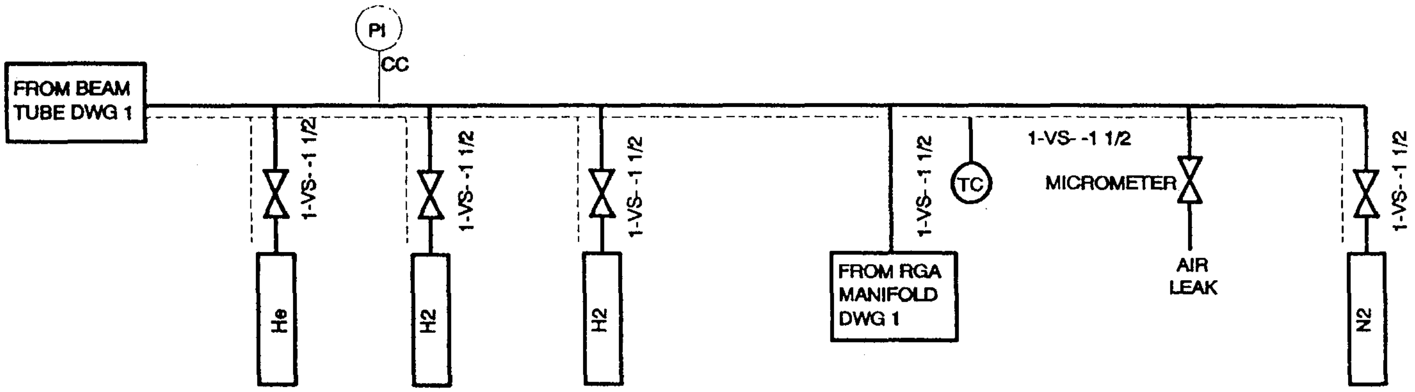
CBI

P & I DIAGRAM
VACUUM SYSTEMS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD _____ DATE 3/11/94
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	1	REV
SHT	1	5



CBI

P & I DIAGRAM
CALIBRATED LEAK SYSTEM
QUALIFICATION TEST
LIGO PROJECT
CALTECH

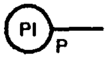
BY WAC CHKD ____ DATE 11/3/93
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG	2	REV
SHT	1	3

P & I SYMBOLS

COLD CATHODE VACUUM GAGE



PIRANI VACUUM GAGE

MANUAL VALVE

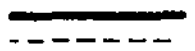
ELECTROPNEUMATEC VALVE

TWO WAY SOLENOID VALVE

FOUR WAY SOLENOID VALVE WITH PNEUMATIC SUPPLY

TWO WAY SOLENOID VALVE WITH PNEUMATIC SUPPLY

TEMPERATURE CONTROL

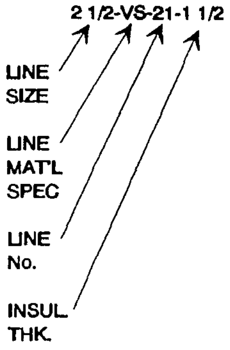


HEAT TRACED PIPING

PRELIMINARY EQUIPMENT SIZING

TMP -1	1000 L/S
TMP-2	60 L/S
TMP-3	60 L/S
TMP-4	60 L/S
TMP-5	60 L/S
RP-1	50 CFM
RP-2	1 CFM
RP-3	1 CFM
RP-4	1 CFM
LNT-1	8" TRAP
LNT-2	2 1/2" TRAP
LNT-3	2 1/2" TRAP

LINE DESIGNATION



CBI

P & I DIAGRAM
P & I SYMBOLS
QUALIFICATION TEST
LIGO PROJECT
CALTECH

BY WAC CHKD ____ DATE 11/10/93
R. C. WEBER
ENGINEERING SUPERVISOR

CONTRACT NO.
930212

DWG 3
SHT 1
REV 4

2.3 Qualification Test Procedures

The process for fabrication, installation and testing of the QT beam tube sections is accomplished by following procedures designed to produce a beam tube which meets performance requirements. The QT process procedures are sequentially listed on the next three pages . This procedure list identifies each procedure as to its authored origination: (1) directly from the detailed design; (2) QT addenda to the detailed design; or (3) QT specific. The procedures listed are included here following the list.

These procedures include material and fabrication specifications, procedure,beam tube can fabrication and module installation procedures.Fabrication and installation operations of the QT Beam Tube Module are sequenced and specified in the procedures identified as FSQT and ISQT, respectively. These procedures/sequences outline the sequential operations including dimensional control, leak testing, and cleaning that have to occur to fabricate the assemblies and install/construct the QT Beam Tube Module.

Qualification Test Procedures

ID	Title	Directly from Detailed Design	QT Addenda to Detailed Design	QT Specific
Material Specifications				
C-240-0186	Coil Material Specification	X		
C-CMBS1	Coil Material Bake Specification	X		
WMS-ER308L	Cleaning and Bakeout Procedure of ER 308L Weld Wire	X		
C-240-0187	Baffle Material Specification	X		
C-CMBS1	Baffle Material Bake Specification	X		
C-240-0194	Expansion Joint Material Specification	X		
Purchasing Specifications				
C-BT-QT	Qualification Test Beam Tube Sections			X
C-EJ-QT	LIGO Beam tube Expansion Joints Qualification Test			X
C-SUPT-1	Beam Tube Support Specification	X		
CBAF-1	Baffle Fabrication Specification	X		
C-PORT-QT	Pump Port Specification			X
C-PORTPAD-1	Pump Port Reinforcing Pad Specification	X		
C-VAC-1	Vacuum Stiffener Specification	X		
C-SUPSTF-1	Support Ring/Baffle Ring Fabrication Specification	X		
Fabrication/Installation Procedures				
FSQT	Beam Tube Can Section Fabrication Sequence for LIGO Qualification Test Addenda		X	
ISQT	Beam Tube Can Section Installation Sequence for LIGO Qualification Test Addenda		X	
FPCircumferential	Fitting/Purge Procedure for Circumferential Butt Welds for LIGO	X		
FPStiffener	Fitting/Purge Procedure for Stiffener Attachment Welds for LIGO	X		
FPPumpPort	Fitting/Purge Procedure for Pump Port Attachment Welds for LIGO	X		
MI	Material Traceability	X		
IR	Receiving Inspection	X		
DCQT	Dimensional Control		X	
Welding Procedures				
WPS-INDEX	Weld Procedure Index	X		
WPS-ER308S/GMA (w/PQR 4858)	Weld Procedure, GMA Welding for 304L Materials	X		
WPS-ER308L/Repair (w/PQRs 10029 & 4858)	Weld procedure, GMA for Repair Welding for 304L Materials	X		

Qualification Test Procedures

ID	Title	Directly from Detailed Design	QT Addenda to Detailed Design	QT Specific
GR-8X	General Repair Procedure for Materials and Welds for LIGO Beam Tube Modules	X		
CUP-8X	Plate Clean-Up Procedure for LIGO Beam Tube Modules	X		
WPS-E7018/STRUCT (w/PQR 8903)	Welding Procedure for Structural (Carbon to Carbon)	X		
WPS-E308-STRUCT (w/PQR 9168)	Welding Procedure for Structural (Stainless to Stainless)	X		
WPS-E309-STRUCT (w/PQR 6190	Welding Procedure for Structural (Carbon to Stainless)	X		
WPS-ER308L-Circ (w/PQR 10029)	Welding Procedure for Expansion Joint to Beam Tube Can Assemblies	X		
WPS-ER308L/Port (w/PQR 10029)	Welding Procedure for 10"∅ Vacuum Port Nozzle to Beam Can Assemblies	X		
WPS-ER308L/Stiffener (w/PQR 4858)	Welding Procedure for Stiffener to Beam Tube Cans	X		
GWPS-SMAW	General Welding Procedure Specification for the Shielded Metal Arc Process	X		
GWPS-GTAW	General Welding Procedure Specification for the Gas Tungsten Arc Process	X		
GWPS-GMAW & FCAW	General Welding Procedure Specification for the Gas Metal Arc and Flux Cored Arc Processes	X		
NDE Procedures				
VI5	Visual Inspection Technique Procedure Standard Procedure	X		
VI8	Visual Inspection Requirements for ASME Section VIII Code - Division 1 & 2 Pressure Vessels	X		
Cleaning Procedures				
CLCOUP	Steam Cleaning of Coupons for Outgassing Test	X		
LIGOCPQT	Planned Approach for Cleaning Maintenance for LIGO Qualification Test Addenda		X	
CL1QT	Cleaning Of Completed Beam Tube Can Sections Before And After Leak Testing And Final Assembly For Ligo Qualification Test Module Addenda		X	
CL2QT	Maintenance Of Partially Completed Beam Can Sections For Ligo Qualification Test Module Addenda		X	

Qualification Test Procedures

ID	Title	Directly from Detailed Design	QT Addenda to Detailed Design	QT Specific
CL3QT	Final Cleaning and Inspection of LIGO Beam Tube Inner Surfaces Including Baffles for LIGO Qualification Test Addenda		X	
CRWAQT	Clean Room Wearing Apparel for Beam Tube Access for LIGO Qualification Test Addenda		X	
Leak Testing Procedures				
LIGOTPQT	Planned Approach to Leak Testing for LIGO Qualification Test Addenda		X	
HMST1QT	Helium Mass Spectrometer Hood Test of Beam Tube Can Sections for LIGO Qualification Test Addenda		X	
HMST2QT	Helium Mass Spectrometer Hood Test of Closing Weld Joints Between Beam Tube Cans for LIGO Qualification Test Addenda		X	
HMST4QT	Helium Mass Spectrometer/Performance Test of Beam Tube Modules for LIGO Qualification Test Addenda		X	
Outgas Testing Procedures				
Coup-02	Coupon Outgassing Test Procedure Qualification Test			X
OUTGAS	Pump Down and Outgassing Test Procedure			X
Alignment Procedures				
AQT	Installation Alignment and Support Adjustment Procedure for LIGO Qualification Test			X
Bakeout Procedures				
BO-QT	Preliminary Procedure for Bakeout of Qualification Test Beam Tube			X
Data Acquisition Procedures				
DAQT	Data Acquisition Procedure			X

CBI

IDENTIFICATION
C-BT-QT

TITLE LIGO BEAM TUBE SECTIONS QUALIFICATION TEST	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 02/22/94	DATE 02/23/94	DATE	DATE

0.1 SCOPE

This specification gives the technical requirements for spiral welded tube sections to be used in the LIGO Beam Tube Qualification Test (QT). The scope of work consists of the fabrication of four sections of spiral welded tube sections and the associated documentation and inspection as defined by this specification. The beam tube sections will be incorporated into a high vacuum qualification test by CBI(Purchaser). Although not subjected to internal pressure, the qualification test will be built to the requirements of ASME Section VIII, Division 1 as applicable to ultra high vacuum facilities.

1.0 MATERIALS

1.1 The beam tube sections will be fabricated from material supplied by the purchaser. Sufficient material will be provided to enable the spiral welded tube manufacturer to produce approximately 60' of tube to establish the correct mill and welding parameters as required. All material provided and tube sections fabricated, including trial sections, shall remain the property of CBI. 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.

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

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 Welding and Brazing Qualifications 1992 Edition, 1993 Addenda.
2.4 CBI Specification WMS-ER308L
2.5 CBI Coil Material Specification C-40-0186
2.6 CBI Material Bake Specification C-CMBS1
2.7 LIGO Specification 110004, Rev. C, "Beam Tube Module Specification dated May 11, 1993
2.8 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 qualification test configuration is shown on the attached sketch SK-1. The QT pressure boundary is composed of four stiffened spiral welded tube sections, heads, an expansion joint and associated pumping and test equipment. The qualification will be evacuated to ultra high vacuum and stiffeners are provided to prevent collapse of the tube

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	IDENTIFICATION C-BT-QT			
TITLE LIGO BEAM TUBE SECTIONS QUALIFICATION TEST	REFERENCE NO. 930212		SHT 2 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
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sections. Only the unstiffened tube sections are covered by this specification. All tube sections shall have a nominal inside diameter of 48.75". Tube section lengths are shown below:

Two sections at 60'-0 each.
One section at 10'-0.
One section at 8'-0.

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. Tube sections shall have the following tolerances:

Perdendicularity 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:	+/- .25"
Longitudinal straightness of tube:	.25"
Diameter when supported to prevent sag or stiffened:	+.25,-0
Concentricity of expanded end to the tube axis (if ends are expanded)	.010"

Longitudinal straightness will be critical for 10% of the tube sections used for the LIGO facilities. The longitudinal straightness of the tube sections will be checked before and after stiffener attachment by the Purchaser.

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. The Purchaser will assume complete conformance unless deviations are noted.

5.1.2 A description of the vendor's 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 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.

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

5.1.7 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 Review and 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.

5.2.5 NDE personnel qualifications (Available for review)

5.2.6 Cleaning Procedures

5.2.7 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 / or 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. Purchaser will provide weld material if special processing is required.)

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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 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".

.050/130 5/13 ~ 35% only

6.1.8 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 type 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 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 out.

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. Abnormalities include all stops and starts, weld depressions, areas of wide gap, and excessive mismatch.

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.

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9.0 PACKAGING, STORING AND SHIPPING

9.1 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.

9.2 Tubes shall be shipped four to a truck and be supported within 5' of the tube ends and at the midpoints for sections over 30'. Tubes 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.

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QUALIFICATION TEST

PRODUCT
LASER INTERFEROMETER
GRAVITATIONAL-WAVE OBSERVATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO.
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DATE	DATE	DATE	DATE
03/07/94	03/10/94	03/23/94	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 qualification test. The qualification test will consists of two 48.75" inside diameter beam tube sections and one expansion joint. The qualification test will have an approximate overall length 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. The qualification test will be used to demonstrate that the technical requirements can be met. If the configuration proves to be successful, two Laser Interferometer Gravitational-Wave Observatories may be built through the construction option.

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.

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PRODUCT LASER INTERFEROMETER GRAVITATIONAL-WAVE OBSERVATORY CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
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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).

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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.

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2.0 MATERIALS

2.1 Strip or sheet

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

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° F or 338° F (see Paragraph 3.7.2)
Minimum: -16° F
Maximum operating: 100° F
Installation temperature: 20° to 100° 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 restraint, 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° to 100° F
1.21" Extension, 70° to -16° 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) due to differential settlement.

3.7.2 Transient

The expansion joint shall be designed for either condition below. The combination of both conditions is NOT required. If Condition #2 controls the design, design the expansion joint for Condition #1 and specify the maximum axial contraction for 3 cycles.

Condition #1
Axial: 3.26" Contraction (20 cycles) 70° to 302° F.
Lateral: 0.00"
Rotational: 0.10 to 0.20 degrees (20 cycles)

Condition #2
Axial: 3.76" Contraction (3 cycles) 70° to 338° F.
Lateral: 0.00"
Rotational: 0.10 to 0.20 degrees (3 cycles)

3.8 Rods (Tie/Limit/Control): None

3.9 Dimensional limitations: See Figure 2

Overall length:	2'-8 Length may be adjusted with purchaser approval
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"

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REFERENCE NO.			SHT
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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° F material temperature.)

Axial:	Supplied by Vendor, Less than 8000 lbs/in, based on a full stroke per 3.7.2, Condition #1, at 70° 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.

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PRODUCT LASER INTERFEROMETER	MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
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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 use on the vacuum side when welding attachments including shipping lugs and the name plates.

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 Joint 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

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4.4.1 Wrap the Expansion Joint securely in plastic and seal at both ends to maintain a clean state until installation by others. Cover the ends of the Expansion Joint 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 joint in a crate to protect the expansion joint and plastic wrap during shipping. Provide a procedure specifying how paragraph 4.4.1 will be met, and state what type of crate will be used.

4.4.3 The vendor shall attach a shipping device 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 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.

4.5 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° and 80° Fahrenheit.

4.6.2 The outside circumference of the ends of the expansion joints shall be within ±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 the expansion joint shall not be more than 20% of the specified maximum spring rate specified in paragraph 3.10. The measured spring rate shall be based on a full stroke per paragraph 3.7.2, Condition #1.

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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.

Need tooling to support while evacuating

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 The expansion joint shall be tested to determine the axial spring rate based on the axial movement specified in paragraph 3.7.2 Condition #1. 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.

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MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
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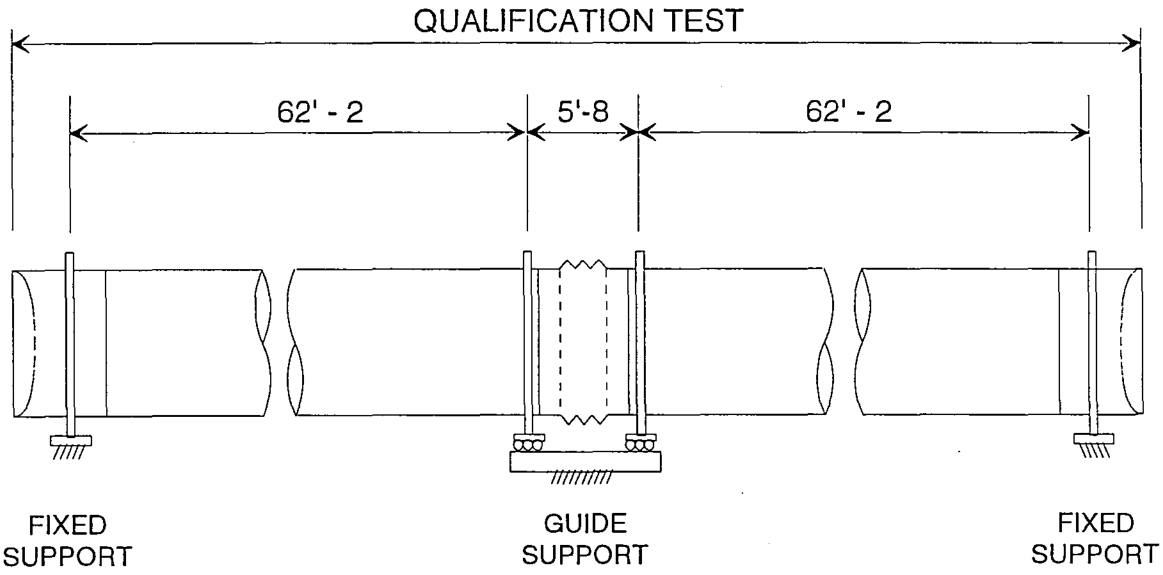

FIGURE 1

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MADE BY RJW	CHKD BY WJC	MADE BY RJW	CHKD BY WJC
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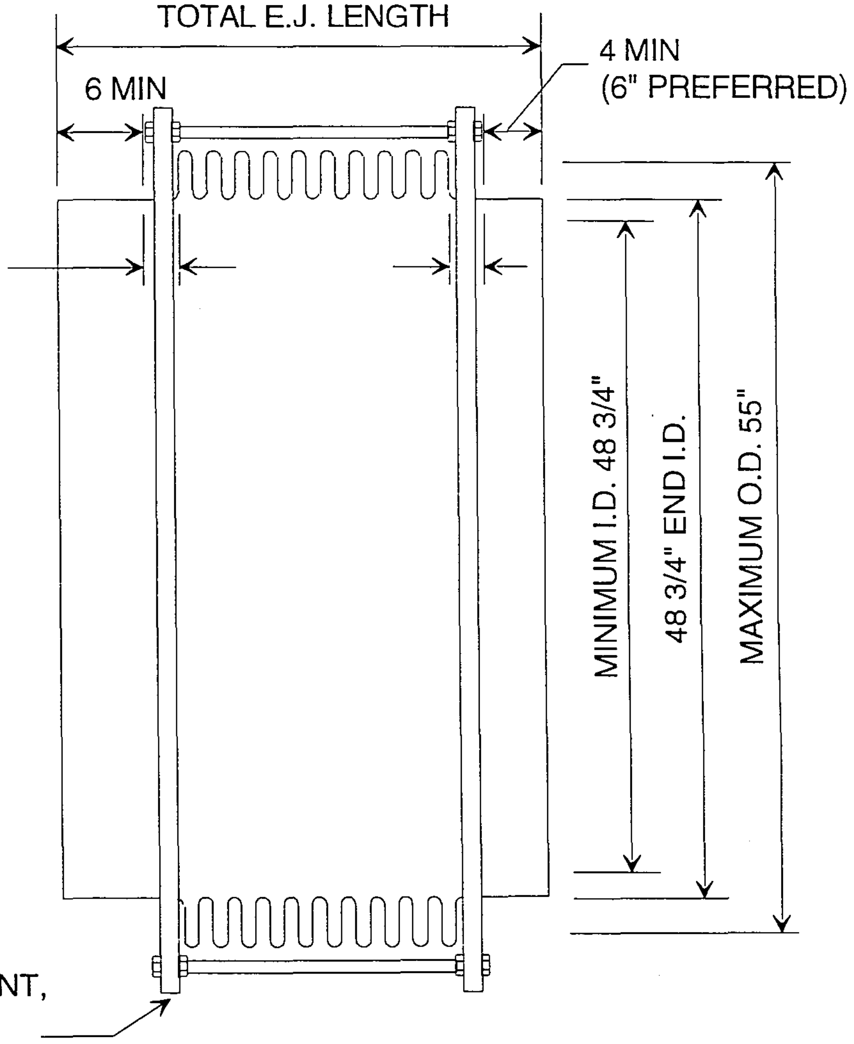


LENGTH REQUIRED
FOR SHIPPING
RESTRAINT
(TYPICAL)

EXPANTION JOINT
SHIPPING RESTRAINT,
MAY BE REUSABLE
MAXIMUM O.D. 62"
(CONCENTRIC TO
EXPANSION JOINT)

FIGURE 2

CBI	IDENTIFICATION C-PORT-QT			
TITLE PUMP PORT FABRICATION SPECIFICATION QUALIFICATION TEST	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 <u>not</u> required).

ASME Welding Qualifications, Section IX.

DROP

~~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

CBI

	IDENTIFICATION C-PORT-QT			
TITLE PUMP PORT FABRICATION SPECIFICATION QUALIFICATION TEST	REFERENCE NO. 930212		SHT 2 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

2.1 One (1) or two (2) pump ports with gaskets, test bolts, and blind flanges per Figure 1 shall be supplied to the Purchaser for the performance of a Design Qualification Test.

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 one (1) and two (2) units for the Design Qualification Test. Units shall include gaskets, test bolts, and blind flanges.

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.

CBI

	IDENTIFICATION C-PORT-QT			
TITLE PUMP PORT FABRICATION SPECIFICATION QUALIFICATION TEST	REFERENCE NO. 930212		SHT 3 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

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 an~~d 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.

CBI

IDENTIFICATION

C-PORT-QT

TITLE PUMP PORT FABRICATION SPECIFICATION QUALIFICATION TEST	REFERENCE NO. 930212		SHT 4 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

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.

CBI

TITLE PUMP PORT FABRICATION SPECIFICATION QUALIFICATION TEST	IDENTIFICATION C-PORT-QT			
	REFERENCE NO. 930212		SHT 5 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

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 x 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 x 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.

specify the protection of the sealing ~~[illegible]~~ surfaces

8.0 SCHEDULE

8.1 The vendor shall satisfy the following tentative schedule requirements:

- Supply one (1) or two (2) completed pump ports by May 1, 1994.

Planned

TITLE: BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
	BGG				PM JAC	

	BY	DATE
PREPARED	WLR	4-11-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD FABSEQ REV. No. 0		

1.0 SCOPE

1.1 This addendum outlines the changes to **Beam Tube Can Section Fabrication Sequence for LIGO** DOC ID **"FABSEQ"** procedure. The fabrication sequences that are specific to the beam tube qualification test are supplemented with details, additional supporting procedures or procedure addenda for cleaning, testing, installing, etc., and are referenced as required.

1.2 Portions of procedure Doc ID "FABSEQ" requiring changes or deletions are briefely described with applicable paragraph numbers.

2.0 FABRICATION SEQUENCE

2.1 CBI Houston Corporate Welding is the fabrication site for beam tube can section assemblies. CBITSC Plainfield is the site for final fabrication and installation. The receiving area at each location will simulate the option receiving in a similar manner.

2.2 to
2.5 See FABSEQ.

2.6 See FABSEQ and add the following: "Perform dimensional measurements using reference procedure."

****

Reference

See
Dimensional Control Procedure for LIGO
Qualification Test Module Addenda
Doc ID "DCQT"

****

2.7 to
2.14 See FABSEQ.

2.14.1 Perform dimensional measurements and baffle performance test using Dimensional Control Procedure for LIGO Qualification Test Module Addendum.

2.0 FABRICATION SEQUENCE (Continued)

2.15 See FABSEQ and change end step to the following:

2.15.1 CBI Houston Corporate Welding skip and go to step 2.30.

2.15.2 CBITSC Plainfield performs steps 2.16 through 2.29 for fabrication sequences for assembling beam tube can sections into sub-assemblies. The beam tube can sections shall be visually inspected for shipment damage and the shop release for shipment check list shall be complete before continuing.

2.15.3 CBITSC Plainfield performs steps 2.16 through 2.29 for installation of expansion joint sub-assembly to the forward assembly and performs the circumferential weld joint test using added steps 2.24.1 through 2.24.4 for the forward assembly. The sub-assembly check list testing sequence shall be complete before continuing.

2.16 See FABSEQ and change step to the following: "Move stiffened tube can section(s) or expansion joint assembly (sub-assemblies) to assembly fabrication area."

2.17to
2.24 See FABSEQ and change "expansion bellows" or "expansion joint" to "sub-assembly" as applicable. Add the following steps for testing the circumferential weld joint of the expansion joint sub-assembly to the tested forward sub-assembly. Skip steps 2.24.1 through 2.24.4 for sub-assemblies and aft assembly.

2.24.1 Shut valve on annular evacuation line.

2.24.2 Evacuate annular space using vacuum pump to 29.9" Hg.

2.24.3 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.

2.24.4 Install helium mass spectrometer vacuum cover and test beam tube weld joint.

****

Reference

See
"Helium Mass Spectrometer Hood Test of Circumferential Closing
Weld Joints Between Beam Tube Can Sections
Qualification Test Module Addenda
Doc ID "HMST2QT"

****

2.24.5 If leak is detected, vent, repair and retest in accordance with the applicable steps of procedure addendum HMST2QT.

TITLE: BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

2.0 FABRICATION SEQUENCE (Continued)

2.24.6 Remove helium mass spectrometer vacuum cover from weld joint exterior.

2.24.7 Shut helium test gas and nitrogen ring seal gas supply.

2.25 See FABSEQ. Skip if for forward assembly final fabrication.

2.26 to
2.29 See FABSEQ.

2.30 See FABSEQ delete step 2.30 and add the following steps.

2.30.1 CBI Houston Corporate Welding shall continue steps 2.31 through 2.41 for installation of pumping port. Skip and go to step 2.42.1 for beam tube can sections without pumping port.

2.30.2 CBI Plainfield skip and go to step 2.42.5.

2.31 to
2.35 See FABSEQ and add the following after step 2.35: "Perform visual inspection to assure 100% penetration and fusion. Use reference general welding procedure specification for repair when applicable."

2.36 to
2.41 See FABSEQ.

2.42 See FABSEQ delete step and add the following steps.

2.42.1 CBI Houston Corporate Welding shall perform facing of weld ends on beam tube can sections.

2.42.2 CBI Houston Corporate Welding shall perform dimensional measurements using Dimensional Control Procedure for LIGO Qualification Test Module Addendum.

2.42.3 CBI Houston Corporate Welding shall set beam tube can section with pumping port in the fabrication fit-up and weld area and position the end closure plate at the end per contract drawings. Position assembly in a fixed temporary support.

2.42.3.1 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 of 25 cfh (light positive flow).

Purge to be maintained at less than 1.0% oxygen within tube. Check periodically during any tacking and welding operation.

****

Warning

Welding or tack welding at weld
joint to be only performed after
completion of the above weld purge.

****

2.0 FABRICATION SEQUENCE (Continued)

2.42.3.2 Tack end closure flat plate to beam tube can section.Tack welding is allowed at this step.

****

Reference

See
Weld Procedure Specification
for Circumferential Welds
Doc ID "WPS-ER308L/Circ"

****

2.42.3.3 Final position, fit and tack end closure stiffener ring. Set up and position automatic weld equipment and complete welding of beam tube weld joint. Weld end closure plate and stiffener ring.

2.42.3.4 Complete fit up and weld end closure stiffener component weld joints.

****

Reference

See
Weld Procedure Specification
for GMA Welding for 304L Materials
Doc ID "WPS-ER308L/GMA"

****

2.42.3.4 Perform dimensional measurements using Dimensional Control Procedure for LIGO Qualification Test Module Addendum.

2.42.4 CBI Houston Corporate Welding shall visually inspect the interior surfaces of each beam tube can section for visible contamination with dirt, grease or heaavy layers of dust. Wipe with acetone or alcohol to remove all visible deposits of these materials. Following this solvent wipe, install end caps for shipment.

2.42.5 CBI Plainfield shall perform dimensional measurements using Dimensional Control Procedure for LIGO Qualification Test Module Addendum and install end caps

2.43 See FABSEQ and add the following steps.

2.43.1 CBI Houston Corporate Welding package and ship beam tube can sections (sub-assemblies) to CBI Plainfield.

2.43.2 CBI Plainfield for tested forward assembly skip steps 3.0 through 3.13.1 and go to step 4.1.

3.0 TESTING SEQUENCE

3.1 See FABSEQ.

3.2 See FABSEQ and change to "Perform pretest cleaning and black light testing using reference cleaning procedure addendum ."

****

Reference

See
Cleaning of Completed Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "CL1QT"

****

3.3 See FABSEQ and add the following: "CBI Corporate Welding, install end caps and go to step 4.0."

3.4 See FABSEQ and add the following: "Perform leak test on beam tube can section using reference procedure with addendum."

****

Reference

See
Helium Mass Spectrometer Hood Test
of Beam Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "HMST1QT"

****

3.5 See FABSEQ.

3.6 See FABSEQ and change to "Steps 3.7 through 3.11 are for repair and repeat testing of beam tube assemblies that have failed previous test. Skip and go to step 3.12 if not applicable to specific beam tube can section."

3.7 See FABSEQ.

3.8 See FABSEQ and change to "Step 3.4 addendum reference locates leak(s)."

3.9 See FABSEQ.

3.10 See FABSEQ and change to "Repeat step 3.4 addendum reference."

3.11 to
3.13 See FABSEQ and add the following step.

3.0 TESTING SEQUENCE (Continued)

3.13.1 Move the tested forward sub-assembly to the fabrication area for installation of the expansion joint sub-assembly and go to step 2.15.3 to continue.

4.0 BEAM TUBE CAN SECTION CLEANING

4.1 See FABSEQ.

4.2 See FABSEQ and add the following: CBITSC Plainfield shall set-up for aft and forward assembly cleaning using reference cleaning procedure addendum."

****

Reference

See
Cleaning of Completed Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "CL1QT"

****

4.3 to
4.7 See FABSEQ and change "beam tube can section" to "sub-assembly" or "assembly" as applicable.

5.0 REFERENCED PROCEDURES

See FABSEQ and add the following:"This addendum is to be used in conjunction with FABSEQ and the following additional references."

5.1 to
5.3 See FABSEQ and addendum for the Qualification Test Module Fabrication.

5.4to
5.8 See FABSEQ.

5.9 Dimensional Control Procedure for LIGO Doc ID "DC"

5.10 Dimensional Control Procedure for LIGO Qualification Test Module Addenda Doc ID "DCQT"

5.11 Helium Mass Spectrometer Test of Beam Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "HMST1QT"

5.12 Helium Mass Spectrometer Hood Test of Circumferential Closing Weld Joints Between Beam Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "HMST2QT"

5.13 Cleaning of Completed Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "CL1QT"

TITLE: BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

6.0 SEQUENCE DIAGRAM AND SKETCHES

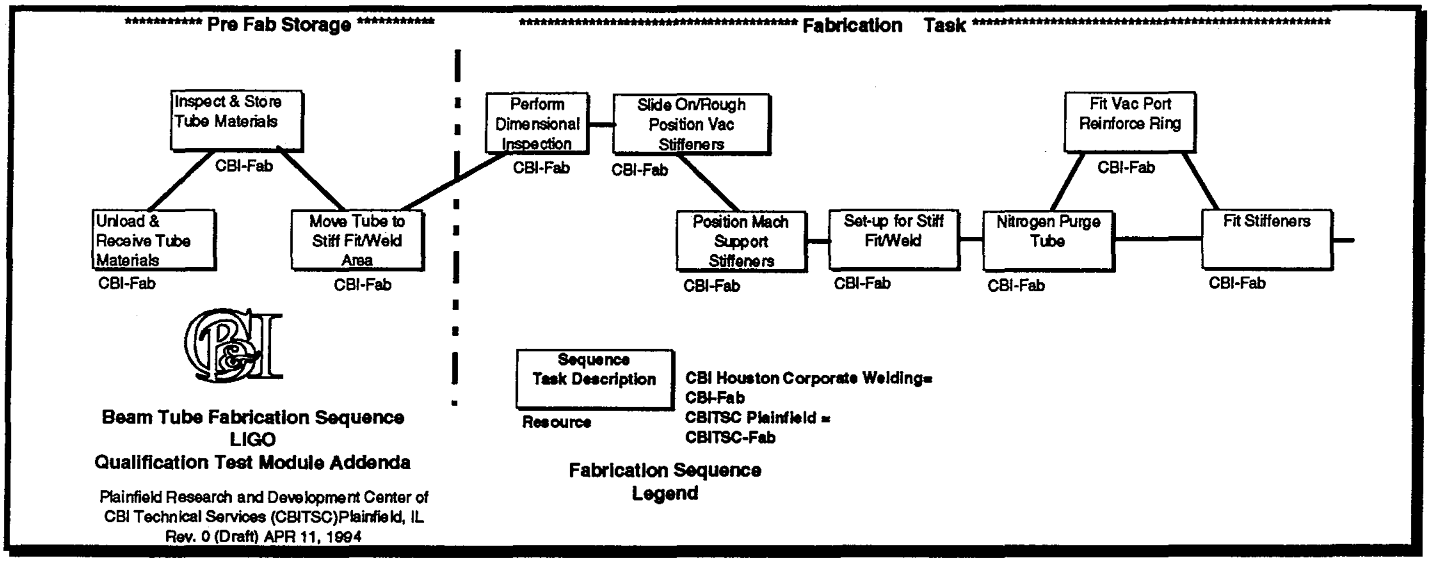
See FABSEQ and add the following: "Attached find the following related to this addendum fabrication sequence:"

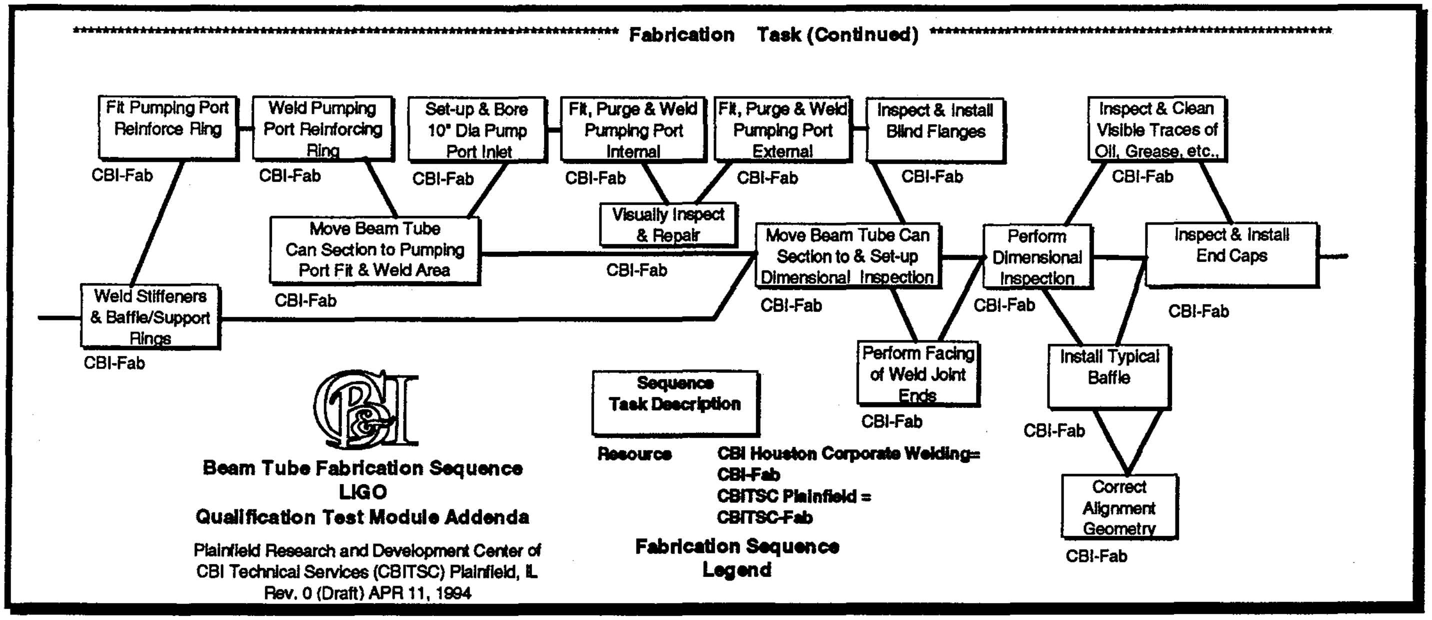
6.1 See FABSEQ.

6.2 Change to the following: "Beam Tube Fabrication Sequence Logic Diagram -- (Page 8 of 9 to Page 9 of 9)

TITLE: BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

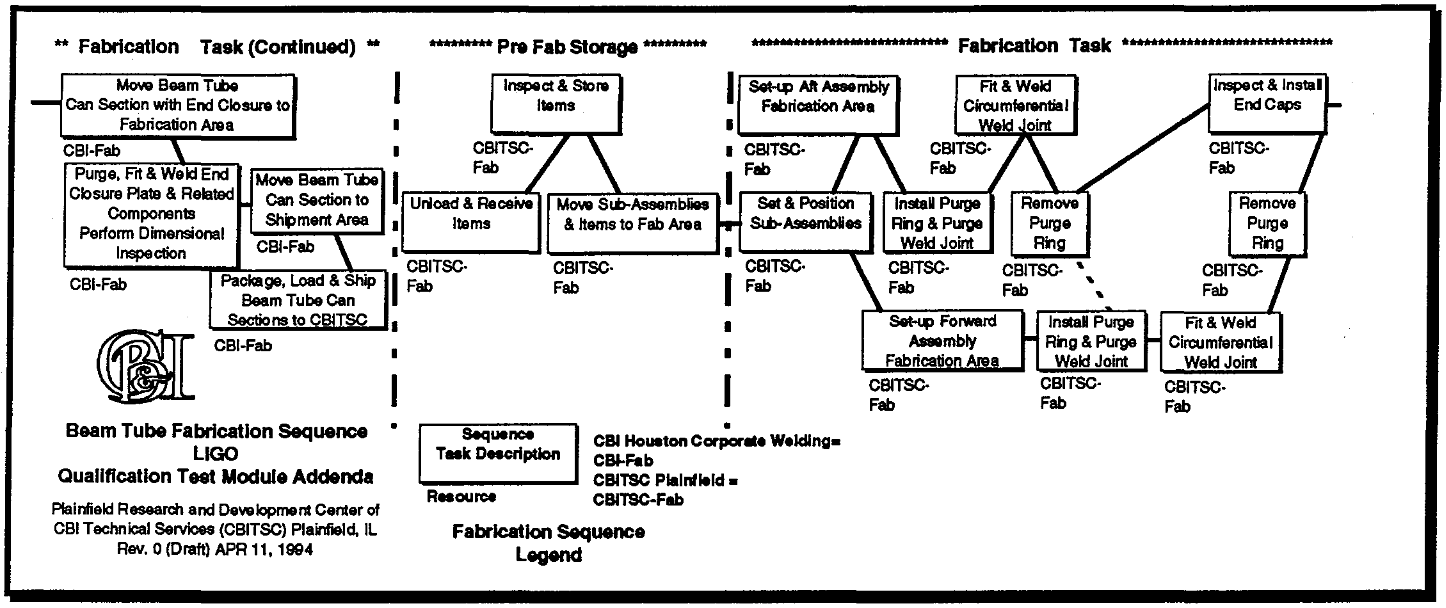
ATTACHMENT – BEAM TUBE FABRICATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA

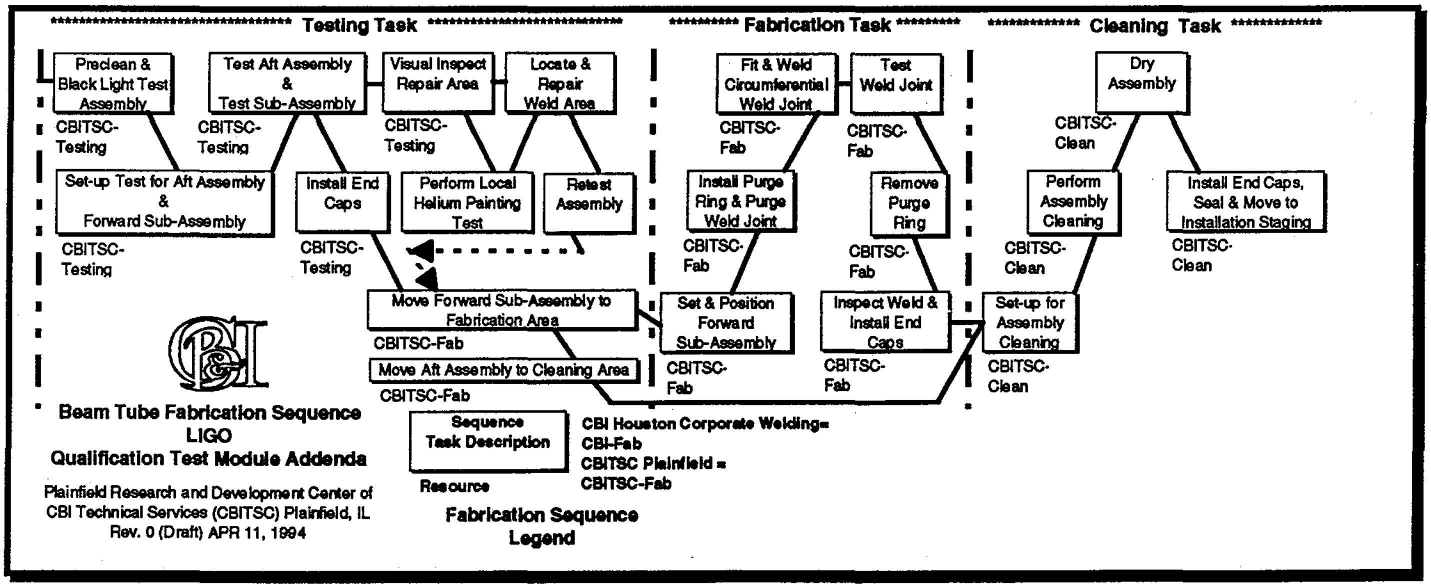




TITLE: BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

ATTACHMENT – BEAM TUBE FABRICATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA





TITLE: BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED							
Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech	
					PM JAC		

	BY	DATE
PREPARED	WLR	4-11-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD		
INSTALLSEQ REV. No. 0		

1.0 SCOPE

1.1 This addendum outlines the changes to **Beam Tube Can Section Installation Sequence for LIGO (INSTALLSEQ)** procedure. The installation sequences that are specific to the beam tube qualification test are supplemented with details, additional supporting procedures or procedure addenda for cleaning, testing, installing, etc., and are referenced as required.

1.2 General Changes:

Reference to clean room or clean enclosure shall be changed to QT installation area throughout the procedure.

synonymous

Reference to beam tube, beam tube can, beam tube can section, can, or can section shall be synominus with aft assembly, forward assembly, sub-assembly, or assembly as applicable.

1.3 Portions of procedure INSTALLSEQ requiring changes or deletions are briefely described with applicable paragraph numbers.

2.0 INSTALLATION SEQUENCE

2.1 See INSTALLSEQ, after first sentence delete remainder of step and add the following: "CBITSC Plainfield is the site for installation.

See the "Beam Tube Can Section Fabrication Sequence For Ligo" procedure and "FABSEQ for LIGO Qualification Test Module Addenda" (Doc ID's "FABSEQ" & "FSQT") for the specific sequences and procedures that are followed during the fabrication sequence.

The installation sequence begins with a beam tube assembly specific to the beam tube qualification test module. The ensuing beam tube assembly is likewise specific. The two (2) beam tube assemblies (forward and aft) with related equipment and components are assembled using methods and procedures that duplicate beam tube section installation within reasonable proximity.

Perform prerequisite installation alignment task .

****

Reference

See
"Installation Alignment and Support Adjustment
Procedure for LIGO Qualification Test"
Doc ID "AQT"

****

TITLE: BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

2.0 INSTALLATION SEQUENCE (Continued)

Move the aft assembly into position. Set aft assembly on temporary adjustable supports located clear of the contract structural support area and clear of adjoining end. Remove pumping port blind flange and connect temporary positive clean air flow tubing to qualification test vacuum lab clean room. The aft assembly is under a positive clean air flow condition. The positive clean air flow is maintained as the forward assembly is moved into position or installed. Perform the following additional steps (See INSTALLSEQ steps 2.36 through 2.45).

(2.36)
2.1.1 Remove end cap from end of aft assembly. Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry.

****

Reference

See
"Final Cleaning and Inspection of LIGO Beam Tube
Inner Surfaces Including Baffles
for LIGO Qualification Test Module Addenda"
Doc ID "CL3QT"

****

Note

****

See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.

****

(2.37)
2.1.2 Inspect and clean aft assembly interior as workman "backs out" and install baffles into the clean area per Doc ID "CL3QT" and contract drawings.

(2.38)
2.1.3 Perform dimensional check information and complete records on aft assembly at support locations and installed baffles.

(2.39)
2.1.4 Install tube access plug 8" from end of aft assembly immediately upon completion of cleaning, baffle installation and exit from aft assembly.

(2.40)
2.1.5 Install end cap.

2.0 INSTALLATION SEQUENCE (Continued)

(2.41)
2.1.6 At this point installation is complete and the forward assembly installation may be started.

(2.42)
2.1.7 Install contract fixed structural support on aft assembly after equipment has been removed clear of structural support point.

(2.43) to
(2.45)
2.1.8 Remove the temporary adjustable supports. Grout is not required for the QT.

The forward assembly is moved into position in a tested and internally cleaned condition with end caps installed on both ends.

2.2to
2.3 See INSTALLSEQ.

2.4 See INSTALLSEQ and delete step.

2.5 to
2.6 See INSTALLSEQ.

2.7 See INSTALLSEQ and change step to the following: "Align forward assembly centerline and elevation to the previously installed alignment reference points per Doc ID "AQT".

2.8 to
2.9 See INSTALLSEQ. Delete steps.

2.10 See INSTALLSEQ and change step to the following: "Remove end cap from end of forward assembly ."

****

Note

****

**See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.**

****

2.11 to
2.16. See INSTALLSEQ and change reference to the following:

2.0 INSTALLATION SEQUENCE (Continued)

****

Reference

See
"Helium Mass Spectrometer Hood Test of Circumferential
Closing Weld Joints between Beam Tube Cans
for LIGO Qualification Test Module Addenda"
Doc ID "HMST2QT".

****

2.17to
2.21 See INSTALLSEQ.

2.22to
2.23 See INSTALLSEQ. Steps not used for qualification test module.

2.24 See INSTALLSEQ and change step to the following: "Install helium mass spectrometer vacuum cover and test circumferential weld joint per procedure Doc ID "HMST2QT."

2.25 See INSTALLSEQ. Change procedure Doc ID to "HMST2QT"

2.26 to
2.31. See INSTALLSEQ.

2.32 to
2.35 See INSTALLSEQ. Steps not used for qualification test module.

2.36 See INSTALLSEQ and add additional task before step 2.36 as follows:

2.36.A "Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry."

2.36 to
2.37 See INSTALLSEQ and add the following note.

****

Note

****

See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.

****

2.0 INSTALLATION SEQUENCE (Continued)

2.38 to
2.40 See INSTALLSEQ.

2.41 See INSTALLSEQ and Change step to the following: "At this point installation of the beam tube qualification test module is set-up for the alignment acceptance test."

2.42 See INSTALLSEQ and change step to the following: "Install contract fixed & guided structural support on forward assembly after equipment has been moved from structural support points."

2.43 to
2.45 See INSTALLSEQ and add the following steps.

2.46 Perform post installation alignment task and alignment acceptance test per Doc ID "AQT" and contract drawings.

2.47 Remove end cap and the internal tube access plug from the beam tube module end. Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry. Verify final beam tube module cleaning per procedure Doc ID "CL3QT."

****

Note

****

**See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.**

****

2.48 Set-up for fitting and purge for end closure and related component installation. Align the end closure and rough position near final location. Remove pump port temporary positive clean air flow tubing to qualification test vacuum lab clean room and install qualification test module vacuum lab testing valve.

2.50 Purge beam tube module 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 of 25 cfh (light positive flow).

Purge to be maintained at less than 1.0% oxygen within tube. Check periodically during any tacking and welding operation.

2.0 INSTALLATION SEQUENCE (Continued)

****

Warning

Welding or tack welding at weld joint to be only performed after completion of the above weld purge.

****

2.51 Verify purge prior to welding. Tack welding is allowed at this step. Final position, fit and tack end closure and related components.

2.52 Complete fit up of weld joints.

****

Reference

See
Weld Procedure Specification
for Circumferential Welds
Doc ID "WPS-ER308L/Circ"
and
Weld Procedure Specification
for GMA Welding for 304L Materials
Doc ID "WPS-ER308L/GMA"

****

2.53 Set up and position weld equipment as applicable and complete welding of end closure and related component weld joints. Perform final visual check of completed welds. Install qualification test supplemental support components on fixed supports.

2.54 Set-up for beam tube module testing. Open vacuum lab valve and vent purge gas through vent valve installed in beam tube module end closure using positive clean air flow. Close valve and perform installation leak test before final testing.

****

Reference

See
"Helium Mass Spectrometer/Performance Test
of Beam Tube Module
for LIGO Qualification Test Module Addenda"
Doc ID "HMST4QT"

****

2.55 Perform helium mass spectrometer test of installed valve and qualification test beam tube module.

2.56 Perform documentation review and final visual check before qualification test testing.

TITLE: BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

3.0 REFERENCED PROCEDURES AND SPECIFICATIONS

See INSTALLSEQ and add the following: "This addendum is to be used in conjunction with INSTALLSEQ and the following additional references."

3.1 to 3.9 See INSTALLSEQ references and applicable addendum for the Qualification Test Module Installation.

3.10 Welding Procedure Specification for GMA Welding for 304L Materials Doc ID "WPS-ER308L/GMA"

3.11 Dimensional Control Procedure for LIGO Doc ID "DC"

3.12 Dimensional Control Procedure for LIGO Qualification Test Module Addenda Doc ID "DCQT"

3.13 Installation Alignment and Support Adjustment Procedure for LIGO Qualification Test Doc ID "AQT"

3.14 Maintenance of Partially Completed Beam Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "CL2QT"

3.15 Final Cleaning and Inspection of Internal Surfaces Including Baffles for LIGO Qualification Test Module Addenda Doc ID "CL3QT"

3.16 Helium Mass Spectrometer Hood Test of Closing Weld Joints Between Beam Tube Cans for LIGO Qualification Test Module Addenda Doc ID "HMST2QT"

3.17 Helium Mass Spectrometer/Performance Test of Beam Tube Module for LIGO Qualification Test Module Addenda Doc ID "HMST4QT"

4.0 SEQUENCE DIAGRAM AND SKETCHES

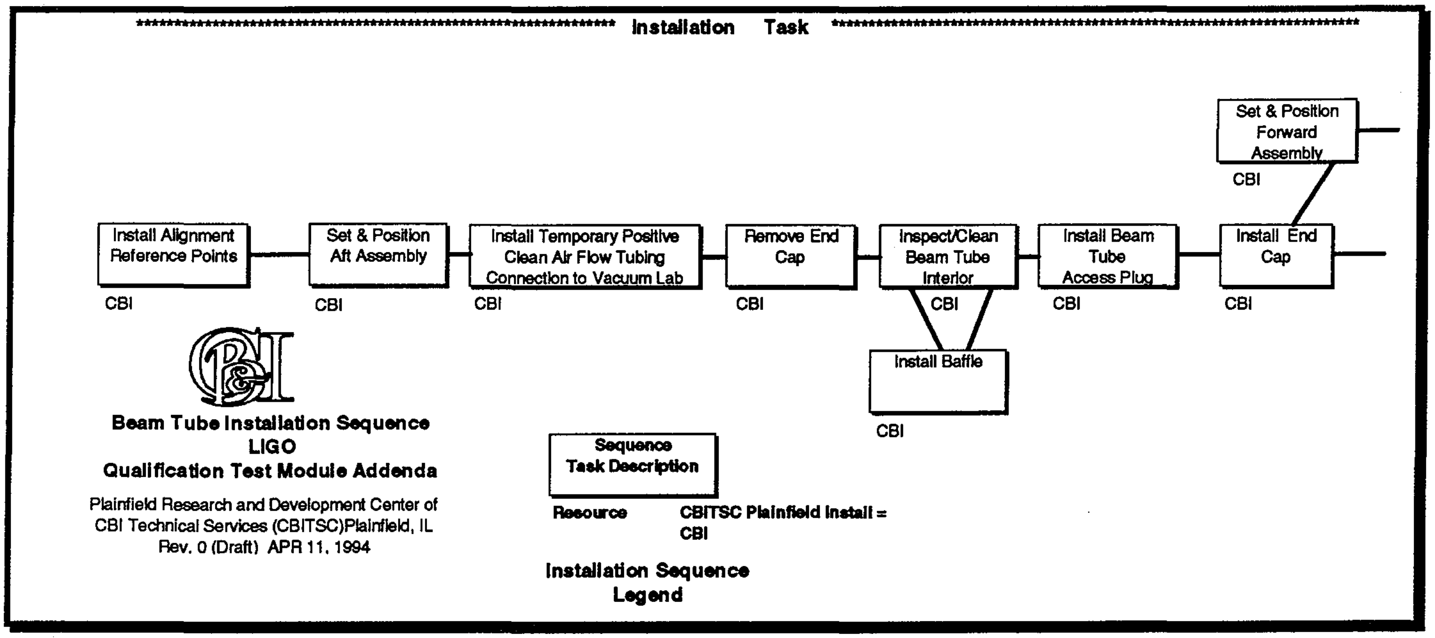
See INSTALLSEQ and add the following: "Attached find the following related to this addendum installation sequence:"

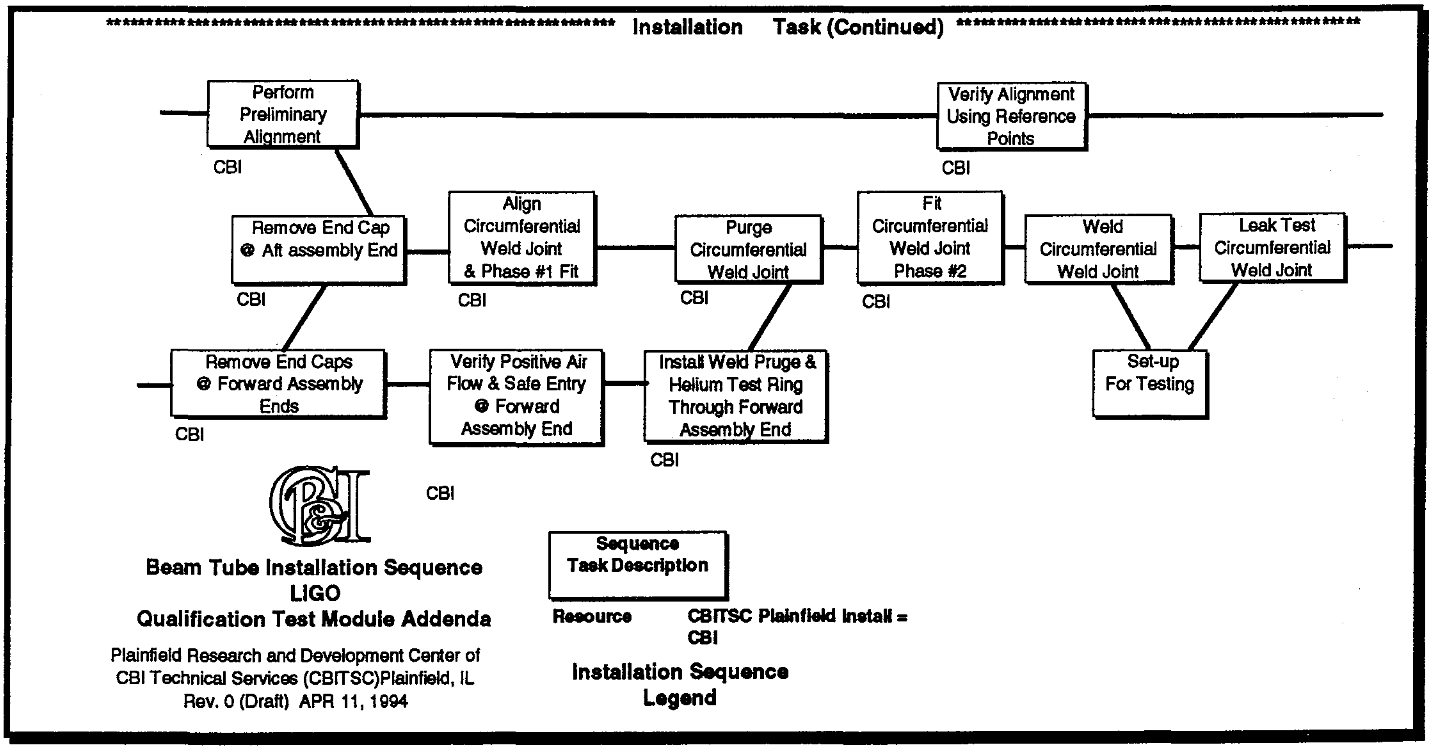
4.1 See INSTALLSEQ.

4.2 Change to the following: "Beam Tube Installation Sequence Logic Diagram -- (Page 8 of 9 to Page 9 of 9)

TITLE: BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

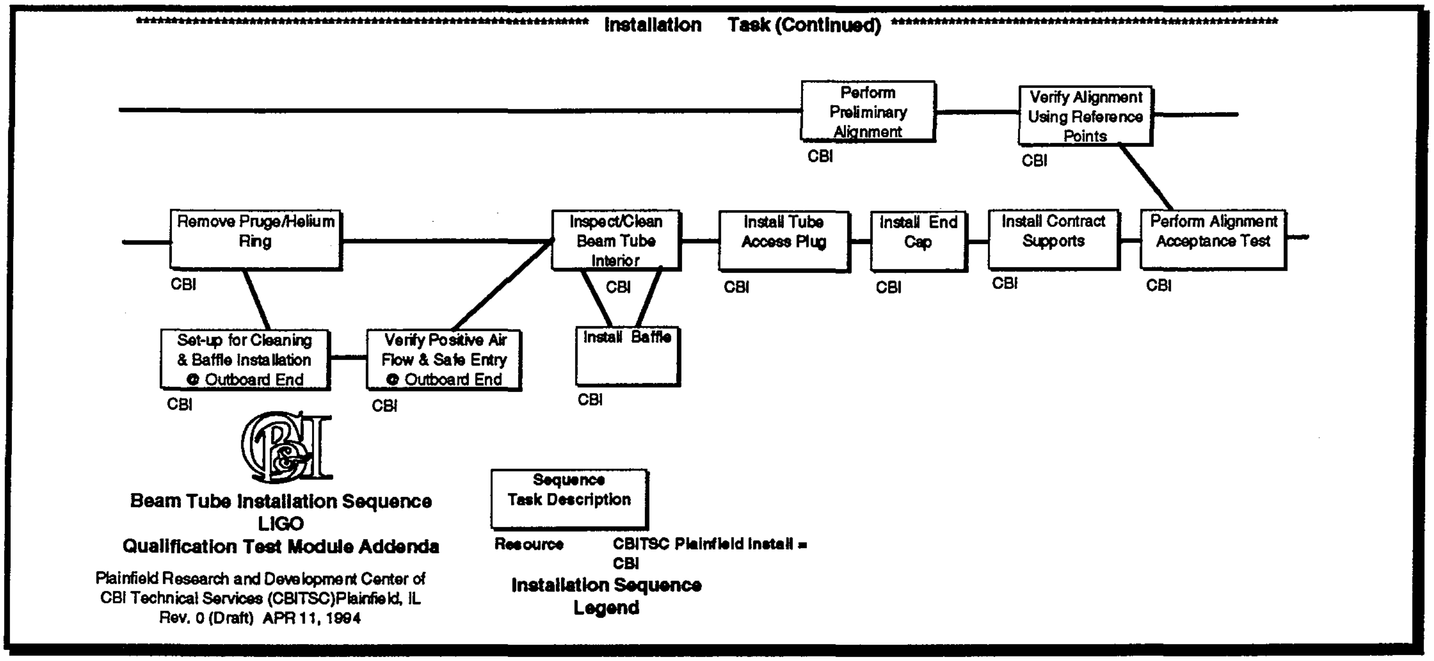
ATTACHMENT – BEAM TUBE INSTALLATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA

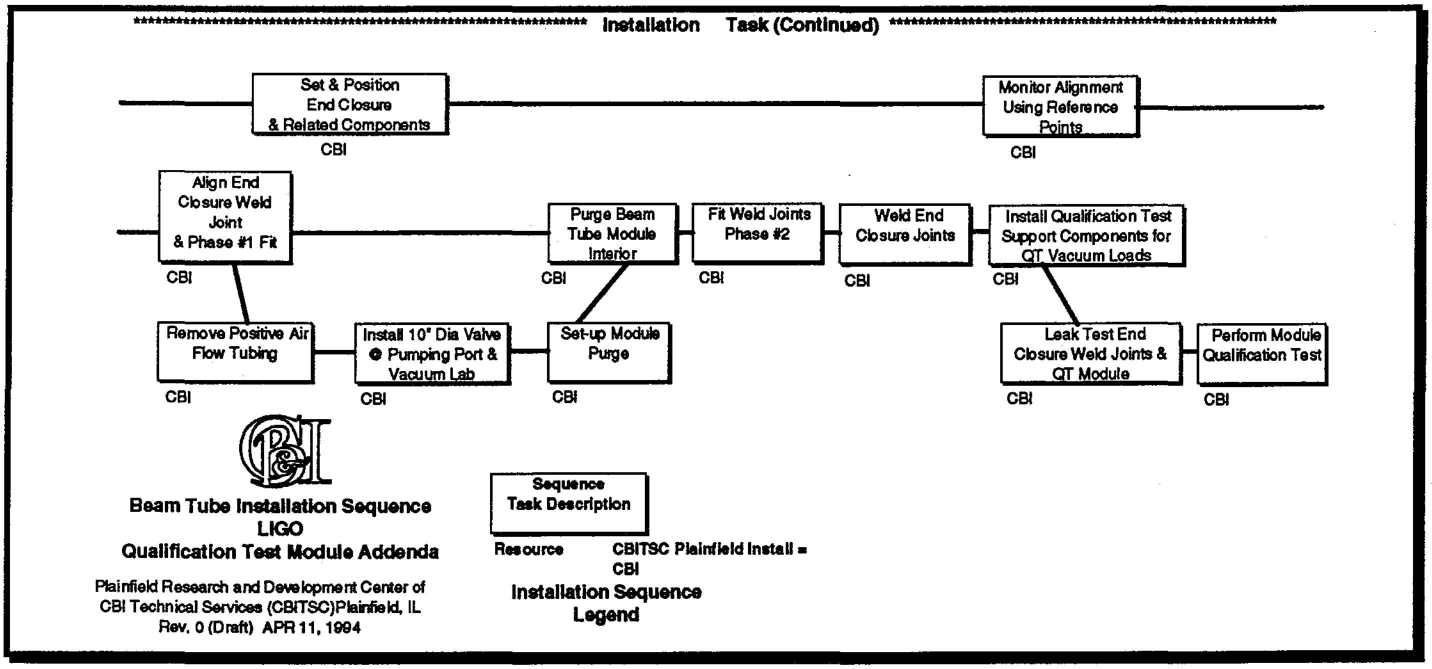




TITLE: BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

ATTACHMENT – BEAM TUBE INSTALLATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA





CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: DCQT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 2

TITLE: DIMENSIONAL CONTROL PROCEDURE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
SWP					PM JAC	

	BY	DATE
PREPARED	WLR	4-8-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	REV. No.	

1.0 SCOPE

1.1 This addendum outlines the changes to **Dimensional Control Procedure for LIGO** Doc ID "**DC.**" The dimensional measurements that are specific to the beam tube qualification test are supplemented with details, additional supporting procedures or procedure addenda and are referenced as required.

1.2 Portions of procedure Doc ID "DC" requiring changes or deletions are briefely described with applicable paragraph numbers.

2.0 DIMENSIONAL CONTROL EQUIPMENT

2.1 Change "CBI's QAM" to "CBI's ASME QCS, Division 3 & 4, Section 9" and "Welding & QC Supervisor" to "Project Manager."

3.0 DEFINITIONS

3.1 to
3.7 See DC.

4.0 MEASUREMENT METHODS

4.1 to
4.2 See DC.

5.0 COMPONENT INSPECTION

5.1 See DC and Change "Option" to "Qualification Test" and add the following component.

J. Qualification Test Module End Closures -- Inspection by supplier, documentation review, receiving inspection with random checks for general dimensions shown on vendor shop drawings.

5.2 Inspection by Supplier

5.2 See DC.

5.3 Receiving Inspection

5.3.1to
5.3.8 See DC and add the following paragraph.

5.3.9 Qualification Test Module End Closures have random measurements verified during receiving inspection with random checks for general dimensions shown on vendor shop drawings.

TITLE: DIMENSIONAL CONTROL PROCEDURE FOR LIGO QUALIFICATION TEST MODULE ADDENDA

5.0 COMPONENT INSPECTION (Continued)

5.4 Assemblies Fabrication

The Qualification Test Fabricated Assemblies have circumferential weld joints that the Option beam tube can sections do not have. The final length and straightness of the assembly shall be measured after the circumferential weld joint joining the short beam tube can section to the longer beam tube can section has been completed. The pumping port assembly has an end closure installed. Measurements shall be taken before and after the end closure and related components are welded. The finished lengths and straightness are similiar to the finished length after installing the expansion joint in the Option. The measurement record and check list shall document the specific lengths for the Qualification Test.

5.4.1 to
5.4.3 See DC.

5.5 Construction Installation

The Qualification Test (QT) Installation Module has a circumferential weld joint at the closure ends that the Option beam tube module does not have. The final length of the QT module shall be taken before and after the end closure and related components are welded. The measurement record and check list shall document the specific lengths for the Qualification Test. The alignment acceptance test will be performed before the end closure is installed.

5.5.1 See DC..

6.0 CALTECH SPECIFICATION DIMENSIONAL TOLERANCES

6.1 to
6.5 See DC.

7.0 ASME CODE, SECTION VIII DIV. 1 DIMENSIONAL TOLERANCES

7.1 See DC.

8.0 RECORDS

8.1 to
8.2 See DC.

8.3 Change "Project Manager" to "Engineering Project Manager."

9.0 ATTACHMENTS

9.1 to
9.2 None See DC.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: LIGOCPQT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 2

TITLE: PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO QUALIFICATION TEST ADDENDA

APPROVED	Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	MJG	4-8-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	REV. No.	

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 CL1QT 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 CL2QT 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 Softened 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 CL1QT for each beam tube can section.

5.2.2 Satisfactory cleaning maintenance during construction per procedure CL2QT 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.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: CL1QT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 3

TITLE: CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
					PM EEB	

	BY	DATE
PREPARED	MJG	4-7-94
REVISED		
AUTHORIZED		
REFERENCED		
STANDARD CL1N	REV. No.	1

1.0 SCOPE

1.1 This procedure covers the on-site initial 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. Unless otherwise noted, this procedure will addend to document CL1N. Use this procedure with procedure LIGOCP.

2.0 PERSONNEL CLOTHING REQUIREMENTS:

2.1 See document CL1N.

2.2 See document CL1N.

3.0 EQUIPMENT AND MATERIALS TO BE USED WITH THIS PROCEDURE:

3.1 See document CL1N.

3.2 See document CL1N.

3.3 Omitted for the qualification test procedure.

3.4 One (tugger) with cable for each cleaning station for pulling the jet cleaning apparatus through the can section.

3.5 See document CL1N.

3.6 Omitted for the qualification test procedure.

3.7 Omitted for the qualification test procedure.

3.8 See document CL1N.

3.9 See document CL1N.

3.10 See document CL1N.

TITLE: CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QUALIFICATION TEST MODULE ADDENDA

4.0 GENERAL PROCEDURE:

4.1 Omitted for the qualification test procedure.

4.2 Omitted for the qualification test procedure.

4.3 Omitted for the qualification test procedure.

4.4 See document CL1N.

5.0 BLACKLIGHT INSPECTION AND SOLVENT CLEANING PROCEDURE:

5.1 See document CL1N.

5.2 See document CL1N.

5.3 Starting at the end of the can section, 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.

5.4 See document CL1N.

6.0 STEAM CLEANING PROCEDURE:

6.1 Omitted for the qualification test procedure.

6.2 See document CL1N.

6.3 See document CL1N.

6.4 See document CL1N.

6.5 See document CL1N.

6.6 See document CL1N.

6.7 Connect the cable from the (tugger) to the end of the jet cleaning apparatus.

6.8 When the jet cleaning head starts to rotate at a speed of 1 rps with a flat spray pattern of 6 inches, pull the (tugger) to start the jet cleaning apparatus moving through the can section toward the low end at a rate of approximately two (2) feet per minute. Open the valve to the recieving tank to carry the condensed steam (used water) to the sanitary sewer. Reel up the excess hose as the jet cleaning apparatus proceeds toward the low end.

TITLE: CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QUALIFICATION TEST MODULE ADDENDA

6.9 When the jet cleaning apparatus reaches the low end of the can section, disconnect the jet cleaning apparatus (tugger) cable.

6.10 See document CL1N.

6.11 See document CL1N.

6.12 See document CL1N.

6.13 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. The helium mass spectrometer leak test can now be performed on the can section.

7.0 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.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: CL2QT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF2

TITLE: MAINTENANCE OF PARTIALLY COMPLETED BEAM CAN SECTIONS FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
					PM	
					EEB	

	BY	DATE
PREPARED	MJG	4-7-94
REVISED		
AUTHORIZED		
REFERENCED		
STANDARD CL1NREV. No. 0		

1.0 SCOPE

This procedure covers the maintenance required to maintain the cleanliness integrity of partially completed beam tube modules during the qualiffication test phase. Unless otherwise noted, this procedure will addend to document CL2N. Use this procedure with procedure LIGOCP.

2.0 PERSONNEL CLOTHING REQUIREMENTS

See document CL2N for further information regarding personnel clothing requirements.

3.0 EQUIPMENT TO BE USED WITH THIS PROCEDURE

Is this req'd for QT

3.1 The vacuum clean room shall continually maintain a positive flow of clean dry air through the port pump end of the beam tube module to ensure that no contaminants enter the beam tube module during installation.

3.2 thru 3.2.5 Omitted for the qualification test procedure.

3.2.6 See document CL2N.

3.2.7 See document CL2N.

3.3 Omitted for the qualification test procedure.

3.4 Omitted for the qualification test procedure.

3.5 Inflatable helium hood enclosure for use during the helium mass spectrometer leak testing of welded joints between can sections.

3.6 See document CL2N.

4.0 PROCEDURE

This procedure has been adapted for the qualification test procedures.

4.1 As soon as the beam tube can section is placed in the vacuum room, **do not** remove the plastic cleaning cover on the outboard end of the 6 inch pump port.

4.2 Omitted for the qualification test procedures

4.3 Omitted for the qualification test procedures.

4.4 Install the next beam tube can section to the pump port's outboard end of the beam tube module.

TITLE: MAINTENANCE OF PARTIALLY COMPLETED BEAM CAN SECTIONS FOR LIGO QUALIFICATION TEST MODULE ADDENDA

4.5 Omitted for the qualification test procedure.

4.6 Move the second can section within 6" to 8" from the outboard end of the first beam tube can section for fit-up of the weld. Remove both the plastic covers for fit-up of the weld and cut slits in the plastic cleaning cover of the second cans outboard's end to allow the vacuum room filtered air to pass through the second beam tube can section.

4.7 Weld the joint formed by the two beam tubes can sections.

4.8 After the weld joint is welded complete, move the fit-up and welding equipment down to the outboard end of the can section.

4.9 Move the helium mass spectrometer and leak test equipment into position over the welded joint. Perform the helium mass spectrometer leak test.

4.10 After successful completion of the helium mass spectrometer leak test, locally clean the inside of the completed 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 are being performed on the welded joint, move the next can section to be installed in line.

4.12 Repeat steps 4.6 through 4.11 for each of the can sections as they are installed.

5.0 DOCUMENTATION

Document the completion of all events associated with this procedure in accordance with 5.0 of procedure LIGOCP.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: CL3QT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

TITLE: FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	MJG	4-7-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	REV. No.	

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. Unless otherwise noted, this procedure will addend to document CL3N.

2.0 PERSONNEL

2.1-2.2 See document CL3N for further information regarding personnel clothing requirements.

3.0 REFERENCES

The following documents detail operations in conjunction to this activity. All references should be followed during the execution of this procedure.

3.1-3.3 See document CL3N for further information regarding reference procedures.

3.4 CBI Cleaning Procedure CL1QT, "Cleaning of Completed Beam Tube Sections After Leak Testing and Before Final Assembly - CALTECH"

3.5 CBI Cleaning Procedure CL2QT, "Local Cleaning of partially Completed Beam Tube Modules After Closing Weld Area of Final Assembly and During Construction - CALTECH"

3.6-3.8 See document CL3N for further information regarding reference procedures.

4.0 EQUIPMENT

4.1 See CBI Procedure CRWA-1 for complete listing of wearing apparel for Beam Tube and Clean Room access.

4.2 See document CL3N for further information regarding special equipment requirements.

5.0 PROCEDURE

WARNING
ALL FACTORS GOVERNING "CONFINED SPACE" ENTRY INCLUDING DOCUMENTATION SHALL BE STRICTLY ENFORCED.

5.1-5.7 See document CL3N for further information regarding special procedures.

TITLE: FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA

6.0 DOCUMENTATION

6.1-6.3 See document CL3N for further information regarding special documentation procedures.

6.4 These records will be turned in to the QC Manager at the end of the workday. The final inspection turnover documents shall include these reports.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: CRWAQT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 3

TITLE: CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST MODULE ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	MJG	4-7-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	CRWA-1 REV. No. 0	

1.0 SCOPE

This procedure covers protective wearing apparel for beam tube access through the clean box. All personnel entering beyond the vacuum room shall be properly clothed. Unless otherwise noted, this procedure will addend to document CRWA-1.

2.0 PURPOSE

See document CRWA-1.

3.0 REFERENCES

The alignment maintenance procedures for the Beam Tube Module are based on the following references:

3.1-3.3 See document CRWA-1.

4.0 EQUIPMENT & MATERIALS

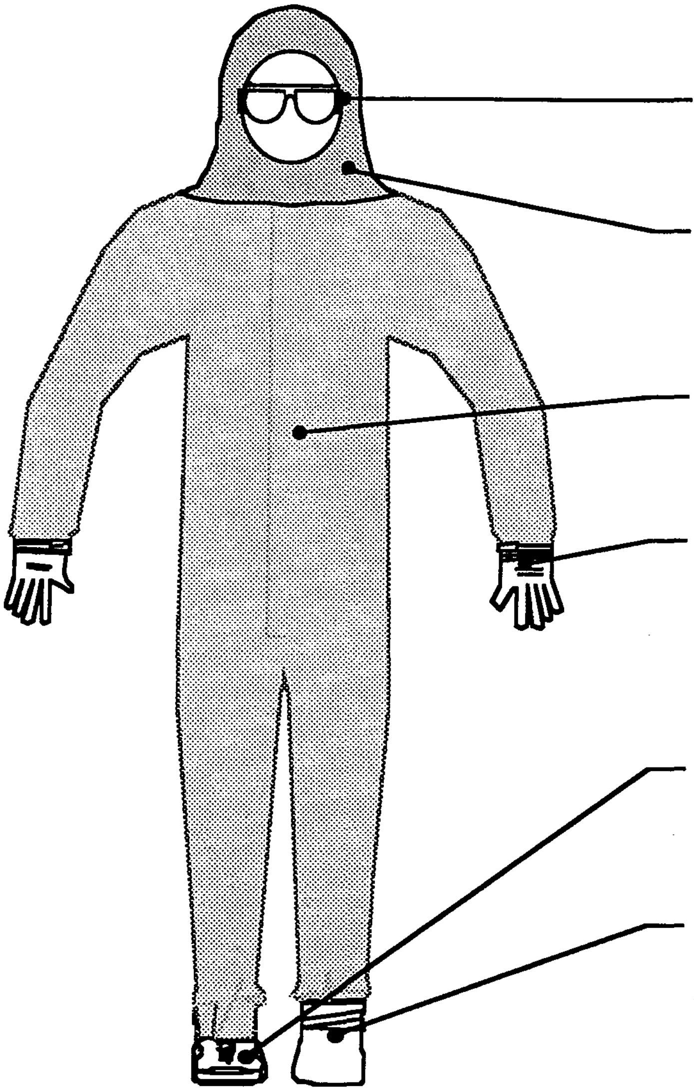
The following is a listing of safety equipment and wearing apparel required for access into the clean box and final access into the beam tube.

4.1	Omitted for the qualification test procedure.
4.2	Omitted for the qualification test procedure.
4.3-4.8	See document CRWA-1.
4.9	Omitted for the qualification test procedure.
4.10-4.11	See document CRWA-1.

See the following detail(Figure 4.1) for information. Substitution of the above equipment and/or materials shall be approved by site QA Manager.

TITLE: CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGP QUALIFICATION TEST MODULE ADDENDA

FIGURE 4.1



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

TITLE: CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST MODULE ADDENDA

5.0 APPAREL INSTRUCTIONS REQUIRED FOR VACUUM ROOM ENTRY

Vacuum room access instructions are described in procedure CL3N. The following is a detailed set of instruction for wearing clean room compatable clothing.

5.1 Omitted for the qualification test procedure.
5.2 Personnel shall 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 See document CRWA-1.
5.4 Omitted for the qualification test procedure.
5.5 Omitted for the qualification test procedure.
5.6 Remove disposable shoe covers and if un-soiled, store in designated location. If soiled, place in designated waste disposal.
5.7 Omitted for the qualification test procedure.
5.8 Omitted for the qualification test procedure.
5.9 Store solvent Protection Gloves in the Flamable Materials Cabinet inside the clean room.
5.10 Omitted for the qualification test procedure.

6.0 INSTRUCTIONS REQUIRED FOR VACUUM ROOM EXIT

Vacuum room exit instructions are described in procedure CL3N. The following is a detailed set of instruction for the removing, storing and cleaning of clean box compatable clothing and equipment.

6.1 See document CRWA-1.
6.2 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 Omitted for the qualification test procedure.
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.
6.6 See document CRWA-1.

7.0 LAUNDRY SERVICE

Omit these sections for the qualification test procedures:

7.1
7.2
7.3
7.4
7.5
7.6
7.7
7.8
7.9

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: LIGOTPQT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No. 07

TITLE: PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
					"XX"	

	BY	DATE
PREPARED	EEB	4-5-94
REVISED		
AUTHORIZED	"XXX"	"X-XX"-94
REFERENCED STANDARD		REV. No.

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 HMST1QT.

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 HMST2QT.

1.3 Omitted for Qualification Test.

1.4 The helium mass spectrometer/performance test of the QT beam tube module in accordance with the current approved revision of procedure HMST4QT.

1.5 Omitted for Qualification Test.

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 - 3.5 See LIGOTP.

4.0 LEAK TESTING EQUIPMENT USED IN ALL LEAK TEST PROCEDURES:

4.1 Helium mass spectrometer (HMS) 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. The HMS shall be on a separate 110 Vac 30 ampere electrical breaker circuit.

4.2 - 4.6 See LIGOTP.

4.7 Electrical power for all electrical leak testing equipment such as mechanical vacuum pumps, turbomolecular pumps, vacuum gauges, helium mass spectrometers (see item 4.1).

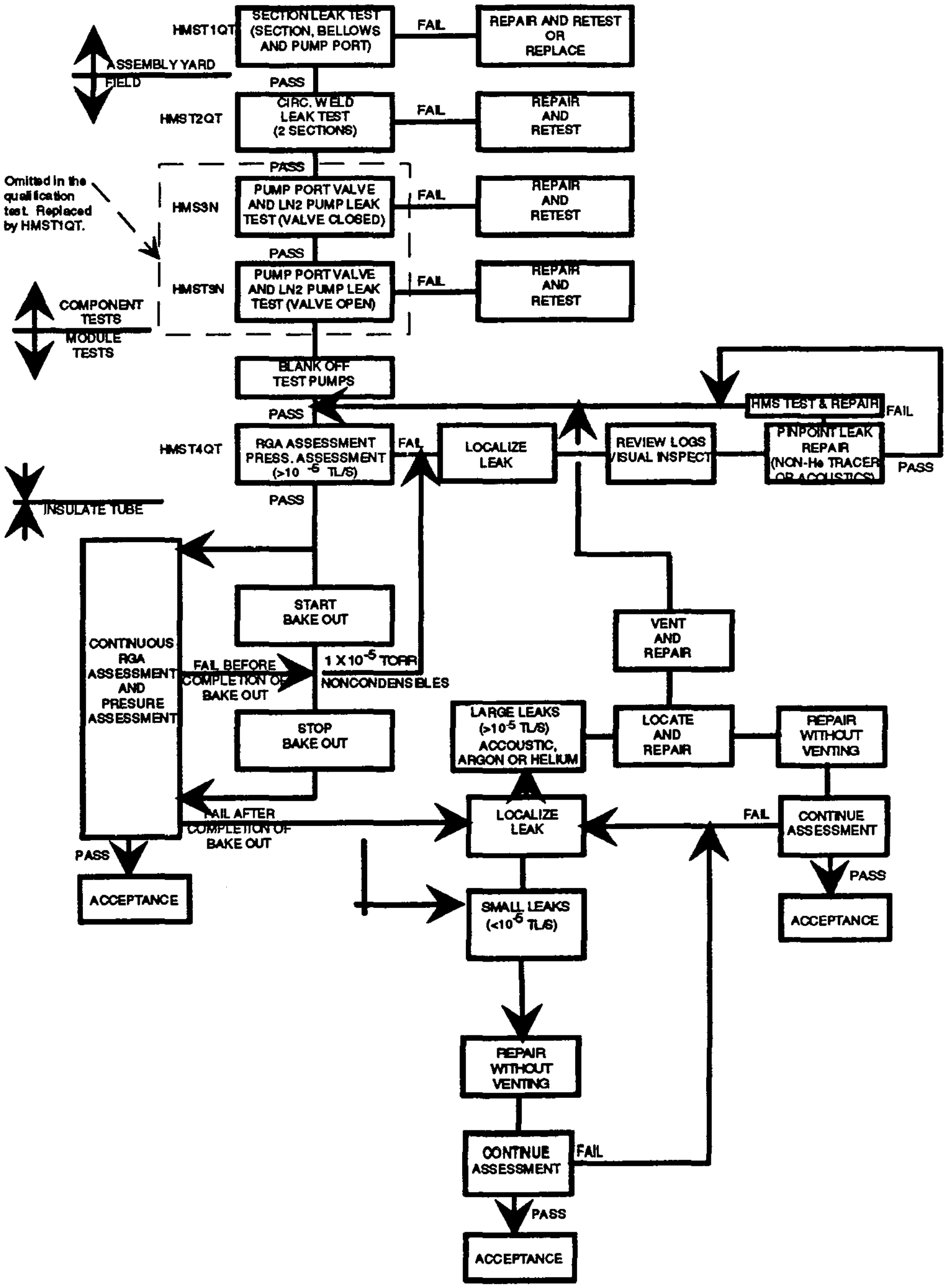
4.8 - 4.9 See LIGOTP.

TITLE: PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA

5.0 DECISION TREE:

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

LEAK DETECTION DECISION TREE
QUALIFICATION TEST



TITLE: PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA

6.0 DOCUMENTATION:

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

6.2 Maintain a construction record for the QT beam tube module and make entries of all noteworthy events, such as leaks repaired, etc., as they occur during the fabrication of each can section and closing weld joints between can sections of that module.

6.3 - 6.4 See LIGOTP.

6.5 Provide a log of each helium spectrometer instrument.. Make entries in this log 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.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: HMST1QT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No. 07

TITLE: HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA

APPROVED	Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	EEB	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. Unless otherwise noted, this procedure will addend to HMST1N. Perform this procedure in conjunction with the current revision of procedure LIGOTP.

1.2 See HMST1N Document

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

2.1 See Document HMST1N

2.2 The hood test enclosure will be replicated by fabricating an enclosure from sheet polyethylene and duct tape bag:

2.2.1 Venting will be accomplished by a hose and exhaust fan.

2.2.2 The hood (plastic bag) will be exhausted by attaching a hose to centrifical exhaust system.

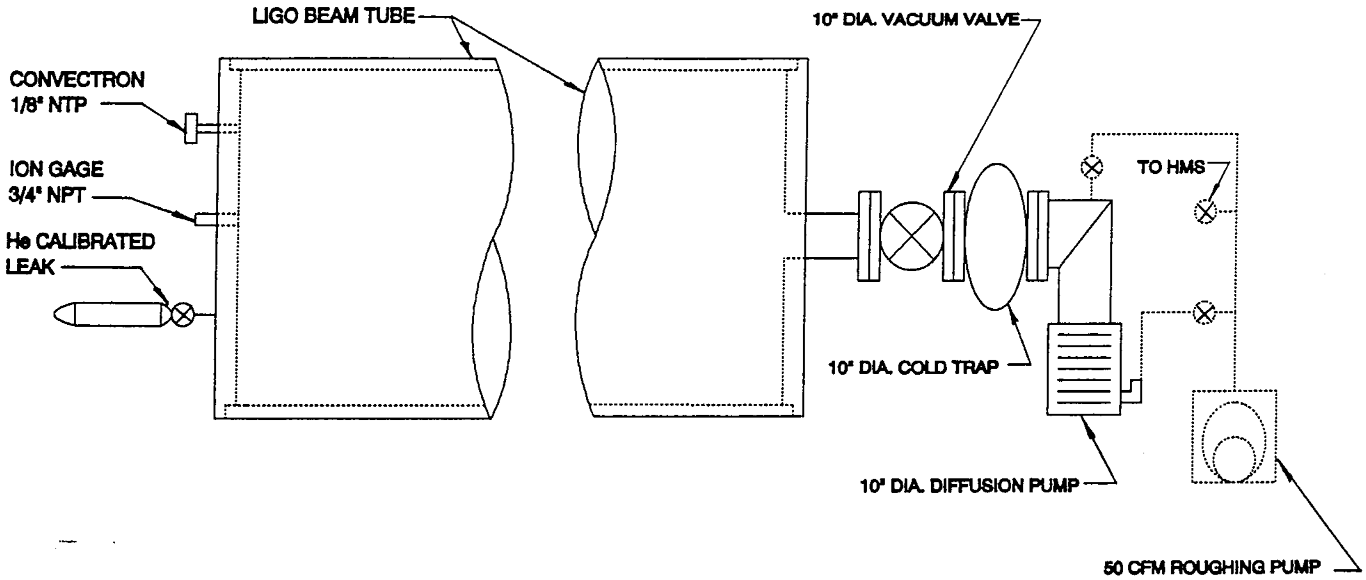
2.2.3 Omitted for the Qualification Test.

2.2.4 Omitted for the Qualification Test.

2.3 This portion of the procedure will not be done since there is not an outer full-vacuum container. Location of leakage will be done either by painting the surface of the tube with a fine spray of helium or by isolating successive areas with plastic sheets, duct tape, and injection of helium into these areas.

2.3.1 - 2.3.5 Omitted for the qualification test.

2.4 This section will remain essentially unchanged except that certain pump sizes may change. See the illustration below describing the beam tube and test apparatus.



2.5 Omitted for the qualification test procedure.

2.6 - 2.8 See Document HMST1N

3.0 <u>PROCEDURE</u>:

3.1 Install beam tube can section in the test enclosure.

3.2 Engage the end-seal assembly at each of the beam tube can section. Seal these assemblies with electrical tape or vacuum putty.

3.3 Energize the roughing pump and evacuate the can sections. Also evacuate the diffusion pump and foreline. When the absolute pressure in the beam tube can section reads about 1000 millitorr, begin cooling the LN2 cold trap.

3.4 Omitted for the qualification test procedures.

3.5 When the absolute pressure in the beam tube can section reads approximately 400 millitorr, energize the diffusion pump.

3.6 When the absolute pressure in the can section reads 50 to 75 millitorr, close the roughing pump valve and open the 10"Ø diffusion pump valve.

3.7 Omitted for the qualification test procedure.

3.8 Put the helium mass spectrometer instrument into operation and calibrate (peak tune) the instrument to ensure that it meets the instrument to ensure that it needs the optimum testing sensitivity requirements.

3.9 When the absolute pressure in the can section reaches approximately 2 x 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 10"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~~ [illegible] 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 Omitted for the qualification test procedure.

→ 3.10.3 When unacceptable leakage in the can section has been verified, evacuate the helium from the test enclosure bag and backfill it with air. If the verified leakage is larger than 1 x 10^{-5} atm. cc/sec., open the test enclosure and pinpoint the location of the leak or leaks by the conventional helium probe technique.

3.10.4 Omitted for the qualification test procedure.

3.10.5 Engage the end seal assemblies at each end of the leaking beam tube can section in accordance with steps 3.2 through 3.7.

3.10.6 Omitted for the qualification test procedure.

3.10.7 Omitted for the qualification test procedure.

TITLE: HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA

3.11 See Document HMST1N.

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 Omitted for the qualification test procedure.
- 3.12.2 Close the valve to the test bag 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 See Document HMST1N.
- 3.12.6 See Document HMST1N.

3.13 See Document HMST1N.

3.14 See Document HMST1N.

4.0 DOCUMENTATION

See procedure LIGOTP for documentation requirements.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: HMST2QT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 1

TITLE: HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS FOR LIGO QUALIFICATION TEST ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	EEB	3-30-94
REVISED		
AUTHORIZED	"XXX"	"X-XX"-94
REFERENCED		
STANDARD	REV. No.	

1.0 SCOPE:

This procedure covers the helium mass spectrometer hood test of the closing weld joint between beam tube can sections.

The only change and addenda portion of HMST2N is the following:

2.1 The helium mass spectrometers used to perform the leak testing outlined in this procedure shall be the Alcatel Model ASM 110TCL, Leybold Model UL400, Veeco Model 18AB or equivalent with an optimum high sensitivity in the range of 10^{-11} atm. cc/sec. of helium.

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: HMST4QT
REV. 1 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 3

TITLE: HELIUM MASS SPECTROMETER/PERFORMANCE TEST OF BEAM TUBE MODULES FOR LIGO QUALIFICATION TEST ADDENDA

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech

	BY	DATE
PREPARED	EEB	4-7-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	REV. No.	

1.0 SCOPE:

1.1 This procedure covers the helium mass spectrometer/leak test of the qualification test tube module. Use this procedure in conjunction with the current revision of procedure LIGOTP-QT.

1.2 Perform the leak testing outlined in this procedure on the qualification test beam tube module after:

1.2.1 All beam tube can sections in the qualification test module have been successfully HMS leak tested in accordance with procedure HMST1N, final cleaned and installed.

1.2.2 All closing weld joints except the outboard end closure head have been successfully HMS leak tested in accordance with procedure HMST2N and locally cleaned.

1.2.3 Omitted for the qualification test.

1.2.4 The qualification test vacuum pump set has been installed.

2.0 LEAK TESTING EQUIPMENT TO BE USED IN THIS PROCEDURE:

2.1-2.2 See HMNST4N.

2.3 The LN_2 panel will be supplied by CBI for this test.

2.4 CBI RGA will be used.

2.5 CBI turbo - molecular pump will be used in lieu of Caltech supplied equipment.

2.6 See HMST4N.

2.7-2.9 Omitted for qualification test.

3.0 PROCEDURE:

3.1-3.4 See HMST4N

3.5 Conduct a blank-off and a HMS tracer probe test of the mechanical vacuum pump and turbomolecular pump sets. When both the blank-off and HMS tracer probe test results are satisfactory, begin evacuating the beam tube module.

3.6-3.9 See HMST4N

3.10 When the pressure in the beam tube is less than $1x10^{-5}$ Torr conduct an RGA analysis. Record the values for the following masses: 2, 12, 14, 15, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55, and 57. If at this step of the procedure the system appears to be pumping down as expected, proceed to step 3.16.

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 inleakage 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.

3.11.2 Record the absolute pressure simultaneously with the RGA readout.

3.11.3-3.14 Omitted for qualification test

3.15 This portion of the procedure will not be done. Location of leakage will be done either by painting the surface of the tube with a fine spray of helium or by isolating successive areas with plastic sheets, duct tape, and injection of helium into these areas.

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.

3.15.2 If the leak is a hole or crack in a weld which is not jeopardizing structural integrity, cover the leak area with a piece of plastic and apply sealing 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 jeopardizing 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 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 decrease, continue to pump and monitor with the RGA to determine if the signature analysis still indicates no unacceptable inleakage.

3.17 Omitted for the qualification test.

3.18 The leakage rate of the module shall be considered satisfactory and the module shall be considered ready for bake out if the following conditions are met:

3.18.1 When the beam tube module reaches an absolute pressure in the low end of the 10^{-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 Or 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.

3.20 If unacceptable leakage develops in the beam tube module during bake-out, remove the insulation and repeat applicable steps of this procedure.

3.21 After bakeout, 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 x 10^{-9} atm. cc/sec. or larger, repeat the applicable steps of 3.15.

4.0 DOCUMENTATION:

Document in accordance with item 5.0 of procedure LIGOTP.

COUPON OUTGASSING TEST
PROCEDURE
QUALIFICATION TEST

DOC ID: COUP-02
REV. 1
CONTRACT: 930212
CDRL No:

TITLE: **COUPON OUTGASSING TEST PROCEDURE QUALIFICATION TEST**

APPROVED	Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech		by	date
								Prepared	WAC	03/30/94
								Revised		
								Authorized	MLT	

COUPON OUTGASSING TEST PROCEDURE

Single 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, not in an across pattern 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

The system valving shall be aligned as follows:

• Chamber isolation valve	closed
• Chamber re pressurization valve	closed
• Calibrated leak system isolation valve	closed
• Hydrogen calibrated leak valve	closed
• RGA isolation valve	closed
• Cold trap vent valve	closed
• Turbomolecular pump isolation valve	closed
• Roughing pump isolation valve	closed

Roughing

Start the roughing pump and allow the pump to warm-up for five minutes. The automatic viscous flow inbleed valve will open when the pressure in the roughing line reaches 0.3 torr. After the warm-up period, open the roughing isolation valve. Open the turbomolecular pump isolation valve. Open the chamber isolation valve. Evacuate the system until the viscous flow inbleed valve reopens.

High Vacuum Pumping

Start the turbomolecular pump. 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 RGA Isolation valve and the calibrated leak system isolation valve. Allow the pump to evacuate the system to below $1 \text{ X } 10^{-5}$ 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 RGA isolation valve when confident that no leak exists.

BAKE-OUT

Activate the bake-out system for the piping manifold and the turbomolecular pump system. 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 (1×10^{-2} torr). If the pressure nears 1×10^{-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. 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 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. Start recording the RGA measurements. Exactly at the end of the chamber accumulation time, shut the turbomolecular pump 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}

IN ST
NOT Coupon

RGA Calibration

Shut the chamber isolation valve 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 system 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 down 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, 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

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)

$k_{cc}=k_{cu}*CF$

PUMP DOWN AND OUTGASSING
TEST PROCEDURE
FOR
LIGO BEAM TUBE MODULES
QUALIFICATION TEST

DOC ID: OUTGAS
REV. 0
CONTRACT: 930212
CDRL No:

PAGE No. 1 OF 4

TITLE: PUMP DOWN AND OUTGASSING TEST PROCEDURE QUALIFICATION TEST

APPROVED	Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech		by	date
								Prepared	WAC	3/14/94
								Revised		
								Authorized	MLT	3/14/94

QUALIFICATION TEST
PUMP DOWN AND OUTGASSING TESTS

Need more Permit reads P vs T

RECORD KEEPING

All operating data taken, the time, the date, all physical actions (such as opening or closing a valve) and all mental impressions, visual evidence or unusual occurrences (such as how fast the system is pumping down or that the power is fluctuating) shall be recorded in the lab notebook and the appropriate computer. Operating data shall include pressures, piping, and tube temperatures, bake-out durations etc. The operator shall initial each page of the lab notebook. All RGA data will be automatically recorded on the RGA computer.

PREPARATION

It is assumed that the system is in all respects ready for evacuation and bake out with the exception that the insulation shall not be installed. The system (including the tube sections, ports and all weld seams) shall have been leak tested. The system including the beam tube and all piping and fittings has been cleaned in accordance with the project procedures. It is also assumed that the pump out and outgassing measurement system has been operated, baked out and calibrated such that the background outgassing levels are known and acceptable.

The facility shall be inspected to ensure that the utilities are available. Electrical 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

EVACUATION

All ports again will be visually inspected to ensure that they are closed. The roughing pump shall be started and operated to bypass the intermediate turbomolecular pump (TMP-2) by opening the foreline bypass valve and closing the valve on the inlet to the intermediate turbomolecular pump.

The beam tube isolation valve and the pumping system isolation valve shall be opened in order to rough pump the beam tube. The system shall be evacuated until the pressure reaches 0.1 torr. The high vacuum turbomolecular pump is now started. The system is monitored until the pressure gages indicate a pressure less than 1 X 10 $^{-5}$ torr. During the pump down, the system is monitored to ensure that the pump down is proceeding in accordance with the estimated pump down curves. If the system is not being evacuated properly, the system must be leak tested in accordance with the leak test procedures.

After the system has pumped down below 1 X 10 $^{-5}$ torr the RGA shall be activated, in the faraday cup mode and a sweep shall be made of the full RGA range and a table shall be produced of the mass numbers agreed by CBI and Caltech. The RGA cold trap shall be activated and RGA measurements (in the faraday cup mode) shall be evaluated for an air signature which indicates a leak larger than 1 X 10 $^{-5}$ torr liters per second.

Need to have
Cal AIR LEAK

If the air signature indicates leakage, the system will be releak tested, repaired and reevaluated until no leakage is detectable. If no leakage is indicated by the air signature evaluation, the tube shall be insulated and connected to the bake out power supplies.

NOTES: (these notes apply to any section of the procedure)
1. The RGA shall be activated in the selected mode of operation for at least 15 minutes prior to taking any RGA data. This will allow the RGA to warm up prior to the measurement.
2. Ion or Cold Cathode vacuum gaging shall be shut off prior to any RGA measurement.

BAKE OUT

Evacuation will continue until the system has been evacuated to 1 X 10 $^{-6}$ torr or lower. The bake out heaters and the intermediate turbomolecular pump may then be activated. The heaters shall be controlled such that the system pressure does not go above 1 X 10 $^{-5}$ torr. Heater set point will be 140°C.

— Run continuously

The RGA will be activated every 30°C (50, 80, 110 &140°C) through the bake out and once per day after the bake out has reached 140°C. The bake out will continue for 30 days after the tube temperature reaches 140°C.

WATER VAPOR OUTGAS TEST

Once the bake out has been completed, the RGA will be activated to determine an air signature. If a leak is detected, the system will be leak tested(in accordance with the leak test procedures) until the RGA shows no air signature. The system is now ready for formal outgassing tests.

WATER VAPOR OUTGAS TEST

Valve Alignment

Beam Tube isolation valve	open
Calibrated leak manifold isolation valve	closed
Main pumping system isolation valve	open
Auxiliary pumping system isolation valve	closed
RGA isolation valve	open

The pumping, outgassing and calibrated leak systems will be baked for a minimum of 24 hours at 250°C. For the first four hours of the bake, the RGA cold trap (LNT-2) shall be empty of LN2 and purged with the nitrogen sweep system. After completion of the bake, with the beam tube and systems at ambient temperature and the vacuum gages turned off, the RGA will be activated in the electron multiplier mode. The water vapor partial pressure shall be measured by the RGA. The RGA will be monitored until the water vapor partial pressure stabilizes (comes to equilibrium with the system surfaces under vacuum). During the measurement, the isolation valve for the TMP-3 pumping system will be closed. This will ensure that all water vapor pumping is accomplished by the cold trap (LNT-1). The RGA cold trap shall not be filled with LN2 at any time during the water vapor outgas test.

will not work because of H_2 evolution

HYDROGEN OUTGAS TEST

Valve Alignment

Beam Tube isolation valve	open
Calibrated leak manifold isolation valve	closed
Main pumping system isolation valve	open
Auxiliary pumping system isolation valve	open
RGA isolation valve	open

The RGA cold trap shall be filled with LN2 and the system will be allowed to stabilize. The RGA will again be operated in the electron multiplier mode. The hydrogen partial pressure shall be measured on the RGA with all pumping systems active, the calibration system closed and the vessel isolation valve open.

HYDROGEN CALIBRATION

The system shall be calibrated for hydrogen by utilizing a hydrogen inbleed. Both pumping systems shall be operating and the beam tube isolation valve shall be closed. The calibration system isolation valve shall be opened. The hydrogen calibrated leak shall then be opened and the system pressure stabilized. The RGA will then be operated and hydrogen partial pressure measurements will be made with the hydrogen calibrated leak in the open position and then with the valve in the closed position.

WATER VAPOR CALIBRATION

The RGA cold trap shall be allowed to warm up to ambient and a gaseous nitrogen sweep shall be energized to remove the water vapor from the trap. The sweep will be energized for a minimum of 4 hours. Activate the calibrated leak and let the RGA measurements stabilize. Record the RGA measurement, shut the calibrated leak valve, again let the partial pressure stabilize and record the RGA partial pressure.

What gas is
[illegible]

TITLE: INSTALLATION ALIGNMENT AND SUPPORT ADJUSTMENT PROCEDURE FOR LIGO QUALIFICATION TEST

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
SWP					PM JAC WLR	

	BY	DATE
PREPARED	SWP	4-8-94
REVISED		
AUTHORIZED		
REFERENCED STANDARD	REV. No.	

1.0 SCOPE

1.1 This procedure describes the operations and equipment that will be used during the Qualification Test to demonstrate installation alignment and support adjustment.

1.2 The location of the beam tube centerline reference points on the concrete slab will be established using conventional surveying and layout equipment instead of the Global Positioning System that is proposed for use in the Option.

2.0 REFERENCE DOCUMENTS

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

2.2 Procedure ALI-1, "Initial & Final Alignment During Installation of LIGO Beam Tube Modules Using GPS - Caltech"

2.3 Procedure ISQT, "Beam Tube Can Section Installation Sequence for LIGO Qualification Test Module Addenda"

3.0 EQUIPMENT

3.1 The following is a listing of the special equipment that will be used in this procedure.

A. The QT beam tube assemblies listed below:

- QT Aft Assembly - This assembly includes a 60' long section of beam tube and the beam tube end assembly with the vacuum port and end closure.
- QT Forward Assembly - This assembly includes a 60' long section of beam tube, the expansion joint and a beam tube end assembly.
- An End Closure - A stiffened flat plate that attaches to the end of the Forward Assembly.
- Two Fixed supports - One for the Aft Assembly and one for the Forward Assembly.
- One Guided Support - for the Expansion Joint.

B. A hydraulic jacking system for raising and lowering the supports.

C. A hydraulic jacking system for moving the supports laterally.

D. Six (6) dial Indicators with magnetic bases to measure and monitor movements during alignment.

E. A jig transit, tilt level and 100' tape for establishing the centerline reference points on the concrete slab.

F. The necessary spacers or shim plates to temporarily support the beam tube during the raising and lowering operations.

G. An machinist level that has an accuracy of 0.001"/12" or better.

4.0 PROCEDURE

4.1 Install the Beam Tube Centerline reference points and Support Anchors

4.1.1 Make a drill template for locating and drilling the holes in the concrete slab for the beam tube centerline markers and the support anchors.

4.1.2 Locate the drill template using the jig transit and 100' tape..

4.1.3 Drill the hole for the beam tube centerline reference points and the support anchors.

4.1.4 Remove the drill template and install the centerline reference markers and the support anchors.

4.1.5 Measure and record the coordinates (x,y and z) of the centerline markers.

4.1.6 Repeat steps 4.1.2.3 through 4.1.2.5 for all support and baffle locations.

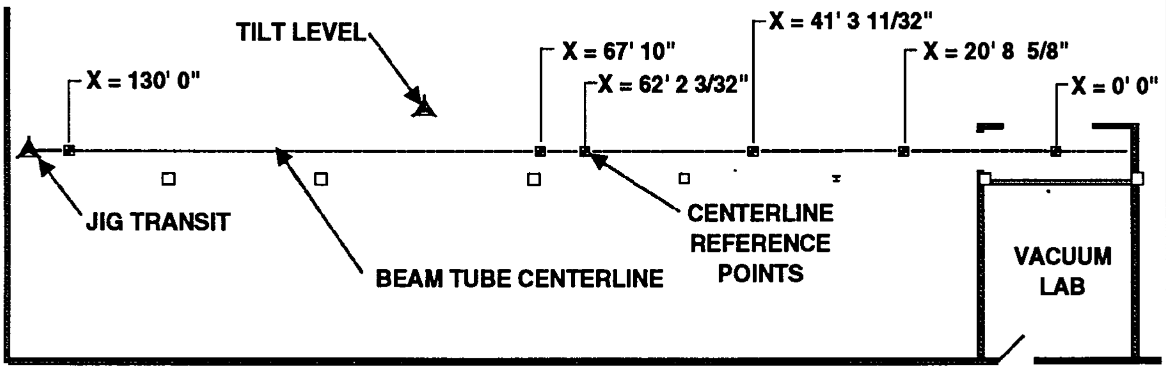


FIGURE 4.1A
INSTALLATION OF THE QT BEAM TUBE CENTERLINE REFERENCE POINTS

4.2 Align the QT Aft Assembly (Beam Tube Can Section with the Vacuum Port)

4.2.1 Move the Aft Assembly into position and support it on temporary supports.

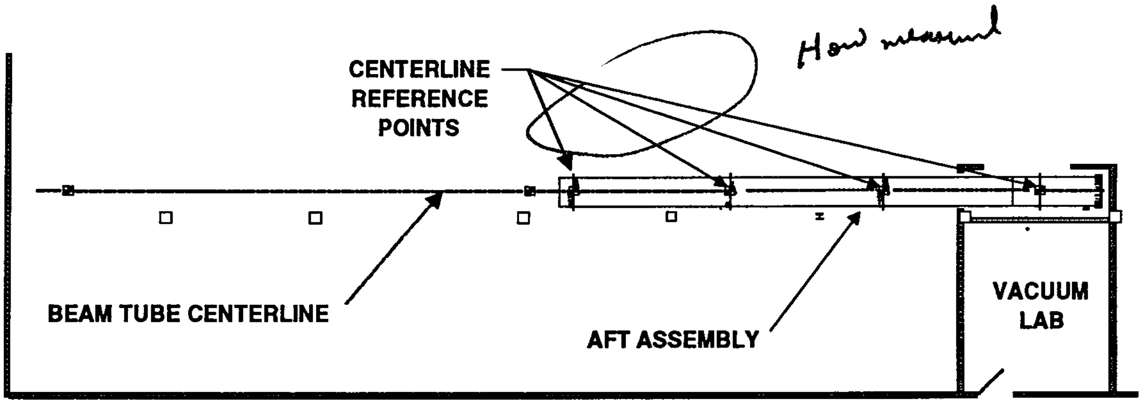
4.2.2 Align the support rings at the ends of the Aft Assembly to the centerline reference markers previously established on the concrete slab. Align both laterally and longitudinally.

4.2.3 Rotate the Aft Assembly about its longitudinal centerline to level the holes in the support rings.

4.2.4 Install the permanent fixed support to the end of the Aft Assembly.

4.2.5 Raise or lower the ends of the Aft Assembly to the correct distance above the centerline markers. Measure from the bottom of the support rings to the centerline reference markers.

4.2.6 Clamp the fixed support and secure the beam tube at the temporary support so it will not be moved while installing the Forward Assembly.



How measured

FIGURE 4.2A
ALIGNMENT OF THE AFT ASSEMBLY

4.3 Align the QT Forward Assembly (Beam Tube Can Section with the Expansion Joint)

4.3.1 Move the Forward Assembly into position and support on temporary supports.

4.3.2 Rotate the Forward Assembly about it's longitudinal axis to level the holes in the support rings.

4.3.3 Fit the end of the expansion joint on the Forward Assembly to the Aft Assembly. Move the free end of the Forward Assembly as needed to fit the circumferential weld joint. **Be careful not move the Aft Assembly.**

4.3.4 Before welding the circumferential joint measure and record the location of the support ring at the free end of the Forward Assembly. Take measurements to the centerline reference markers located on the concrete slab under the support ring. Determine the location of the support rings to the beam tube centerline. Do not attempt to align the end of the Forward Assembly at this time. Alignment will be performed after the circumferential weld joint has been welded, inspected and leak tested.

4.3.6 After the circumferential weld joint is welded, inspected and leak tested and the permanent beam tube supports installed, the end of beam tube can be aligned.. Move the beam tube so that the center of the support ring at the end of the Forward Assembly coincides with the beam tube centerline as defined by the centerline reference markers on the concrete slab under the beam tube.

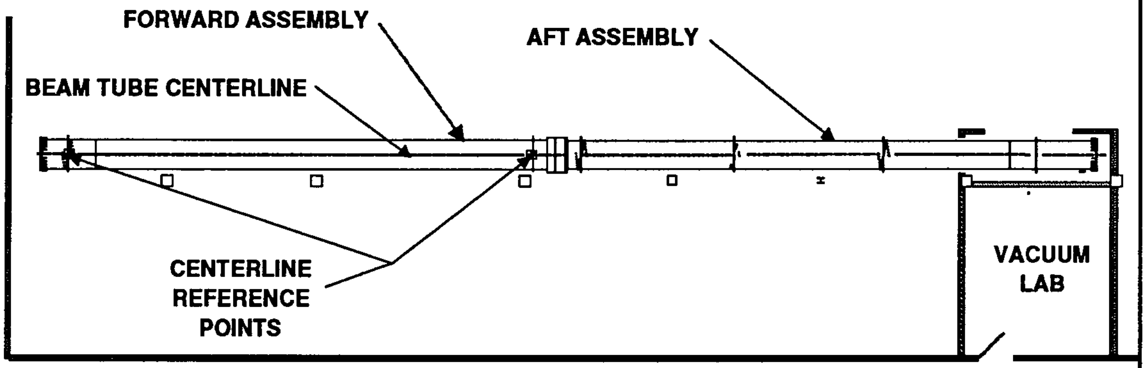


FIGURE 4.3A
ALIGNMENT OF THE FORWARD ASSEMBLY

4.4 Measure and Record the Locations of the Support/Baffle Rings.

4.4.1 Use a pipe centering head to verify the bottom vertical centerline on the outside diameter of the beam tube support/baffle rings. Place the vertical centerline reference mark on the outside diameter of the support/baffle rings. This will be used later to measure amount of rotation.

4.4.2 Measure and record the distance of the support/baffle rings from the centerline as defined by the centerline reference markers on the concrete floor under the beam tube.

4.5 Adjust the Beam Tube Supports to Re-Align the Beam Tube

4.5.1 Review the alignment data and determine whether or not the beam tube baffles at locations must be moved to provide the specified 1.07 meter clear aperture. For each baffle location calculate the direction and magnitude of movement required to provide the specified clear aperture.

4.5.2 Identify the baffle rings that need adjustment and determine the direction and movement at the supports to provide the desired change.

4.5.3 Raise or lower the beam tube:

4.5.3.1 Install the hydraulic jacks between the concrete slab and support frame and/or between the support brackets and the support frame at the designated jacking points. The hydraulic jacks are to be placed at equal distances from the tube centerline. Connect the hydraulic lines using a manifold so that equal forces will be applied at the jacking points while the support is being raised or lowered. This is done so that the hydraulic jacks will not apply a differential load to the support and twist the beam tube.

Note - The vertical jacks have only 1 1/2" stroke. Add or remove shim plates under the jacks as needed to raise or lower the jacks. Also, use shim plates to support the beam tube when the jacks must be removed and raised or lowered to permit additional movement of the beam tube.

4.5.3.2 Attach dial indicators, at all hydraulic jack locations, to monitor the movements between the beam tube and fixed support brackets. Set the dial indicators to monitor both vertical and lateral movements.

4.5.3.3 Zero all dial indicators and slowly loosen the clamps holding the support frame to the fixed support brackets.

Note - Do not remove the clamps. Only loosen the clamps to remove clamping force to permit the support frame to move for re-alignment.

4.5.3.4 Extend the hydraulic jacks until contact is made with the beam tube support. Pressurize the hydraulic jacks to about 100 psi. This will apply a nominal force to the hydraulic jacks.

Note - The beam tubes must always be supported vertically at the supports with jacks or shims before the support clamps are loosened. Loosening these clamps without first providing vertical support will allow the beam tube to drop and can cause damage to the beam tube and personal injury.

4.5.3.5 Raise or lower the support frame to the specified movement. Use the dial indicators to measure and monitor the movement made during the operation.

4.5.3.6 Continue to section 4.5.4 if lateral adjustment is required. If lateral adjustment is not required re-clamp the support and remove jacking equipment and proceed to section 4.5.5.

4.5.4 Move the beam tube laterally:

Note - The beam tubes must always be supported vertically at the supports with jacks or shims before the support clamps are loosened. Loosening these clamps without first providing vertical support will allow the beam tube to drop and can cause damage to the beam tube and personal injury.

4.5.4.1 Perform steps 4.5.3.1 through 4.5.3.4 or continue from step 4.5.3.6

4.5.4.2 Install the hydraulic cylinder for moving the beam tube laterally. The cylinder will be placed between the beam tube support frame and the fixed support brackets.

4.5.4.3 Extend the hydraulic cylinder and pressurize to 100 psi to apply a nominal force.

4.5.4.4 Move the support frame the specified movement. Use the dial indicators to measure and monitor the movement made during the operation.

4.5.5 Rotate the Beam Tube

Note - The beam tubes must always be supported vertically at the supports with jacks or shims before the support clamps are loosened. Loosening these clamps without first providing vertical support will allow the beam tube to drop and can cause damage to the beam tube and personal injury.

4.5.4.1 Make vertical and lateral adjustments to the beam tube before making rotational adjustments. Continue from steps 4.5.3.5 or 4.5.4.4.

4.5.5.2 Check the current rotation of the stiffener ring using the pipe centering head that is attached to the top of the support ring. Use the pipe centering head to measure the rotation of the support/baffle rings. Determine the direction and amount of rotation to reposition the ring to it's original orientation.

4.5.5.3 Determine whether or not an adjustment in rotation is needed.

4.5.5.4 If a adjustment in rotation is needed the beam tube may be rotated using the leveling jacks under the support frame by closing the valve(s) to the leveling jacks(s) on one side of the beam tube and extending the jacks on the opposite side of the beam tube. Each of the leveling jacks has a valve that can permit differential leveling to rotate the beam tube.

4.5.5.5 Re-clamp the support frame to the fixed support brackets and release the jacks.

4.5.5.6 Confirm that the support has been moved the specified amount.

5.0 DOCUMENTATION

A. Maintain a written log of all operations performed under this procedure.

B. Keep a written record of the levelness and locations of support/baffle rings during the QT installation operations.

C. Keep a record of the rotations of the baffle rings.

CB&I

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: BOQT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No. 07

PAGE No. 1 OF 3

TITLE: PROCEDURE FOR BAKEOUT OF BEAM TUBE FOR LIGO QUALIFICATION TEST

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
					"XX"	

	BY	DATE
PREPARED	DGM	4-8-94
REVISED		
AUTHORIZED	"XXX"	"X-XX"-94
REFERENCED STANDARD	REV. No.	

1.0 SCOPE:

1.1 This procedure covers the bakeout of the Qualification Test beamtube at 140°C under vacuum for the purpose of removing water and hydrocarbons from the tube inside surfaces.

1.2 This bakeout will occur after the Qualification Test beamtube has been assembled, leak checked and cleaned. A post-bakeout outgas rate measurement will follow.

2.0 OBJECTIVES OF THE ACTIVITY

2.1 The objective of this Qualification Test bakeout is to emulate the parameters of the field bakeout of complete beamtube modules that affect the level of post bake outgassing. This then will contribute to the accuracy of predictions of outgassing rates and pumping requirements on the complete modules.

2.2 The procedure will hold a temperature of 140°C within a range of +30/-0°C at all points and at all times on the beamtube. Closer temperature tolerances will be sought as much as possible within the limitations of such things as the spacing of the heater cables.

Not planned for direct heating

2.3 The means of heating will not necessarily be the same on the qualification test as is planned for the complete modules.

2.4 Data will be collected during the bakeout period on the rate of outgassing.

3.0 EQUIPMENT:

3.1. Electric Resistance Heating Cable: About 2000 feet of cable is needed. Cable shall have braided nickel heating elements with silicone rubber dielectric jacket having about 0.036 ohms/ft resistance at 140 C. The cable shall be temperature rated to 200°C or higher. i.e. Cooperheat Versatrace VTN or equal. Five 400' circuits will be used and powered by 240 volt AC.

3.2 About 10 Thermocouples.

3.3 Temperature control equipment: One time proportioned thermal regulator per circuit. Honeywell Dialatrol or equal.

3.4 Temperature monitoring and recording equipment: One data acquisition personal computer.

3.5 Equipment for vacuum pumping and measurement of outgassing rates is described in the Outgassing Test Procedure (No. XXXXXX). Note that the liquid nitrogen trap is sized for 600 liters/sec water pumping speed.

Not the LN_2 trap but the ~~cap~~ opening to the system

4.0 TEST PREPARATION:

4.1 The Qualification Test beamtube will have been assembled, leak checked and cleaned prior to bakeout.

4.2 The assembled Qualification Test beamtube will be located in the basement of the Plainfield Research Center and will be in its final bakeout/outgas test position where about 10 feet of the beamtube extends into the vacuum lab where the vacuum pumping and instrumentation will be located.

4.3 Wrap the beamtube with resistance heating cable in a helical pattern, with space turns of cable at ~11".

4.4 Install thermocouples in contact with the beamtube at locations midway between cables. Thermocouple leads shall be run under the insulation for at least 2' in order to ensure minimal conduction from room ambient temperature to thermocouple. Locate thermocouples at the following positions.

4.4.1 Topside of the tube at mid length of each tube section
4.4.2 Bottomside of the tube at mid length of each tube section
4.4.3 Top center of the expansion joint
4.4.4 At the base of a vacuum stiffener
4.4.5 At one location, a pair of thermocouples, one centered between conductors, the other about 0.5" from a conductor

4.5 Insulate the beam the beamtube with Knauf Duct Wrap or similar insulation to a total thickness of 4". Cut the insulation so that the first layer of insulation fits between the vacuum stiffeners.

4.6 Connect the heater cable to thermal controller described in the EQUIPMENT section of this procedure.

4.7 Connect thermocouples to data acquisition computer.

4.8 Preparation of the vacuum pumping system is covered in procedure XXXXXXXX.

5.0 TEST EXECUTION:

5.1 Evacuate the beam tube to 10^{-5} torr.

5.2 Over a period of 24 hours, raise the temperature of the beamtube to 140°C.

5.3 Hold the beamtube at 140°C for 30 days. During which time:

5.3.1 Vacuum pumping will take place continuously.

5.3.2 Temperature data from all thermocouples will be passed to a data acquisition personal computer. Data will be displayed continuously and recorded to disk on a hourly basis. This task will be done automatically by simple software.

5.3.3 Review temperature data daily and adjust the thermal controller settings as needed

5.3.4 Measure and record outgassing rate at the following points in time

i) TBD
ii) TBD
iii) TBD
iv) TBD

5.3.5 Record all significant events in a lab notebook

5.4 At the end of 30 days turn off the heaters and allow the tube to return to ambient temperature.

From ljones@ligo.caltech.edu Wed Jul 20 11:49:07 1994
Received: from ligo.caltech.edu by tristan.mit.edu AA02212; Wed, 20 Jul 94 11:49:05 EDT
Received: from polecat.ligo.caltech.edu by ligo.caltech.edu (4.1/SMI-4.1)
        id AA24733; Wed, 20 Jul 94 08:48:44 PDT
Received: by polecat.ligo.caltech.edu (4.1/SMI-4.1)
        id AA01425; Wed, 20 Jul 94 08:48:42 PDT
Date: Wed, 20 Jul 94 08:48:42 PDT
From: ljones@ligo.caltech.edu (Larry Jones)
Message-Id: <9407201548.AA01425@polecat.ligo.caltech.edu>
To: weiss@ligo.caltech.edu
Subject: review of CBI's DAQT
Cc: ljones@ligo.caltech.edu
Status: R

Please provide me your comments on the referenced data acquisition procedure (located at the back of section 2 of the 1" 3-ring white binder provided before the FDR, "Final Qualification Test Plan and Procedures").

Larry

CB&I

CONTRACT PROCEDURE
FOR
LIGO BEAM TUBE MODULES
DESIGN & QUALIFICATION TEST

DOC. ID: DAQT
REV. 0 (Draft)
CONTRACT: 930212
CDRL No.

PAGE No. 1 OF 2

TITLE: DATA ACQUISITION PROCEDURE FOR LIGO QUALIFICATION TEST

APPROVED

Eng	Corp Weld	Corp QA	Const	Mfg	RCE	Caltech
					"XX"	

	BY	DATE
PREPARED	WSS	4-7-94
REVISED		
AUTHORIZED	"XXX"	"X-XX"-94
REFERENCED		
STANDARD	REV. No.	

1.0 SCOPE

This procedure describes the data acquisition for the LIGO Qualification Test. Data acquisition includes collection and maintenance of all measurements, evidence, conditions, and significant observations related to the Qualification Test. Data records may be collected as written records in the form of a laboratory notebook, or collected automatically by data logging systems and maintained as computer files. Computer files may consist of both formatted text in tabular form and as manual single entry text format in the same manner as the traditional laboratory notebook. The mode of data acquisition will be determined by the requirements of the specific test procedure. All files related to the technical aspects of the qualification test will be transmitted to Caltech electronically via modem on a daily basis.

2.0 LABORATORY NOTEBOOKS

Laboratory notebooks will be used to progressively record the entire history of the Qualification Test from coil coupon outgassing through fabrication, construction, etc. to post bake outgassing tests. Documentation to be included in the log for specific operations, such as leak testing is identified in the test procedures required for those operations. All data, ideas, diagrams, calculations, or anything pertinent to the test should be recorded in ink. Incorrect entries must not be erased, but may be deleted by drawing a line through them, noting the correction and signing the changes. Each page should be signed and dated by the recorder. When appropriate, a witness will sign and date the page in the space provided.

3.0 COMPUTER DATA ACQUISITION

Computer data acquisition will be used to automatically record temperatures, pressures and other analog signals, data and reports from the residual gas analyzer (RGA) and to record test "logbook" files.

3.1 Temperature and Pressure measurements

Need the study results for

All temperature and pressure measurements will be made using a Hewlett Packard HP3497 Data acquisition unit and control unit with a HP44422A multiplexer card. A CBI Gateway-2000 486-DX2 50 MHz personal computer using MS-DOS Version 6.2 and Windows 3.1 and running custom data acquisition software will be used to collect, display and record all the data. Data will be continuously displayed and periodically saved at intervals to be determined by the specific test procedure. A new data file is automatically created each day starting at midnight. The file name contains three characters designating the month, two characters for the day and two characters for the year (example: APR0494.CSV). The "CSV" data format is recognized by spreadsheet software such as Microsoft "EXCEL". Data files will be saved to the local hard drive and copied to the LIGO directory on the network file server.

3.1 Residual Gas Analyzer

RGA data will be monitored by a second CBI Gateway-2000 486-DX2 50 MHz personal computer running Windows based software provided by the manufacturer of the RGA. The system is capable of viewing recording, basic interpretation of the spectra and data manipulations. The RGA will be activated after the system has pumped down below 10 $^{-5}$ Torr. The instrument mode, configuration range and mass numbers selected will be determined by the specific test procedure. Files with the ".RGA" extension will consist of periodic tracking at designated intervals of partial pressures of selected atomic mass units. Files with the ".SWE" extension will contain full spectrum sweep with a minimum range of 1-100 amu. Data files will be saved to the local hard drive and periodically copied to the LIGO directory on the network file server.

3.3 Logbook Files

A continuous "logbook" file will be maintained as Microsoft Word document in a separate text window using the same computer described in Section 3.1. This file will be used for recording instrument state vectors indicating the state of each valve, gauge, pump, etc. following a tag indicating date and time. This file may also be used for recording any other comments and observations. Each entry should be time stamped by selecting the "clock" symbol in the toolbar. After each entry, the file should be saved to the hard drive. Once a day, the entries for the preceding day will copied to a separate file and renamed to include the date (see Section 3.1) and the ".DOC" extension which indicates Microsoft Word document format. The daily log files will also be copied to the LIGO directory on the network file server.

3.0 DATA STORAGE AND TRANSMISSION

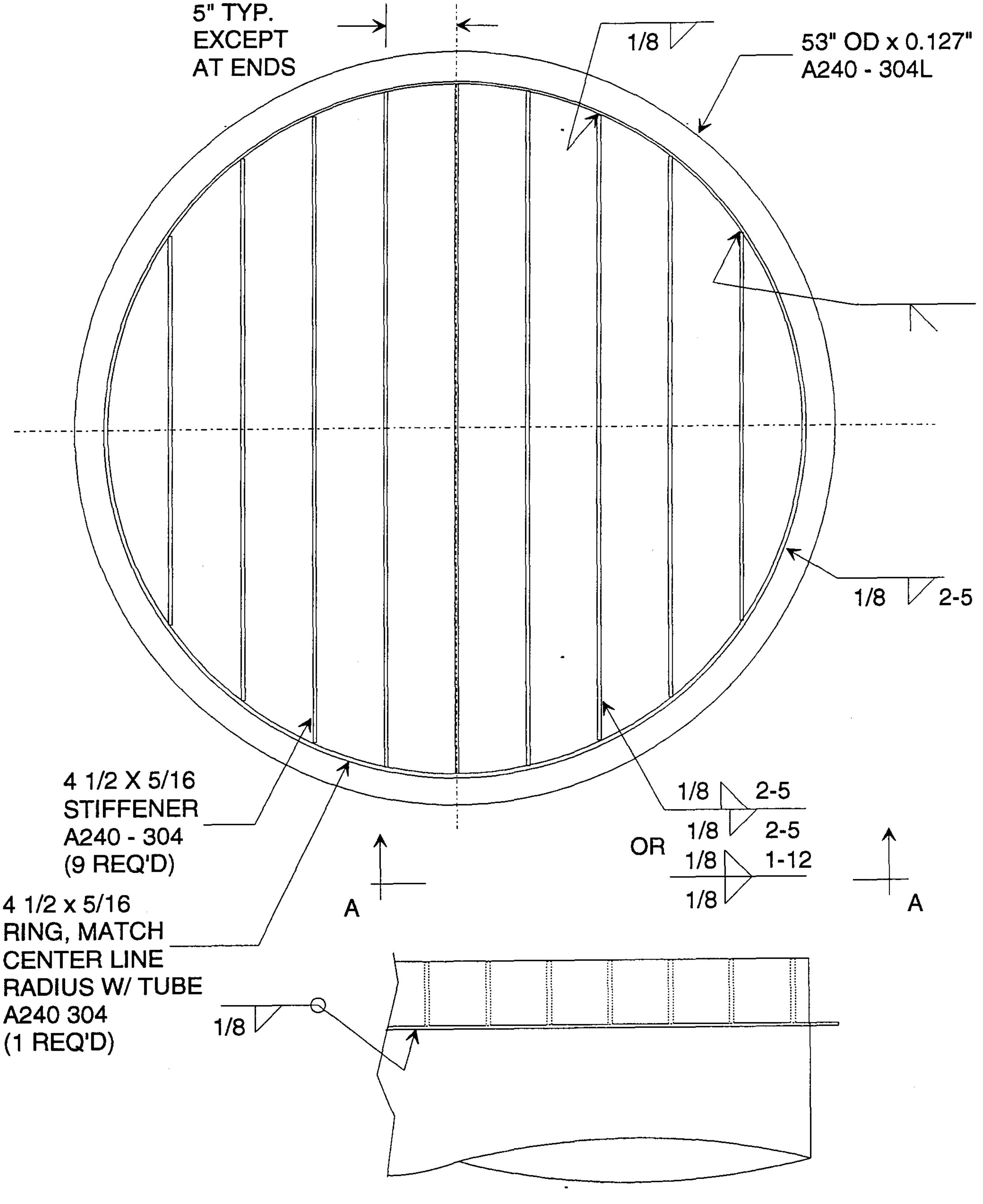
All data files will be saved to the local hard drive and copied to the LIGO directory on the network file server. At least once a day, the individual files representing the previous day's data will combined into a compressed archive file using the PKZIP utility software. The file name will include the date with the ".ZIP" extension. This compressed file will be uploaded via modem to the designated host computer designated by Caltech.

3.0 QUALIFICATION TEST REPORT FORMAT

The Qualification Test Report will follow the outline/index shown at the end of this section. Data will be reported in the same format as it is specified to be recorded in the Qualification Test Procedures. This data will range from initial coupon outgas test results; through fabrication/installation data which includes dimensional, cleaning, and leak testing data; to final acceptance testing data. Documentation will be recorded and reported for each operation performed to identify anomalies, changes, improvements, or identicality to the procedure as written. Computerized data will be formatted and reported as required by the QT Data Acquisition Procedure.

Report Format

1. Cover
2. Executive Summary
3. Table of Contents
4. Nomenclature
5. Glossary
6. Introduction
7. Test Configuration
8. Equipment and Procedures
9. Data/Results
10. Discussion of Results
11. Summary and Conclusions
12. Recommendations
13. Acknowledgments
14. References
15. Appendices

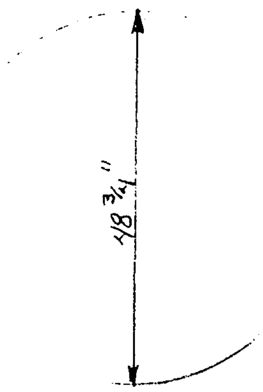


SECTION A

SUBJECT	CBI OFFICE NOE C		REVISION 1		REFERENCE NO. 930212
QT STIFFENED END HEAD	MADE BY RJW	CHKD BY TKH	MADE BY RJW	CHKD BY TKH	SHT ____ OF ____
	DATE 29MAR94	DATE 29MAR94	DATE 30MAR94	DATE 29 MARCH 94	

304L S.S.
338° F

PL THICKNESS 0.127"



PROPERTIES

TEMP	MAX ALLOW STRESS	F_y YIELD STRENGTH
300	12.8	19.2
400	11.7	17.5

ASME SEC. 2 PART D

AT 338°	MAX ALLOW STRESS	YIELD STRENGTH
	12.382 ksi	18.554 ksi

MAXIMUM SPACING OF STIFFNERS

(Design of Plate Structures)

$f = B_2 p \frac{b^2}{t^2}$

$12.382 = (0.75)(14.7) \frac{b^2}{(0.127)^2}$

$18.1142 = b^2$

$4.26'' = b$

f = max fiber stress = 12,382 psi

p = pressure

t = plate thickness

b = sheet side of rectangular plate

$B_2 = 0.75$

IF CONSIDERED FIXED

$f = B_1 P \frac{b^2}{t^2}$

$$b = \sqrt{\frac{f t^2}{B_1 P}} = \sqrt{\frac{12382 (0.127)^2}{(0.5)(14.7)}} = 5.21''$$

SUBJECT	CBI OFFICE	REVISION		REFERENCE NO.
ENDS FOR Q7	NOE-C			930212
	MADE BY TKH	CHKD BY RJW	MADE BY	CHKD BY
	DATE 3-28-94	DATE 29 MAR 94	DATE	DATE

SHT___ OF___

Printed In USA

GO 64 REV SEP 84

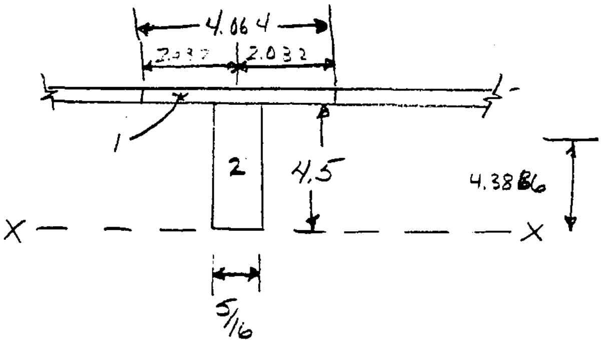
STIFFENER SIZING

$$M_{MAX} = \frac{(14.735)(4.25)(48\tfrac{3}{4})^2}{8} = 18.56 \text{ k-in.}$$

$$F_b = 0.66F_y = 0.66(18,554) = 12.24 \text{ ksi}$$

$$S_{x(req)} = \frac{M}{F_b} = \frac{18.56}{12.24} \quad 1.516 \text{ in}^3$$

Sx of Comp



$16t = 16(.127) = 2.032$

	Area	Y	AY	AY²	Io
1	1.4063	2.25	3.1642	7.1194	0.0007
2	0.5161	4.5635	2.3552	10.7481	2.373
	1.922		5.52		20.24

CENTROID 2.872

I 4.3866

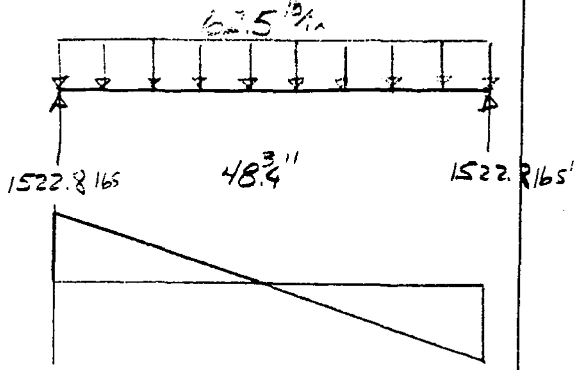
$\boxed{S_1 \quad 1.5274} > 1.516$

S_2 2.5

USE 4.5" x 5/16" 304L S.S. Every 4¼"

SUBJECT	OFFICE	REVISION		REFERENCE NO.
ENDS FOR QT	CBI HOE-C			930212
	MADE BY TKH	CHKD BY RJW	MADE BY	CHKD BY
	DATE 3-28-94	DATE 29 MAR 94	DATE	DATE
				SHT___ OF___

WELD REQUIRED FOR STIFFNER



$$\text{Stress} = \frac{VQ}{tI}$$

(1522.8 lbs)

$$W_g = \frac{VQ}{nI} = \frac{1522.8\,(.127)(4.063)(0.1769)}{1\quad(4.3866)}$$

$$= 31.688 \text{ lbs/lin in}$$

Continuous WELD SIZE – $\frac{W_a}{f_p} = \frac{31.638}{6067} = 0.0052$

$(F_p = .49 \times 12382 = 6067 \text{ lbs.})$ ASME UW-15

Minimum Size Fillet 1/8"

% continuous weld $\frac{.0052}{.1250} = 4.2\%$

		B90-1
Fillet Weld length	2"	Table 3.6a
MAX clear space	3"	Table 3.6b

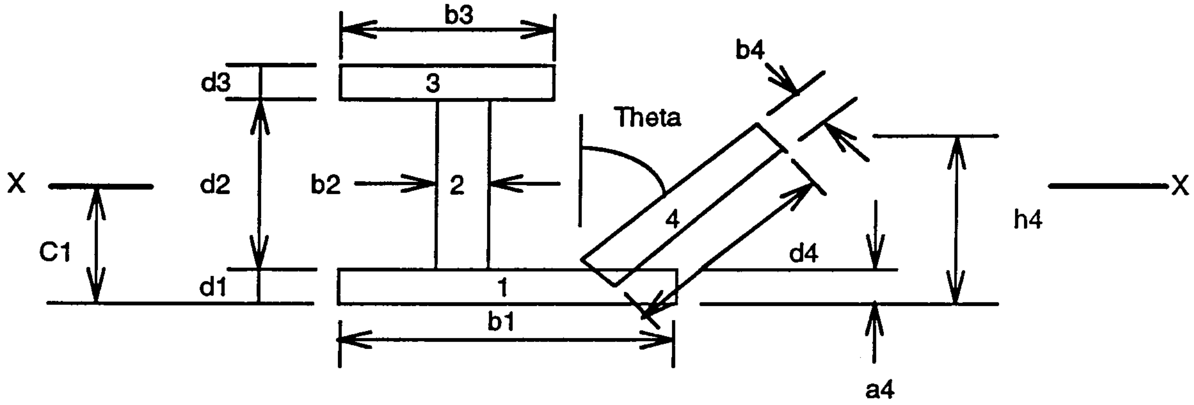
WELD 1/8 weld 2"-5" intermittent fillet on ONE side

SUBJECT
ENDS FOR QT

CBI OFFICE N06-C	REVISION		REFERENCE NO. 930212	
MADE BY TKH	CHKD BY RJW	MADE BY	CHKD BY	SHT__ OF__
DATE 3/29/94	DATE 29MAR94	DATE	DATE	

MOMENT OF INERTIA CALCULATION

INERTIA4.XLS, Rev 4
Pg 1 of 1

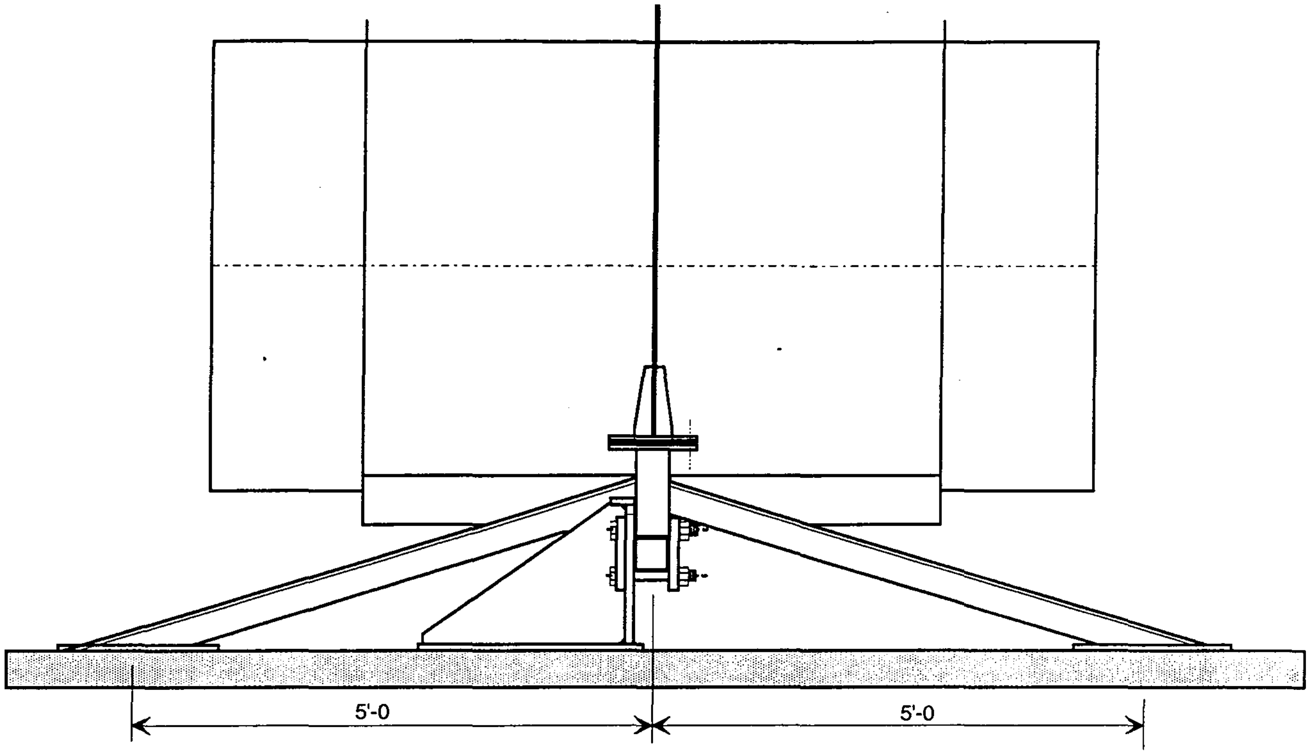


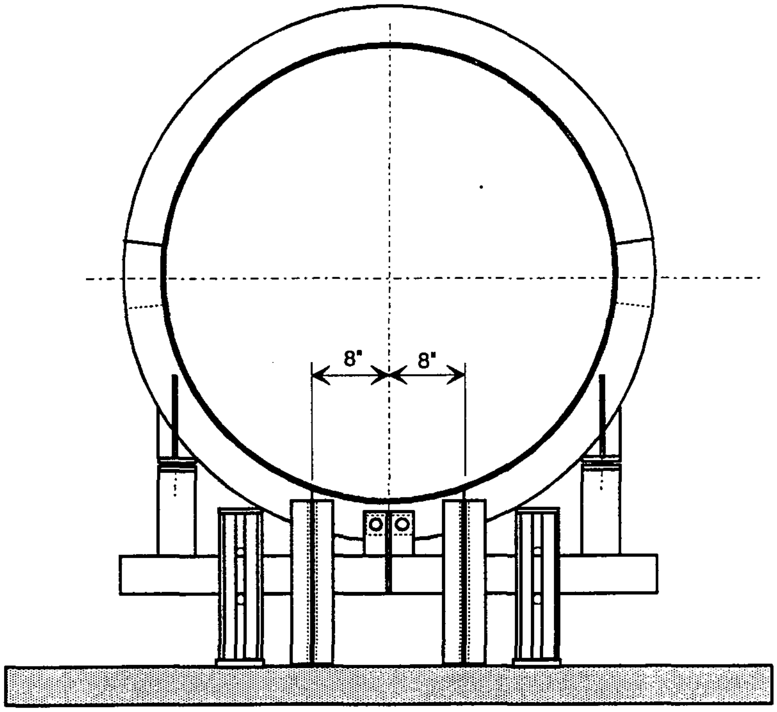
	Previous Area	b	d	Theta	a	h	AREA	Y	AY	AY^2	Io
1	-	0.3125	4.5	0	0.000	4.500	1.406	2.250	3.16	7.1	2.37
2	1	4.064	0.127	0	4.500	4.627	0.516	4.564	2.36	10.7	0.00
3	2	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
4	3	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
5	4	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
6	5	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
7	6	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
8	7	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
9	8	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
10	9	0	0	0	4.627	4.627	0.000	4.627	0.00	0.0	0.00
					TOTAL AREA=		1.922	in^2	5.52		20.2

TOTAL DEPTH = 4.627 in
CENTROID (Y) = SUM(AY)/SUM(AREA) = 2.871 in
C1 = Y = 2.871 in
C2 = DEPTH - Ybar = 1.756 in.

I(total)= [SUM(AY^2)+SUM(Io)]-(AREA)(Y)^2 = 4.4 in^4
Sx1 = I/C1 = 1.53 in.^3
Sx2 = I/C2 = 2.50 in.^3
Radius of gyration (r) = (I/A)^1/2= 1.512 in.

SUBJECT	OFFICE:	NOE-C	REVISION:		REFERENCE NO. 930212
ENDS FOR QT	MADE BY TKH	CHKD BY RJW	MADE BY	CHKD BY	SHT OF
	DATE 3/28/94	DATE 29 MAR94	DATE	DATE	

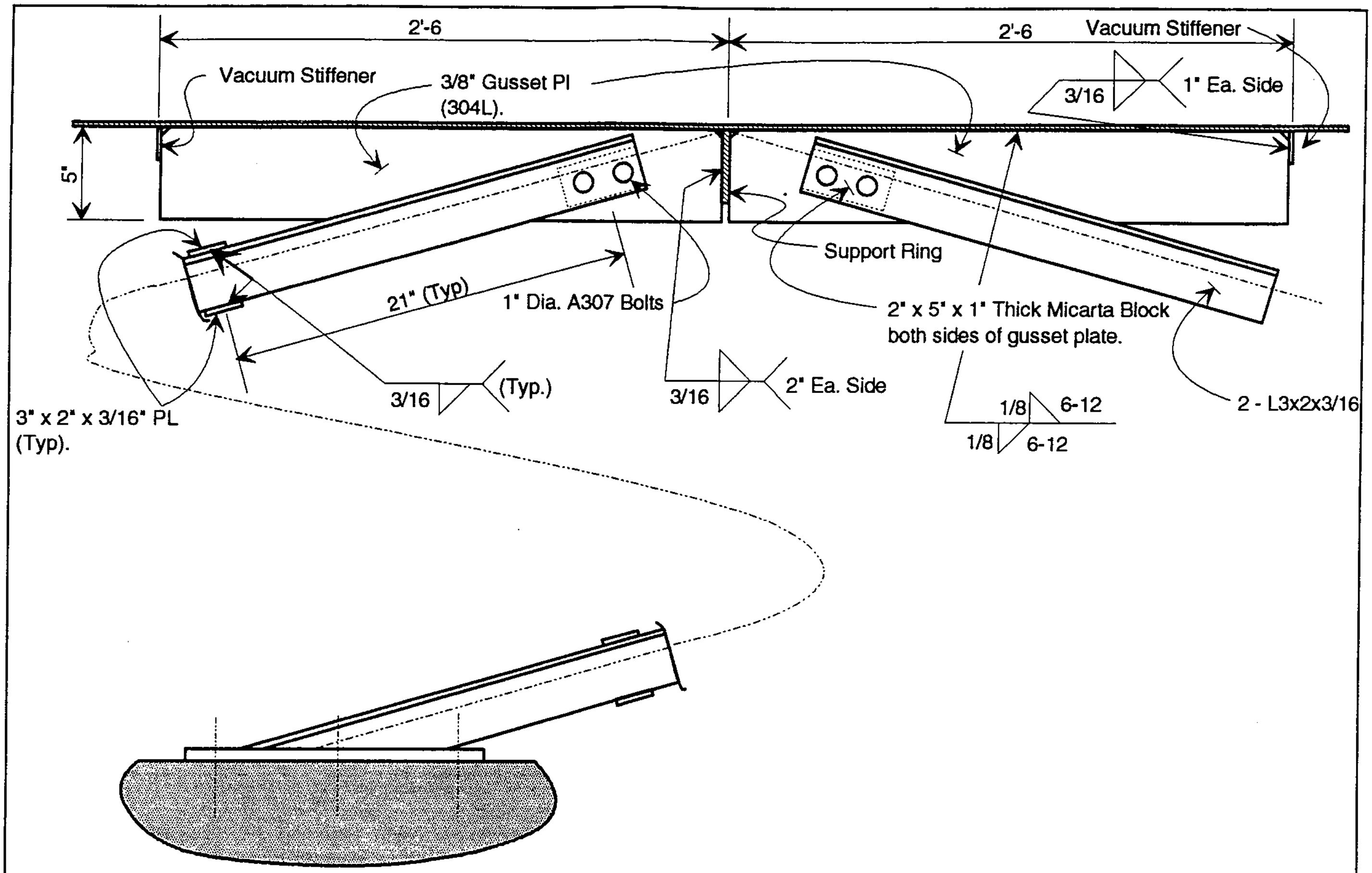


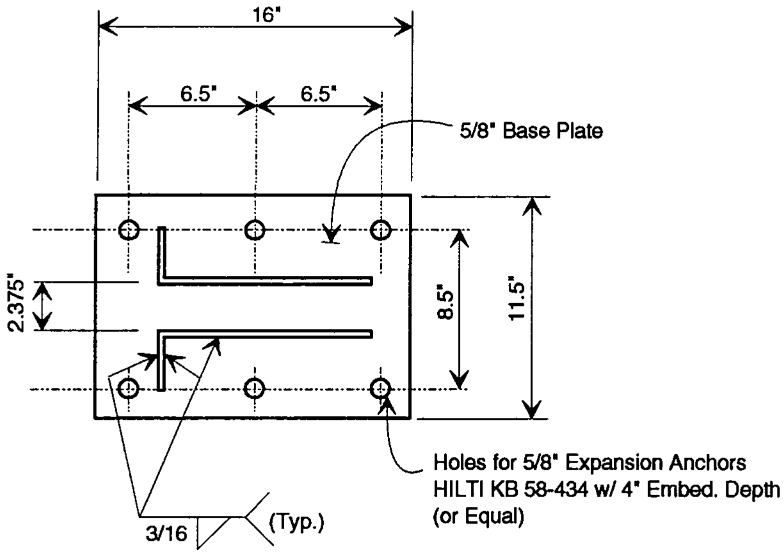


SUBJECT

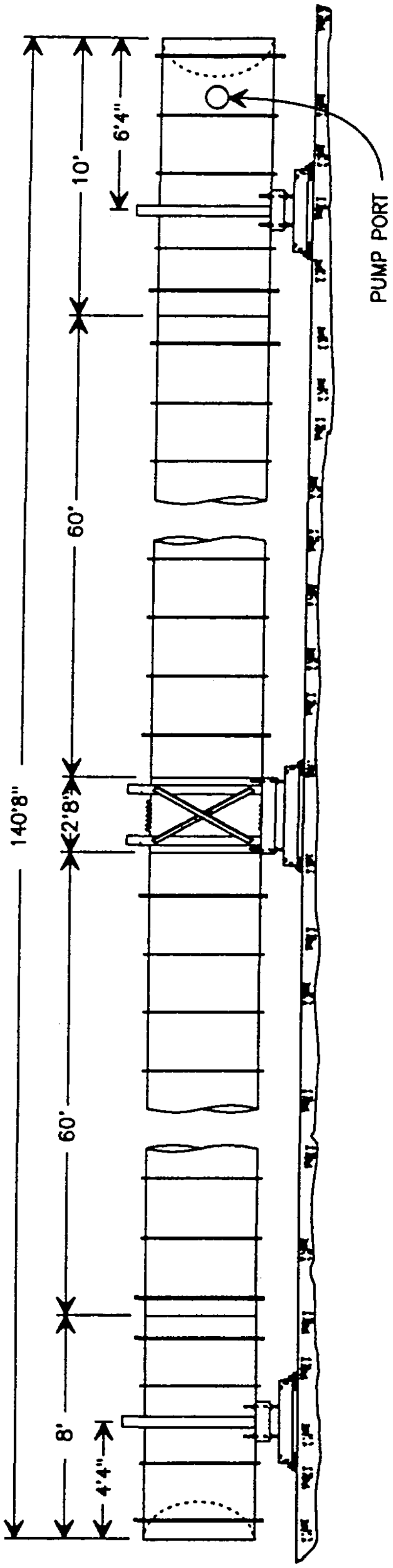
THRUST RESTRAINT
QUALIFICATION TEST
LIGO

CBI	**OFFICE**	**REVISION:**		**REFERENCE NO.**
MADE MRS	**CHK'D** DDG	**MADE**	**CHK'D**	**SHT___OF___**
DATE 4/1/94	**DATE** 4/6/94	**DATE**	**DATE**	**SK-QT1**





SUBJECT THRUST RESTRAINT DETAILS QUALIFICATION TEST LIGO	CBI **OFFICE**		**REVISION:**		**REFERENCE NO.**
	MADE MRS	**CHK'D** DDG	**MADE**	**CHK'D**	**SHT___OF___**
	DATE 4/1/94	**DATE** 4/6/94	**DATE**	**DATE**	**SK-QT2**



LIGO BEAM TUBE MODULE QUALIFICATION TEST CONFIGURATION

SUBJECT LIGO BEAM TUBE MODULE QUALIFICATION TEST CONFIGURATION	CBI OFFICE RCE		REVISION		REFERENCE NO. 930212
	MADE BY JAC	CHKD BY DDG	MADE BY	CHKD BY	SHT___ OF___
	DATE 2/7/94	DATE 4/6/94	DATE	DATE	

QUALIFICATION TEST FIXED SUPPORT DESIGN

AXIAL TUBE FORCES

VACUUM LOAD

CATILEVER END $P_{V_1} = (24.375'')^2(\pi)(14.7\,PSI)$

$= (1866.55\,IN^2)(14.7\,PSI)$

$= 27{,}438^{\#}$ (SHELL COMPRESSION)

BELLOWS SIDE OF SUPPORT

$P_{V_2} = (A_{BELLOWS} - A_{PIPE})\,14.7\,PSI$

$A_{BELLOWS} = 2063\,IN^2$ (PATHWAY BELLOWS EFFECTIVE AREA)

$P_{V_2} = (2063\,IN^2 - 1866.55\,IN^2)(14.7\,PSI) = 2{,}888^{\#}$ (SHELL TENSION)

TOTAL AXIAL PRESSURE FORCE $(P_V) = 27{,}438^{\#} + 2{,}888^{\#} = 30{,}326^{\#}$

BAKEOUT LOAD

$T = 338^\circ F$ $\Delta T = 338^\circ F - 70^\circ F = 268^\circ F$

$\alpha_{SS} = 9.05 \times 10^{-6}\,IN/IN/^\circ F$ @340°F E.J. SPRING RATE = 10,062 #/IN

TUBE GROWTH $\Delta = (268^\circ F)(9.05\times10^{-6}\,IN/IN/^\circ F)(130')(12''/FT) = 3.79''$

$P_B = (3.79'')(10{,}062\,^{\#}/IN) = 38{,}135^{\#}$

20°F TEMPERATURE DROP

$P_C = (20^\circ F)(8.46\times10^{-6}\,IN/IN/^\circ F)(130')(12''/FT)(10{,}062\,^{\#}/IN) = 2{,}656^{\#}$

$P_V + P_C = 30{,}326^{\#} + 2{,}656^{\#} = 32{,}983^{\#}$

SUBJECT QUALIFICATION TEST THRUST RESTRAINT DESIGN	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

MAXIMUM AXIAL FORCE $P = 38{,}135^{\#}$
(BAKE OUT & LOSS OF VACUUM)

CHECK TUBE FOR LONGITUDINAL COMPRESSIVE STRESS

CANTILEVER SIDE OF SUPPORT

$$\text{AXIAL STRESS } (\sigma_A) = \frac{27{,}438^{\#}}{A_{PIPE}} = \frac{27{,}438^{\#}}{19.5\text{ IN}^2} = 1{,}407\text{ PSI}$$

$$A_{PIPE} = (48.75 + .127'')(\pi)(.127'') = 19.5\text{ IN}^2$$

BENDING STRESS

MAX. WEIGHT OF TUBE = $91^{\#}/\text{FT}$ =

$$\text{MOMENT } (M) = \frac{w\ell^2}{2} = \frac{(91^{\#}/\text{FT})(6.333')^2}{2} = 1{,}825\text{ FT-LBS} = 21{,}900\text{ IN-LBS}$$

$$S = \pi r^2 t = \pi(24.4385'')^2(.127) = 238.3\text{ IN}^3$$

$$\sigma_b = \frac{21{,}900}{238.3} = 92\text{ PSI}$$

$$\sigma_C = \sigma_A + \sigma_b = 1499\text{ PSI} < \sigma_{ALLOW} = 5900\text{ PSI} \quad \therefore \text{ OK}$$

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT ___ OF ___
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

EXPANSION JOINT SIDE OF SUPPORT

AXIAL STRESS

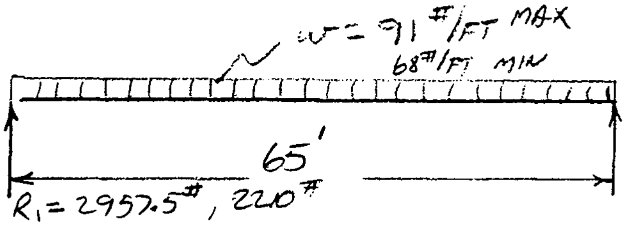
$$\sigma_A = \frac{38,135^{\#}}{19.5\,\text{IN}^2} = 1,956\ \text{PSI} \quad \text{BAKEOUT}$$

$$\sigma_A = 2,888/19.5 = 148\ \text{PSI TENSION (VACUUM)}$$

FIND BENDING STRESS

VERTICAL LOADS

CONSERVATIVELY ASSUME A SIMPLE BEAM.



$$M_V = \frac{wl^2}{8} = \frac{(91^{\#}/\text{FT})(65')^2}{8} = 48,060\ \text{FT-LBS} = 576,720\ \text{IN-LBS MAX}$$

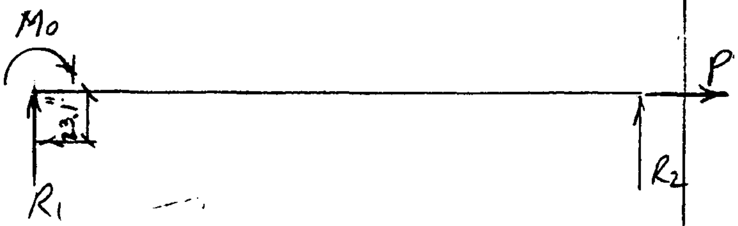
$$= 35,913\ \text{FT-LBS} = 430,950\ \text{IN-LBS MIN}$$

$$M = M_V - R_1 X$$

MOMENT LOAD

DISTANCE FROM TUBE ℄ TO BOTTOM OF SUPPORT RING

$$M_0 = (23.1'')\,P$$



$$P = -38,135^{\#}, \quad M_0 = -880,919\ \text{IN-LBS} \quad \text{(BAKE OUT)} \quad R_1 = 1130^{\#}$$

$$P = +32,983^{\#}, \quad M_0 = +761,907\ \text{IN-LBS} \quad \text{(VACUUM)} \quad R_1 = -977^{\#}$$

$$M = M_0 - R_1 X$$

$$M_{MAX} = 85,048\ \text{FT-LBS} \ @X = 21.8 \ \text{VACUUM}, \quad 73,410\ \text{FT-LBS BAKEOUT} \ @X=0$$

$$\sigma_b = \frac{(85,048)(12)}{238.3\,\text{IN}^3} = 4,283\ \text{PSI} \quad \text{VACUUM}$$

$$\sigma_b = \frac{(73,410)(12)}{238.3\,\text{IN}^3} = 3697\ \text{PSI} \quad \text{BAKEOUT}$$

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 93021
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

Printed In USA

GO 64 REV SEP 84

$\sigma_A + \sigma_b = -148$ PSI $+ 4283$ PSI $= 4135$ PSI VACUUM

$\sigma_A + \sigma_b = 1956$ PSI $+ 3697$ PSI $= 5653$ PSI BAKEOUT NO VACUUM

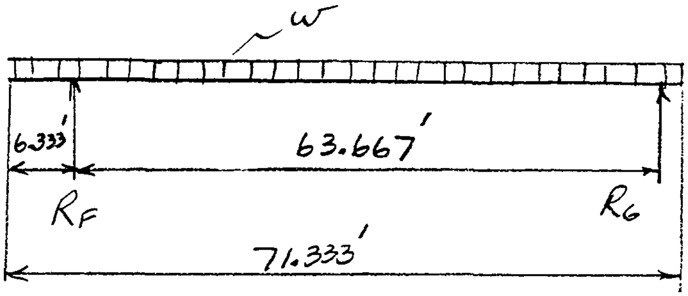
$\sigma_{ALLOW} = 5900$ PSI PER TUBE CALCS $\therefore$ OK

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

SUPPORT LOADS DURING Q.T.

MAX. VERT. LOAD

$w_{max} = 91 \ \#/FT$



$\Sigma M_{R_G} = 0$

$$R_F = \frac{(71.333')(91)(34.333')}{63.667'} = 3,500^{\#}$$

$R_G = 6,491 - 3500 = 2,991^{\#}$

MIN. VERT. LOAD

$w = (4.073')\pi(41.7 \ PSF/IN)(.127'') = 67.7 \ \#/FT$ USE $w = 68 \ \#/FT$

$R_F = (3500^{\#})(68/91) = 2615^{\#}$

$R_G = (2991^{\#})(68/91) = 2,235^{\#}$

SUPPORT LOADS

$$\left.\begin{array}{l}\text{FIXED SUPPORT} = 3500 + 1130 = 4,630^{\#} \\ \text{GUIDED SUPPORT} = 2991 + 997 = 3,988^{\#}\end{array}\right\} \text{MAX}$$

MIN. SUPPORT LOAD $= 2235 - 1130 = 1,105^{\#} > 0 \ \therefore$ NO UPLIFT

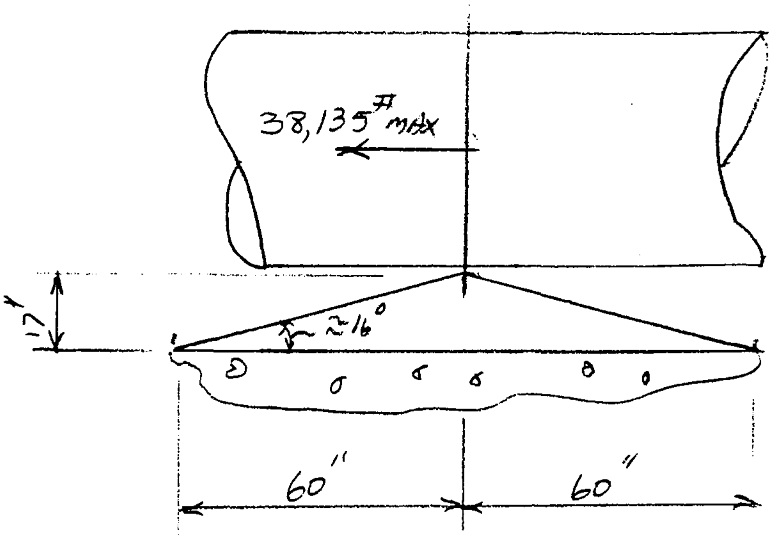
FIXED & GUIDED SUPPORTS WERE DESIGNED FOR $7600^{\#}$ & $5300^{\#}$ RESPECTIVELY $\therefore$ OK

SUBJECT	CBI OFFICE NOE	REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

STRUT DESIGN

USE 2 PAIRS OF TENSION-COMPRESSION STRUTS

WITH 19,100# PER PAIR

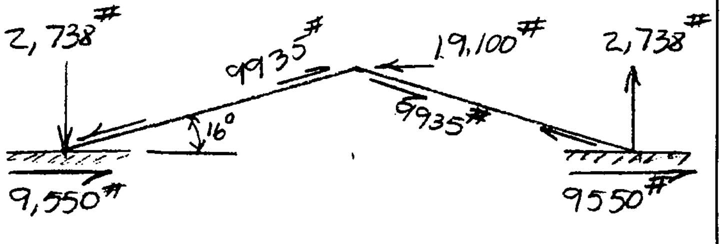


MAX. LOAD IN STRUTS

$$P = \frac{19,100^{\#}}{2\cos 16^{\circ}} = \pm 9,935^{\#}$$

VERTICAL FLOOR LOAD

$$P_V = 9,935^{\#} \sin 16^{\circ} = \pm 2,738^{\#}$$



TRY 2L 3 X 2 X 3/16

$P_{ALLOW} = 27^K$ FOR $L = 6'$ (AISC COLUMN TABLES PG 3-74)

$P_A > 9.9^K$ $\therefore$ OK

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY mRS	CHKD BY DDG	MADE BY	CHKD BY	SHT___ OF___
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

Printed In USA

GO 64 REV SEP 84

LONGITUDINAL STIFFENER DESIGN

RUN 3/8" LONGITUDINAL STIFFENERS FROM THE SUPPORT RING TO VACUUM STIFFENERS ON BOTH SIDES.

THE STIFFENERS ARE USED TO DISTRIBUTE THE THRUST LOADS INTO THE TUBE WALL IN SUCH A WAY AS TO PREVENT BUCKLING OF THE WALL.

LONGITUDINAL SHELL STRESS @ SUPPORT

$$1956\,PSI + - \frac{(6.333')^2\; 91\,\#/FT\;(12''/FT)}{2\,(2383\,IN^3)} = 2{,}050\,PSI$$

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT___ OF___
	DATE 3/31/94	DATE 4/6/94	DATE	DATE	

Printed In USA

GO 64 REV SEP 84

STANDARD 9108-7

BRACKET SUPPORTS ON CYLINDERS

t = 0.127 in. Shell thickness

R = 24.4385 in. Shell radius

L = 60 in. Length of lug

tl = 12 in. Lug thickness

tw = 0 in. Weld size

W = 12 in. $tl + 2(tw)$

P = 19100 lbs. Vertical load

Mact = 0 in-lbs Longitudinal moment on shell from lug

Qact = 0 lbs. Radial load on shell from lug

SL = 0 psi Longitudinal shell stress due to internal pressure.

SH = 0 psi Circumferential shell stress due to internal pressure.

Slc = 2050 psi Longitudinal shell compression stress.

ALLOWABLE STRESS (Sa) = 14400 psi = 1.25(.6Fy)

$B = 1.285/(Rt)^{.5} =$ 0.729397

$M1 = 1390(t^2)\ [6 + 6BL + (B^2)(L^2)]\ W =$ 338415 in-lbs

$M2 = 2520(t^2)\ [6 + 6BL + (B^2)(L^2)]\ W =$ 613530 in-lbs

$Q1 = 8333(t^2)\ WB\ (2 + BL) =$ 31010 lbs.

$Q2 = 15150(t^2)\ WB\ (2 + BL) =$ 56378 lbs.

$Ma/M1 + Qa/Q1 + SL/Sa =$ 0.00 =< 1.0

$Ma/M2 + Qa/Q2 + SH/Sa =$ 0.00 =< 1.0

ALLOWABLE SHELL COMPRESSION (Sca) = 0.0625(E)(t/R) = 5900 psi

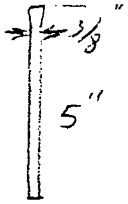
$$Sc = \frac{P}{[1.154(L) + W](t)} + Slc = \quad 3901 \text{ psi}$$

SUBJECT	MADE BY: mRS	R	MADE BY:	REFERENCE NO. 930212
	CHKD BY: DDG	E V	CHKD BY:	
	DATE: 3/31/94		DATE:	SHT____OF____

CHECK GUSSET FOR BUCKLING

$P = 9,600^{\#}$

$L = 30''$



$$I = \frac{b^3 t}{12} = \frac{5^3(.375)}{12} = 3.9\ in^4$$

$A = 5(.375'') = 1.875\ in^2$

$$r = \sqrt{\frac{3.9}{1.875}} = 1.44''$$

$$KL/r = \frac{(1.0)(30)}{1.44} = 21$$

$$Fa = (20.54)\left(\frac{19.2}{36}\right) = 10.9\ KSI$$

$fa = 9.6^K / 1.875\ in^2 = 5.12\ KSI < Fa \therefore OK$

LENGTH OF WELD REQ'D

$$f_{wA} = \left(9600^{\#}/in/in\right)\left(\frac{19.2}{30}\right) = 6,144\ ^{\#}/in/in \quad \text{ALLOWABLE}$$

TRY 1/8" WELD $fa = 768\ ^{\#}/in$

$$Lw = \frac{19,100}{768} = 24.9''$$

USE 1/8" 6-12 / 6-12

SUBJECT

CBI OFFICE NOE

REVISION

REFERENCE NO. 930212

MADE BY	CHKD BY	MADE BY	CHKD BY	
MRS	DDG			SHT ___ OF ___
DATE 4/1/94	DATE 4/6/94	DATE	DATE	

SIZE BOLTS

TRY 2 1" φ BOLTS A307

ALLOWABLE BOLT SHEAR = 15.7^K EACH

$P_{TOTAL} = 31.4^K > 9.9^K \therefore$ OK

SIZE BASE PLATE

MAX DOWN LOAD = $2738^{\#}$

AREA REQ'D = $\frac{2738^{\#}}{750 PSI} = 3.65\ IN^2$

USE 10" X 12" X 3/8" BASE PL.

f_p = 23 PSI

SUBJECT	CBI OFFICE NOE		REVISION	REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 4/1/94	DATE 4/6/94	DATE	DATE	

MAX. SHEAR = 9,550# MAX UPLIFT = 2738#

TRY HILTI EXPANSION ANCHORS KB II 58 - 434

MAX ALLOW SHEAR LOAD PER ANCHOR = 2625#

TRY 6 ALLOW SHEAR = 15,750# > 9,550# ∴ OK

TENSILE PULL OUT ALLOWABLE = 750# EACH

$P_{TOTAL} = 6(750^{\#}) = 4500^{\#} > 2738^{\#}$ ∴ OK

CHECK BASE PLATE

$M_{MAX} = 2.5''(2625^{\#}) = 6,563$ IN-LBS

5" OF BASE PL RESISTS MOMENT

$\sigma_{ALLOW} = .75F_y = 27,000$ PSI

$$t_{REQ'D} = \sqrt{\frac{6M}{b\sigma}} = \sqrt{\frac{6(6563)}{5''(27000)}} = 0.54''$$

USE 5/8" BASE PL

SUBJECT	CBI OFFICE NOE	REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT___ OF___
	DATE 4/1/94	DATE 4/6/94	DATE	DATE	

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DESIGN WELD TO BASE PLATE

$P_{MAX} = 10^{K}$

TRY 1/4" MIN. WELD SIZE

ALLOWABLE WELD LOAD = $9600^{\#}/in/in \; (1/4") = 2400^{\#}/in$

LENGTH OF WELD REQ'D = $\frac{10,000^{\#}}{2400^{\#}/in} = 4.2"$

SUBJECT	CBI OFFICE NOE		REVISION		REFERENCE NO. 930212
	MADE BY MRS	CHKD BY DDG	MADE BY	CHKD BY	SHT__ OF__
	DATE 4/1/94	DATE 4/6/94	DATE	DATE	

CBI PROPRIETARY

		IDENTIFICATION FSQT			
TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 1 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/25/94	DATE 4/25/94	DATE	DATE

This procedure addends FABSEQ as follows:
Omitted for the Qualification Test - ~~2.42 Install end caps.~~
Changed for the Qualification Test - *italics*

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 Beam Tube Can Section Cleaning
5.0 Referenced Procedures
6.0 Sequence Diagram and Sketches

2.0 FABRICATION SEQUENCE

2.1 *CBI Houston Corporate Welding is the fabrication site for beam tube can section assemblies. CBITSC Plainfield is the site for final fabrication and installation. The receiving area at each location will simulate the option receiving in a similar manner.* 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.

****

Notes:

Clean clothing and shoe covers shall be worn for all work inside the beam tube.

&

Factory Tubes, Expansion Bellows, Stiffeners, and Pump Port Materials ~~Valves~~ will have inspection and factory release papers with shipment.

****

To PUT INTO
VOL 3

CBI PROPRIETARY

TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	IDENTIFICATION FSQT			
		REFERENCE NO. 930212		SHT 2 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/25/94	DATE 4/25/94	DATE	DATE

****

Reference

See
Clean Room Wearing Apparel for Beam Tube Access for LIGO
Qualification Test Module Addenda
Doc ID "CRWAQT"

****

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.

****

Notes:

Use nylon slings and designated rigging for
handling beam tubes and expansion bellows.
&
Do not use screw clamps *or chains* for handling beam tubes.

****

2.5 Move beam tube to desired stiffener fitting and weld area.

****

Warning

Do not perform any welding
or tacking on beam tubes until proper
backing purge has been established.

****

Note:

Clean clothing and shoe covers shall be worn
for all work inside the beam tube.

****

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.

2.6.1 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.

CBI PROPRIETARY

IDENTIFICATION FSQT					
TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 3 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/25/94	DATE 4/25/94	DATE	DATE

Perform dimensional measurements using reference procedure.

****

Reference

See
Dimensional Control Procedure for LIGO
Qualification Test Module Addenda
Doc ID "DCQT"

****

****

Notes:

For convention, beam tube direction is outward from apex.

&

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. *Machined guided support stiffeners shall be adjusted after dimensional measurements have been taken for welding shrinkage corrections (see added steps 2.13.1 through 2.13.3). The measurements shall be taken after welding of all vacuum stiffeners are finished per Doc ID "DCQT."*

CBI PROPRIETARY

IDENTIFICATION FSQT					
TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 4 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
	CALIFORNIA INSTITUTE OF TECHNOLOGY	DATE 4/25/94	DATE 4/25/94	DATE	DATE

2.9 Set beam tube in stiffener fit-up and weld area. Position end turning trunnion and opposite end support.

****

Note:

Clean clothing and shoe covers shall be worn for all work inside the beam tube.

****

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. *Do not fit and tack machined guided support stiffeners (see added steps 2.13.1 through 2.13.3).*

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. ~~*Do not weld machined guided support stiffeners (see added steps 2.13.1 through 2.13.3).*~~

****

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"

****

2.13.1 Take dimensional measurements per Doc ID "DCQT" after all vacuum stiffener welding is finished. Install machined guided support stiffener. Machined guided support stiffener halves to be placed in final position.

2.13.2 *Tack machined guided support stiffener. Do not tack within 2" of spiral weld.*

2.13.3 *Weld machined guided support stiffener. Do not weld within 2" of spiral weld.*

2.14 Fit and weld pump port reinforcing ring, if applicable. Verify prior to welding that vacuum port reinforcing ring does not cross spiral weld.

****
Reference

See
Weld Procedure Specification for
GMA Welding for 304L Materials
Doc ID "WPS-ER308L/GMA"
****

2.14.1 ~~*Perform dimensional measurements and baffle performance test using Dimensional Control Procedure for LIGO Qualification Test Module Addendum.*~~

2.15 ~~Steps 2.16 thru 2.29 are for installation of expansion bellows. Skip if not applicable to specific beam tube can section.~~

2.15.1 *CBI Houston Corporate Welding skip and go to step 2.30.*

2.15.2 *CBITSC Plainfield performs steps 2.16 through 2.29 for fabrication sequences for assembling beam tube can sections into sub-assemblies. The beam tube can sections shall be visually inspected for shipment damage and the shop release for shipment check list shall be complete before continuing.*

2.15.3 *CBITSC Plainfield performs steps 2.16 through 2.29 for installation of expansion joint sub-assembly to the forward assembly and performs the circumferential weld joint test using added steps 2.24.1 through 2.24.7 for the forward assembly. The sub-assembly check list testing sequence shall be complete before continuing.*

2.16 Move stiffened tube can section*(s) or expansion joint assembly (sub-assemblies) to assembly fabrication* area.

****
Reference

See
Fitting/Purge Procedure for
Circumferential Butt Welds for LIGO
Doc ID "FPCirc"
****

CBI PROPRIETARY

IDENTIFICATION
FSQT

TITLE **BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES QUALIFICATION TEST**
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO. 930212		SHT 6 OF 16	
OFFICE RCE		REVISION 0	
MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
DATE 4/25/94	DATE 4/25/94	DATE	DATE

2.17 Start aligning *sub-assemblies (including expansion joint assembly when applicable)* using mechanical alignment jig. The *sub-assembly* 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.
&
Clean clothing and shoe covers shall be worn
for all work inside the beam tube.

****

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 *14* of *16* 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 (*sub-assembly)* 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.

****

CBI PROPRIETARY

		IDENTIFICATION **FSQT**			
TITLE	**BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 7 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE **4/25/94**	DATE **4/25/94**	DATE	DATE

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/Circ"

****

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. *Add the following steps for testing the circumferential weld joint of the expansion joint sub-assembly to the tested forward sub-assembly. Skip steps 2.24.1 through 2.24.7 for sub-assemblies and aft assembly.*

2.24.1 Shut valve on annular evacuation line.

2.24.2 Evacuate annular space using vacuum pump to 29.9" Hg.

2.24.3 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.

2.24.4 Install helium mass spectrometer vacuum cover and test beam tube weld joint.

****

Reference

See
"Helium Mass Spectrometer Hood Test of Circumferential Closing
Weld Joints Between Beam Tube Can Sections
Qualification Test Module Addenda
Doc ID "HMST2QT"

****

2.24.5 If leak is detected, vent, repair per WPS- ER308L/REPAIR and retest in accordance with the applicable steps of procedure addendum HMST2QT.

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TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	IDENTIFICATION FSQT			
		REFERENCE NO. 930212		SHT 8 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
	CALIFORNIA INSTITUTE OF TECHNOLOGY	DATE 4/25/94	DATE 4/25/94	DATE	DATE

2.24.6 *Remove helium mass spectrometer vacuum cover from weld joint exterior.*

2.24.7 *Shut helium test gas and nitrogen ring seal gas supply and go to step 2.26.*

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.

****

Note:

Clean clothing and shoe covers shall be worn
for all work inside the beam tube.

****

~~2.30 Steps 2.31 thru 2.41 are for installation of pump port. Skip if not applicable to specific beam tube can section.~~ *Add the following steps.*

2.30.1 *CBI Houston Corporate Welding shall continue steps 2.31 through 2.41 for installation of pumping port. Skip and go to step 2.42.1 for beam tube can sections without pumping port.*

2.30.2 *CBI Plainfield skip and go to step 2.42.5.*

2.31 Move stiffened tube section to pump port fit and weld area.

****

Note:

Clean clothing and shoe covers shall be worn
for all work inside the beam tube.

****

Reference

See
Fitting/Purge Procedure for Pump
Port Attachment Welds for LIGO
Doc ID "FPPumpPort"

****

CBI PROPRIETARY

TITLE BEAM TUBE CAN SECTION
FABRICATION SEQUENCE FOR LIGO
QT ADDENDA

PRODUCT LIGO BEAM TUBE MODULES
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

IDENTIFICATION FSQT			
REFERENCE NO. 930212		SHT 9 OF 16	
OFFICE RCE		REVISION 0	
MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
DATE 4/25/94	DATE 4/25/94	DATE	DATE

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 susect 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.~~ *Add the following steps.*

2.42.1 CBI Houston Corporate Welding shall perform facing of weld ends on beam tube can sections using a turning positioner, rollers and a fixed grinder. A similar method was used during welding procedure specification development.

2.42.2 CBI Houston Corporate Welding shall perform dimensional measurements using Dimensional Control Procedure for LIGO Qualification Test Module Addendum Doc ID "DCQT."

2.42.4 CBI Houston Corporate Welding shall visually inspect the interior surfaces of each beam tube can section for visible contamination with dirt, grease or heaavy layers of dust. Wipe with acetone or alcohol to remove all visible deposits of these materials. Following this solvent wipe, install end caps for shipment.

2.42.5 *CBI Plainfield shall perform dimensional measurements using Dimensional Control Procedure for LIGO Qualification Test Module Addendum Doc ID "DCQT" and install end caps.*

2.43 Move beam tube assembly to post fab storage area. *Add the following steps.*

2.43.1 *CBI Houston Corporate Welding package and ship beam tube can sections (sub-assemblies) to CBI Plainfield.*

2.43.2 *CBI Plainfield for tested forward assembly skip steps 3.0 through 3.13.1 and go to step 4.1.*

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. *Perform pretest cleaning and blacklight testing using reference procedures."*

****

Reference

See
~~**Cleaning of Completed Tube Can Sections**~~
~~**Doc ID "CL1N"**~~

Blacklight Inspection Technique and Solvent
Cleaning Procedure
Doc ID "BI1N"
and
Cleaning of Completed Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "CL1QT"

****

3.3 Perform visual examination noting any suspect areas.

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TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	IDENTIFICATION FSQT			
		REFERENCE NO. 930212		SHT 11 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/25/94	DATE 4/25/94	DATE	DATE

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"**~~
Helium Mass Spectrometer Hood Test
of Beam Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "HMST1QT"

****

3.5 Complete test records for beam tube can section.

3.6 Steps 3.7 thru 3.11 are for *repair and repeat testing* of beam tube assemblies that have failed previous test. Skip *and go to step 3.12* 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~~. *Step 3.4 addendum reference locates leak(s).*

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".~~ *Repeat step 3.4 addendum reference.*

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. *Add the following step.*

3.13.1 Move the tested forward sub-assembly to the fabrication area for installation of the expansion joint sub-assembly (go to step 2.15.3 to continue).

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"**~~

Cleaning of Completed Tube Can Sections for LIGO
Qualification Test Module Addenda
Doc ID "CL1QT"

****

4.3 Clean interior of beam tube *assembly*.

4.4 Dry interior of beam tube *assembly*.

4.5 Install cleaned end protection caps and polyethylene bagged double seal.

4.6 Complete cleaning records for beam tube *assembly*.

4.7 Move cleaned and sealed beam tube *assembly* 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 *Qualification Test Module Addenda Doc ID "LIGOTPQT"* ~~Project Doc ID "LIGOTP"~~

5.2 Helium Mass Spectrometer Hood Test of Beam Tube Can Sections *for LIGO Qualification Test Module Addenda Doc ID "HMST1QT"* ~~Doc ID "HMST1N"~~

CBI PROPRIETARY

IDENTIFICATION **FSQT**				
REFERENCE NO. **930212**	SHT 13 OF 16			
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DATE **4/25/94**	DATE **4/25/94**	DATE	DATE	

TITLE **BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO**
QT ADDENDA

PRODUCT **LIGO BEAM TUBE MODULES**
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

5.3 Cleaning of Completed Tube Can Sections *for LIGO Qualification Test Module Addenda Doc ID "CL1QT"* ~~Doc ID "CL1N"~~

5.4 Fitting/Purge Procedure for Circumferential Butt Welds for LIGO Doc ID "FPCirc"

5.5 Welding Procedure Specification for Circumferential Welds Doc ID "WPS-ER308L/Circ"

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-E308L/GMA"

5.9 Welding Procedure Specification for repair welding of 304L materials Doc ID "WPS-E308L/REPAIR"

5.10 Dimensional Control Procedure for LIGO Qualification Test Module Addenda Doc ID "DCQT"

5.11 Blacklight Inspection Technique and Solvent Cleaning Procedure Doc ID "BI1N"

5.12 Helium Mass Spectrometer Hood Test of Circumferential Closing Weld Joints Between Beam Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "HMST2QT"

5.13 Planned Approach for Cleaning and Cleaning Maintenance for LIGO Qualification Test Module Addenda Doc ID "LIGOCPQT"

6.0 SEQUENCE DIAGRAM AND SKETCHES

Attached find the following related to this fabrication sequence:

6.1 Weld Joint Purging Arrangement (Page *14* of *16*)

6.2 Beam Tube Fabrication Sequence Logic Diagram (Page *15* of *16* to Page *16* of *16*)

CBI PROPRIETARY

TITLE	BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA	IDENTIFICATION FSQT			
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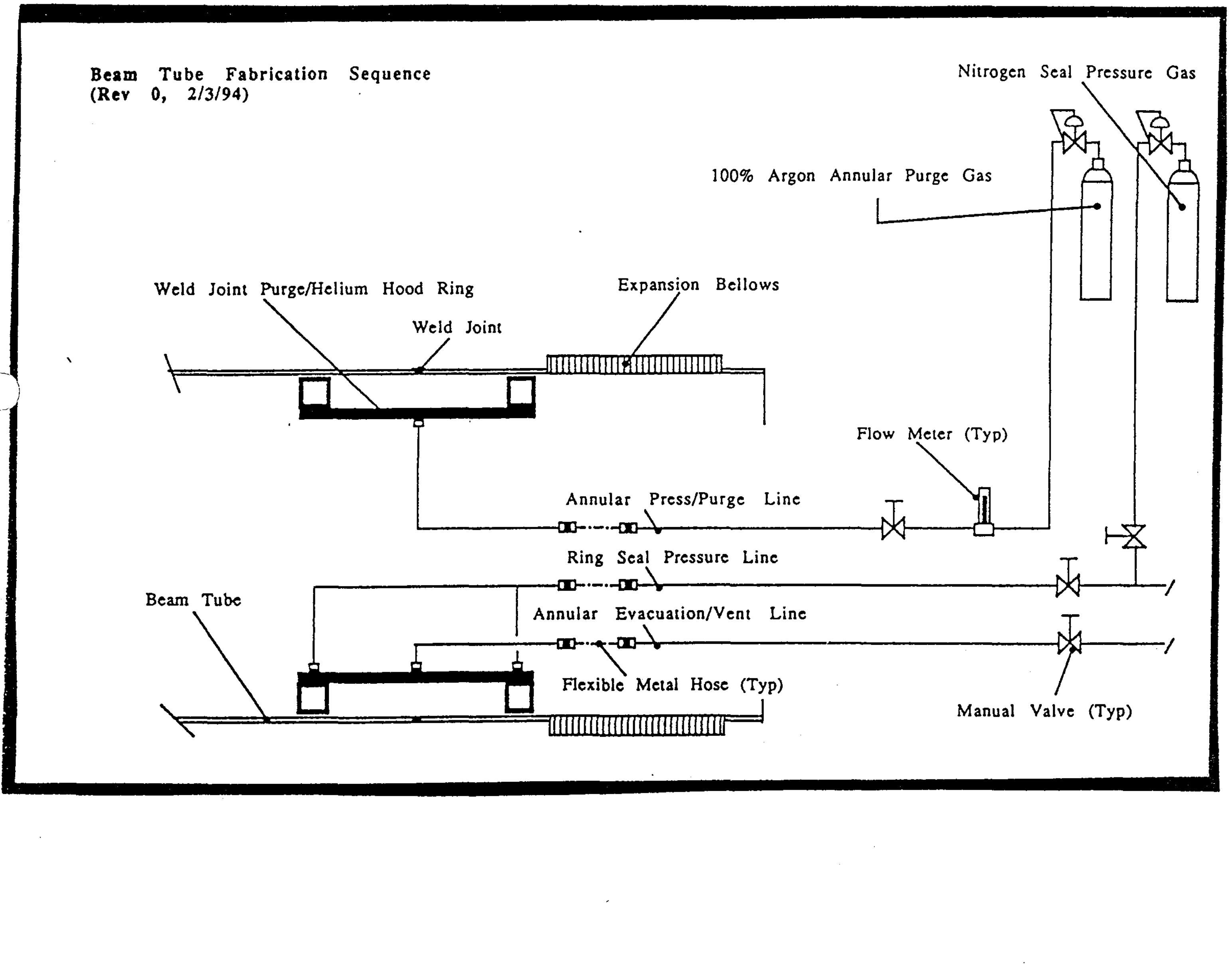
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/25/94	DATE 4/25/94	DATE	DATE

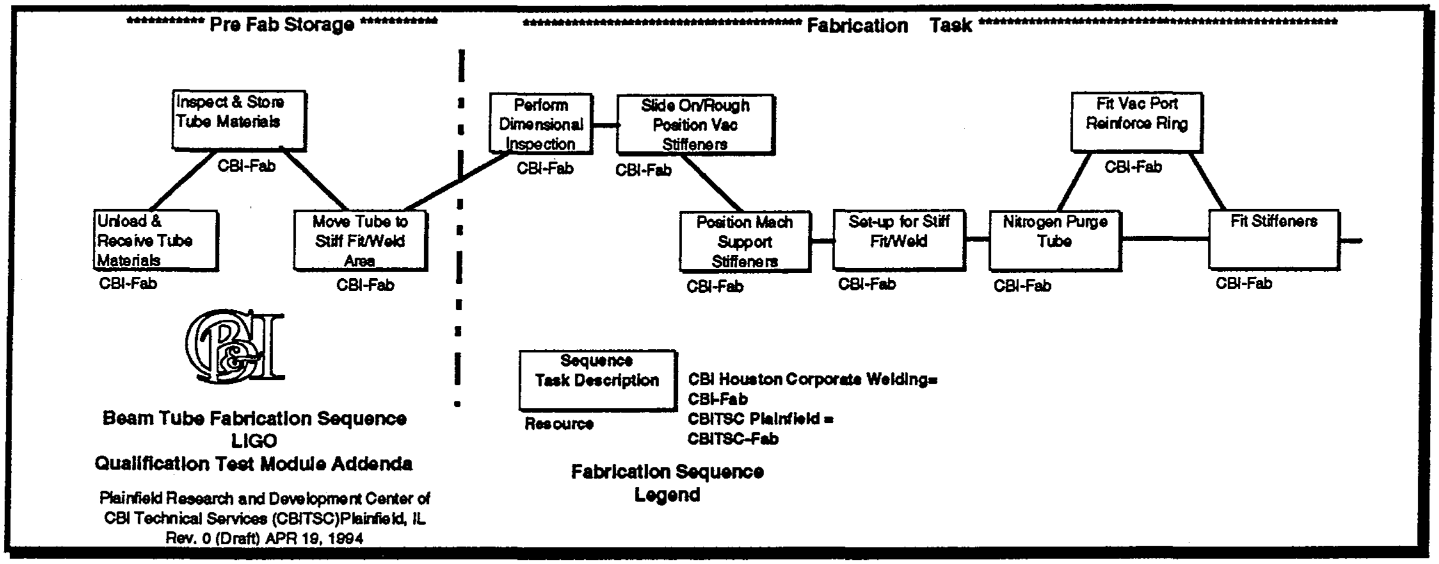
ATTACHMENT -- WELD JOINT PURGING ARRANGEMENT

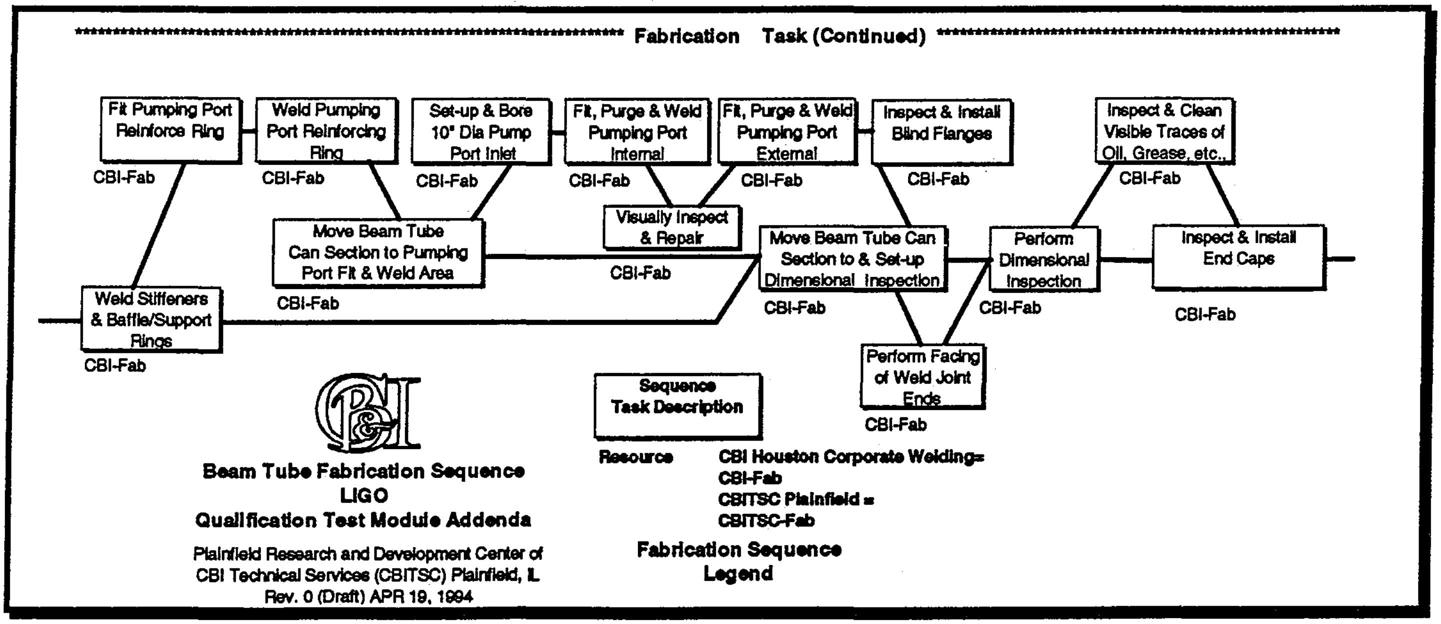


CBI PROPRIETARY

		IDENTIFICATION **FSQT**			
TITLE	**BEAM TUBE CAN SECTION FABRICATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 15 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE **4/25/94**	DATE **4/25/94**	DATE	DATE

ATTACHMENT -- BEAM TUBE FABRICATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA





CBI PROPRIETARY

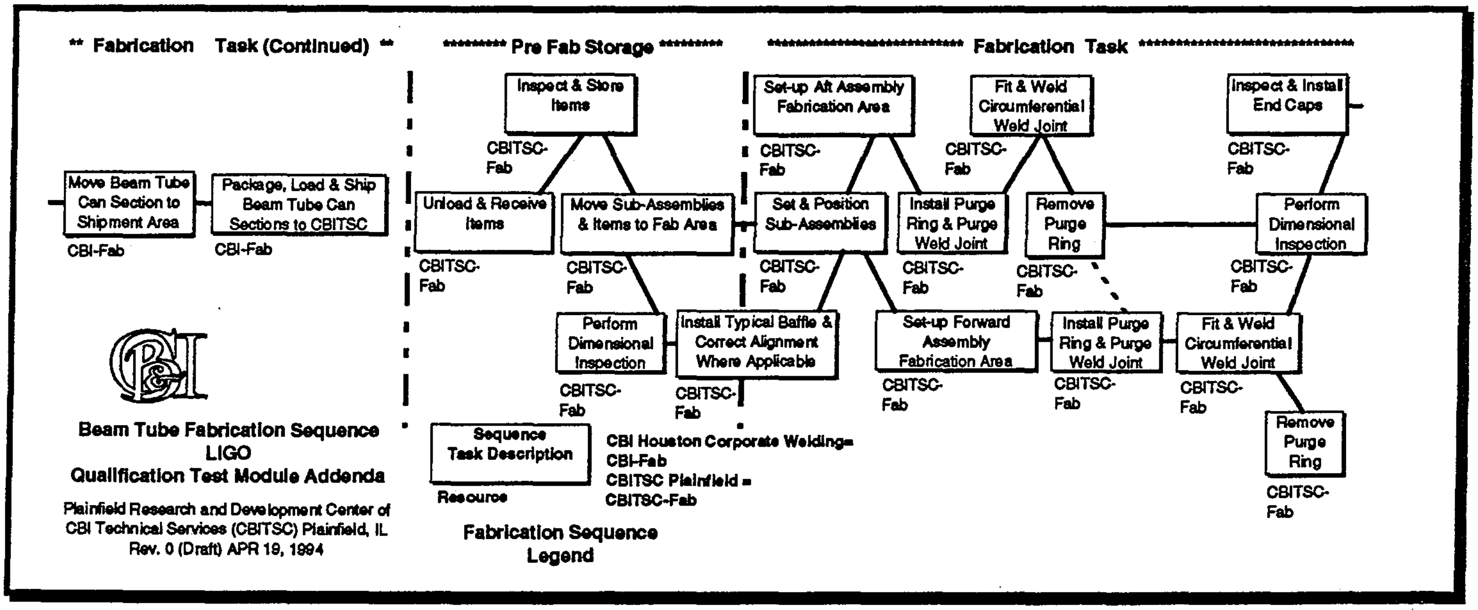
IDENTIFICATION
FSQT

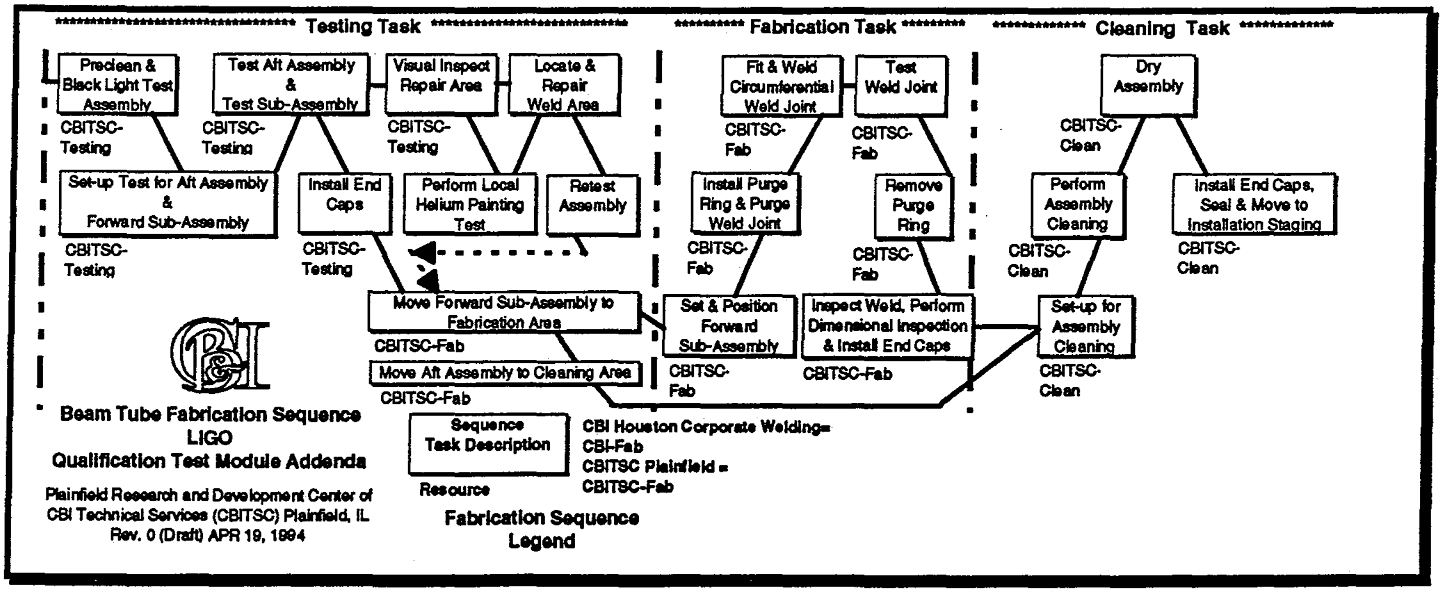
TITLE BEAM TUBE CAN SECTION
FABRICATION SEQUENCE FOR LIGO
QT ADDENDA

PRODUCT LIGO BEAM TUBE MODULES
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO.		SHT 16 OF 16	
930212			
OFFICE		REVISION	
RCE		0	
MADE BY	CHKD BY	MADE BY	CHKD BY
WLR	PM		
DATE	DATE	DATE	DATE
4/25/94	4/25/94		

ATTACHMENT – BEAM TUBE FABRICATION SEQUENCE LOGIC DIAGRAM
QUALIFICATION TEST MODULE ADDENDA





CBI PROPRIETARY

TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA	IDENTIFICATION ISQT			
		REFERENCE NO. 930212		SHT 1 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY	CHKD BY
		DATE 4/21/94	DATE 4/21/94	DATE	DATE

This procedure addends INSTALLSEQ as follows:
Omitted for the Qualification Test - ~~2.42 Install end caps.~~
Changed for the Qualification Test - *italics*

1.0 Scope

This procedure outlines the installation sequences to be followed during the installation of the *Qualification Test (QT)* beam tube *assemblies* ~~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 *assemblies* ~~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~~
~~"Blower-Dryer Filtration System~~
~~Operation and Maintenance"~~
~~Doc ID "EBF1"~~
~~**************~~

CBITSC Plainfield is the site for installation.

The installation sequence begins with a beam tube assembly specific to the beam tube qualification test module. The ensuing beam tube assembly is likewise specific. The two (2) beam tube assemblies (forward and aft) with related equipment and components are assembled using methods and procedures that duplicate beam tube section installation within reasonable proximity.

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		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

Perform prerequisite installation alignment task .

****

Reference

See
"Installation Alignment and Support Adjustment
Procedure for LIGO Qualification Test"
Doc ID "AQT"

****

Move the aft assembly into position. Set aft assembly on temporary adjustable supports located clear of the contract structural support area and clear of adjoining end. Remove pumping port blind flange and connect temporary positive clean air flow tubing to qualification test vacuum lab clean room. The aft assembly is under a positive clean air flow condition. The positive clean air flow is maintained as the forward assembly is moved into position or installed.

2.1.1 *Remove end cap from end of aft assembly. Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry.*

****

Reference

See
"Final Cleaning and Inspection of LIGO Beam Tube
Inner Surfaces Including Baffles
for LIGO Qualification Test Module Addenda"
Doc ID "CL3QT"

****

Note:

****

See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.

****

2.1.2 *Inspect and clean aft assembly interior as workman "backs out" and install baffles into the clean area per Doc ID "CL3QT" and contract drawings.*

2.1.3 *Perform dimensional check information and complete records on aft assembly at support locations and installed baffles.*

2.1.4 *Install tube access plug 8" from end of aft assembly immediately upon completion of cleaning, baffle installation and exit from aft assembly.*

2.1.5 *Install end cap.*

2.1.6 *At this point installation is complete and the forward assembly installation may be started.*

2.1.7 *Install contract fixed structural support on aft assembly after equipment has been removed clear of structural support point.* ***Do not install supplemental QT support components at this time.***

2.1.8 *Remove the temporary adjustable supports. Grout is not required for the QT.*

The forward assembly is moved into position in a tested and internally cleaned condition with end caps installed on both ends.

~~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 *assembly* ~~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 *assembly* ~~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 *assembly* ~~can section~~ to existing beam tube *assembly* ~~can section~~. Do not remove the internal tube access plug from the previously installed beam tube *assembly* ~~can section~~.

CBI PROPRIETARY

IDENTIFICATION **ISQT**					
TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO** **QT ADDENDA**	REFERENCE NO. **930212**		SHT 4 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST** **CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

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 *forward assembly* centerline and elevation to the previously installed alignment reference *points per Doc ID "AQT".*

~~******************~~

~~**Reference**~~

~~**See**~~
~~**"Initial and Final Alignment During**~~
~~**Construction and Installation of Beam**~~
~~**Tube Can Sections"**~~
~~**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"**~~
~~**Doc ID"CRNTSM"**~~
~~**for specific safety precautions and**~~
~~**procedures to be adhered to within**~~
~~**the clean room and beam tube.**~~
~~******************~~

CBI PROPRIETARY

IDENTIFICATION ISQT			
TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212	SHT 5 OF 16
		OFFICE RCE	REVISION 0
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR / CHKD BY SWP DATE 4/21/94 / DATE 4/21/94	MADE BY / CHKD BY DATE / DATE

2.10 Remove end cap from end of beam tube *forward assembly.*

****

Note

****

See Doc ID "CL3QT" for specific safety precautions and procedures to be adhered to within the beam tube interior.

****

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 *14* of *16* 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 nitrogen flow rate to a minimum flow rate 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.

****

CBI PROPRIETARY

IDENTIFICATION
ISQT

TITLE **BEAM TUBE CAN SECTION**
INSTALLATION SEQUENCE FOR LIGO
QT ADDENDA

PRODUCT **LIGO BEAM TUBE MODULES**
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO. **930212**		SHT 6 OF 16	
OFFICE **RCE**		REVISION 0	
MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

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 *circumferential* weld joint.

2.17 Visually inspect closing *circumferential* 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.~~

CBI PROPRIETARY

TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA**	IDENTIFICATION **ISQT**			
		REFERENCE NO. **930212**		SHT 7 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST** **CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

2.24 Install helium mass spectrometer vacuum cover and test beam tube *circumferential* weld joint.

****

Reference

See
~~**"Helium Mass Spectrometer Hood**~~
~~**Test of Closing Weld Joints**~~
~~**Between Beam Tube Cans"**~~
~~**Doc ID "HMST2N"**~~

Helium Mass Spectrometer Hood Test of Circumferential
Closing Weld Joints between Beam Tube Cans
for LIGO Qualification Test Module Addenda"
Doc ID "HMST2QT"

****

2.25 If leak is detected, vent, repair *per WPS-ER308L/REPAIR* and retest in accordance with the applicable steps of procedure *HMST2QT*.

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.~~

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IDENTIFICATION **ISQT**					
TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 8 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST** **CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

~~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 *Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry.* Remove tube access plug from end of previously installed beam tube *aft assembly.*

Note:
****

See Doc ID "CL3QT" for specific safety precautions
and procedures to be adhered to within
the beam tube interior.
****

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"~~

Final Cleaning and Inspection of LIGO Beam Tube
Inner Surfaces Including Baffles
for LIGO Qualification Test Module Addenda
Doc ID "CL3QT"
****

~~*************~~

CBI PROPRIETARY

IDENTIFICATION
ISQT

TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 9 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

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 *forward and aft assemblies* ~~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 *or tape*.

2.41 At this point installation *of the beam tube qualification test module is set-up for the alignment acceptance test.*

~~*************~~

~~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 *fixed & guided* structural support on *forward assembly after equipment has been moved from* 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~~. *Perform post installation alignment task and alignment acceptance test per Doc ID "AQT" and contract drawings.Add the following steps.*

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		IDENTIFICATION **ISQT**		
TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**	SHT 10 OF 16	
		OFFICE **RCE**	REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
	CALIFORNIA INSTITUTE OF TECHNOLOGY	DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

2.46 *Remove end cap and the internal tube access plug from the beam tube module end. Verify positive air flow exists and verify safe entry is feasible. Complete required checks and records for non permit confined space entry. Verify final beam tube module cleaning per procedure Doc ID "CL3QT."*

****

Note

****

See Doc ID "CL3QT" for specific safety precautions and procedures to be adhered to within the beam tube interior.

****

2.47 *Set-up for fitting and purge for end closure plates and related component installation at forward and aft ends. Align the end closure plates and rough position near final location. Remove pump port temporary positive clean air flow tubing to qualification test high vacuum lab clean room and install qualification test module vacuum lab testing valve.*

2.48 *Purge beam tube module interior with nitrogen gas. Purge until oxygen level is less than 1.0% oxygen. End points 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.

****

Warning

Welding or tack welding at weld joint to be only performed after completion of the above weld purge.

****

2.49 *Verify purge prior to welding. Tack welding is allowed at this step. Final position, fit and tack end closure plates at forward and aft ends and related components.*

2.50 *Complete fit up of weld joints.*

****

Reference

See
Weld Procedure Specification
for Circumferential Welds
Doc ID "WPS-ER308L/Circ"
and
Weld Procedure Specification
for GMA Welding for 304L Materials
Doc ID "WPS-ER308L/GMA"

****

2.51 *Set up and position weld equipment as applicable and complete welding of end closure plates at forward and aft ends and related component weld joints. Perform final visual check of completed welds. Install qualification test supplemental support components on fixed supports.*

2.52 *Set-up for beam tube module testing. Open vacuum lab valve and vent purge gas through vent valve installed in beam tube module end closure plates using positive clean air flow. Close valve and perform installation leak test before final testing.*

****

Reference

See
"Helium Mass Spectrometer/Performance Test
of Beam Tube Module
for LIGO Qualification Test Module Addenda"
Doc ID "HMST4QT"

****

2.53 *Perform helium mass spectrometer test of installed valve and qualification test beam tube module.*

2.54 *Perform documentation review and final visual check before qualification test testing.*

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		IDENTIFICATION **ISQT**			
TITLE	**BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 12 OF 16	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
	CALIFORNIA INSTITUTE OF TECHNOLOGY	DATE **4/21/94**	DATE **4/21/94**	DATE	DATE

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 "EBF1"~~

~~3.2 Initial and Final Alignment During Construction and Installation of Beam Tube Cans Sections Doc ID "ALI1"~~

~~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 "CRNTSM"~~

~~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-R308L/Circ"

3.10 Welding Procedure Specification for GMA Welding for 304L Materials Doc ID "WPS-ER308L/GMA"

3.11 Welding Procedure Specification for Repair Welding of 304L Materials Doc ID "WPS-ER308L/REPAIR"

3.12 Dimensional Control Procedure for LIGO Qualification Test Module Addenda Doc ID "DCQT"

3.13 Installation Alignment and Support Adjustment Procedure for LIGO Qualification Test Doc ID "AQT"

3.14 Maintenance of Partially Completed Beam Tube Can Sections for LIGO Qualification Test Module Addenda Doc ID "CL2QT"

3.15 Final Cleaning and Inspection of Internal Surfaces Including Baffles for LIGO Qualification Test Module Addenda Doc ID "CL3QT"

3.16 Helium Mass Spectrometer Hood Test of Closing Weld Joints Between Beam Tube Cans for LIGO Qualification Test Module Addenda Doc ID "HMST2QT"

3.17 Helium Mass Spectrometer/Performance Test of Beam Tube Module for LIGO Qualification Test Module Addenda Doc ID "HMST4QT"

		IDENTIFICATION ISQT			
TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 13 OF 16	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY	CHKD BY
		DATE 4/21/94	DATE 4/21/94	DATE	DATE

4.0 Sequence Diagram and Sketches

Attached find the following related to this installation sequence:

4.1 Weld Joint Purging/Hood Arrangement. (Page 14 of 16)

4.2 Beam Tube Installation Sequence Logic Diagram (Page 15 of 16 to Page 16 of 16)

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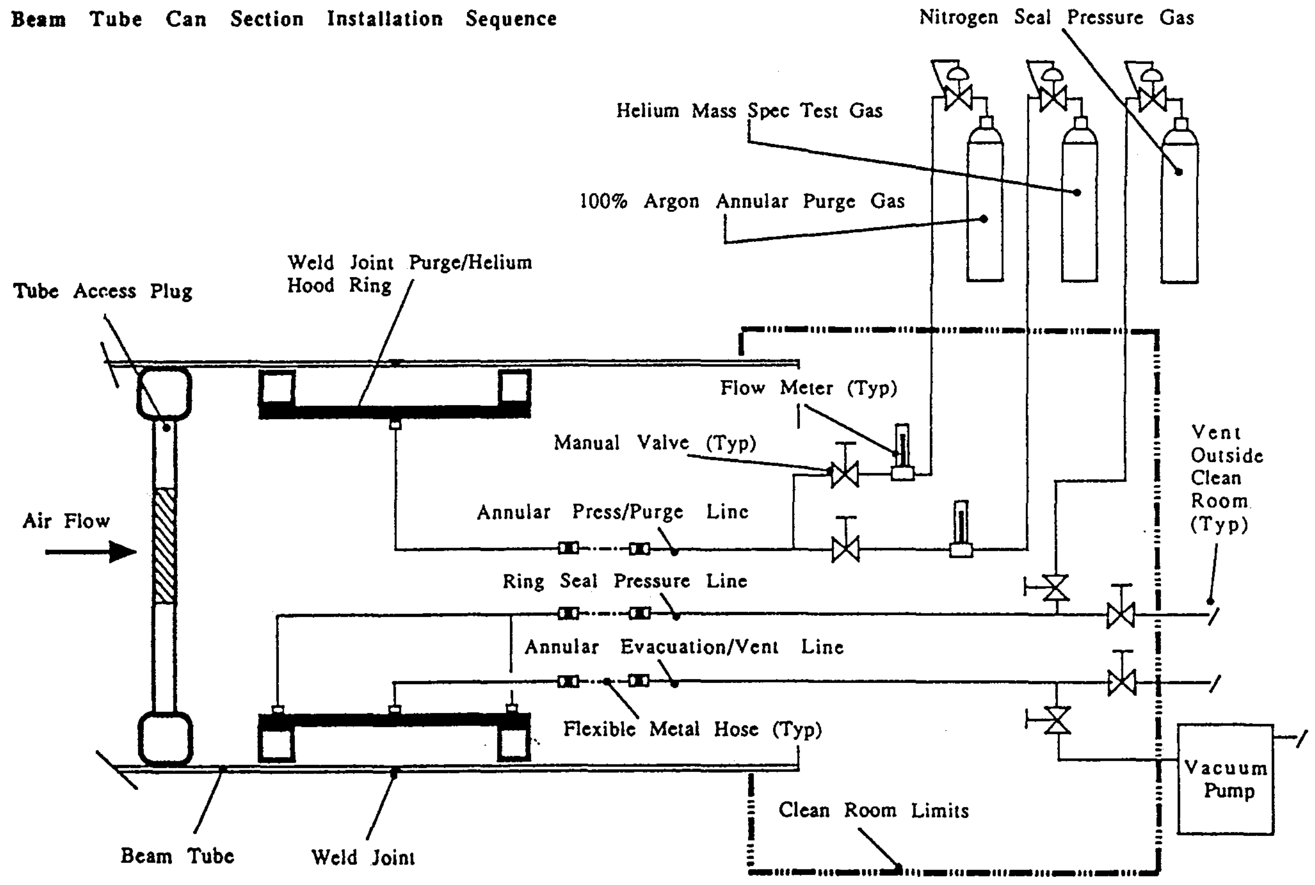
IDENTIFICATION
ISQT

TITLE **BEAM TUBE CAN SECTION**
INSTALLATION SEQUENCE FOR LIGO
QT ADDENDA

PRODUCT **LIGO BEAM TUBE MODULES**
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO.	SHT 14 OF 16		
930212			
OFFICE	REVISION		
RCE	0		
MADE BY	CHKD BY	MADE BY	CHKD BY
WLR	SWP		
DATE	DATE	DATE	DATE
4/21/94	4/21/94		

ATTACHMENT --WELD JOINT PURGING/HOOD ARRANGEMENT



Weld Joint Purging/Helium Hood Arrangement

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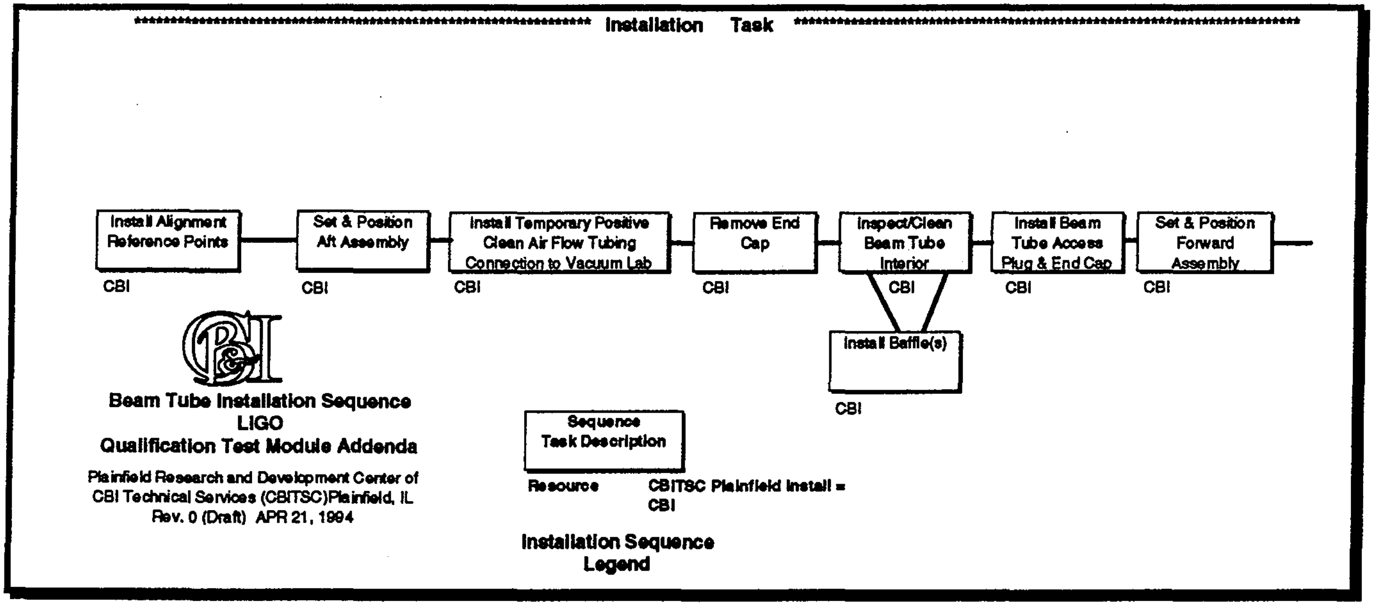
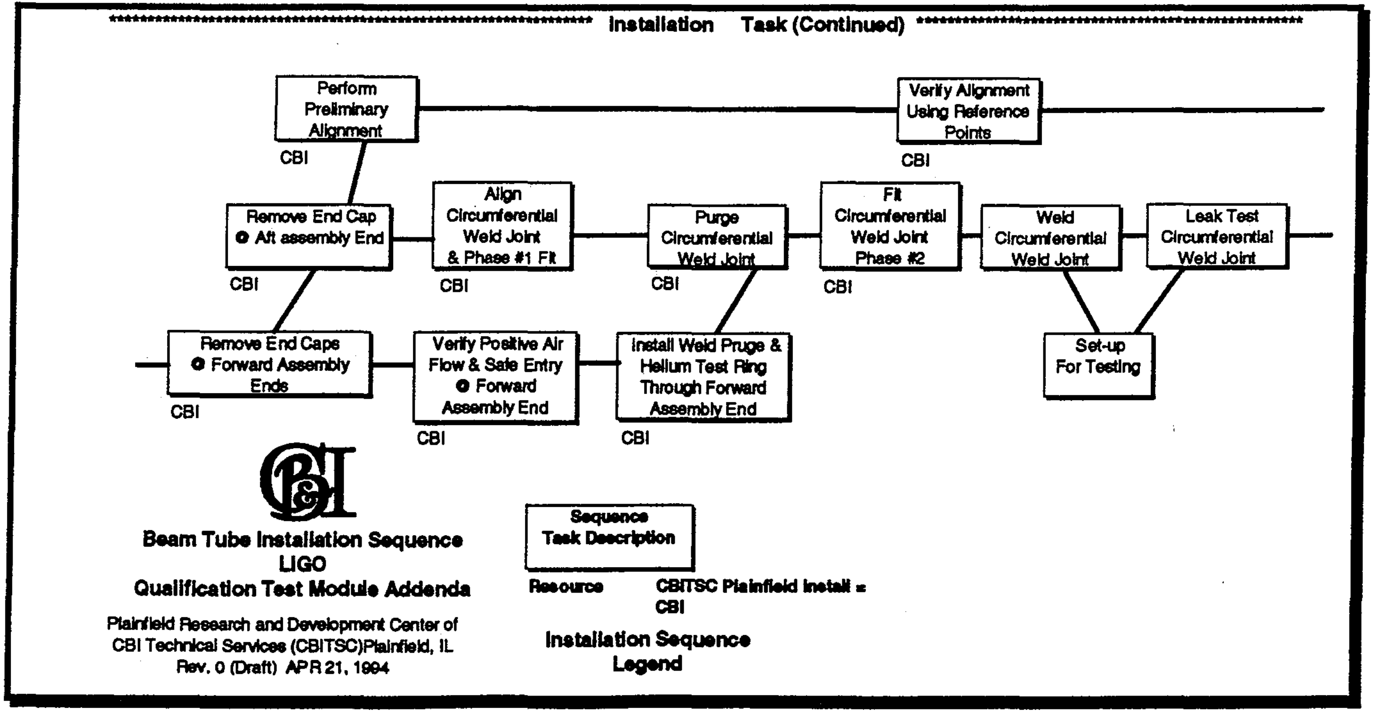
IDENTIFICATION ISQT				
TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212	SHT 15 OF 16	
		OFFICE RCE	REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY
		DATE 4/21/94	DATE 4/21/94	DATE

CHKD BY

DATE

ATTACHMENT -- BEAM TUBE INSTALLATION SEQUENCE LOGIC DIAGRAM QUALIFICATION TEST MODULE ADDENDA





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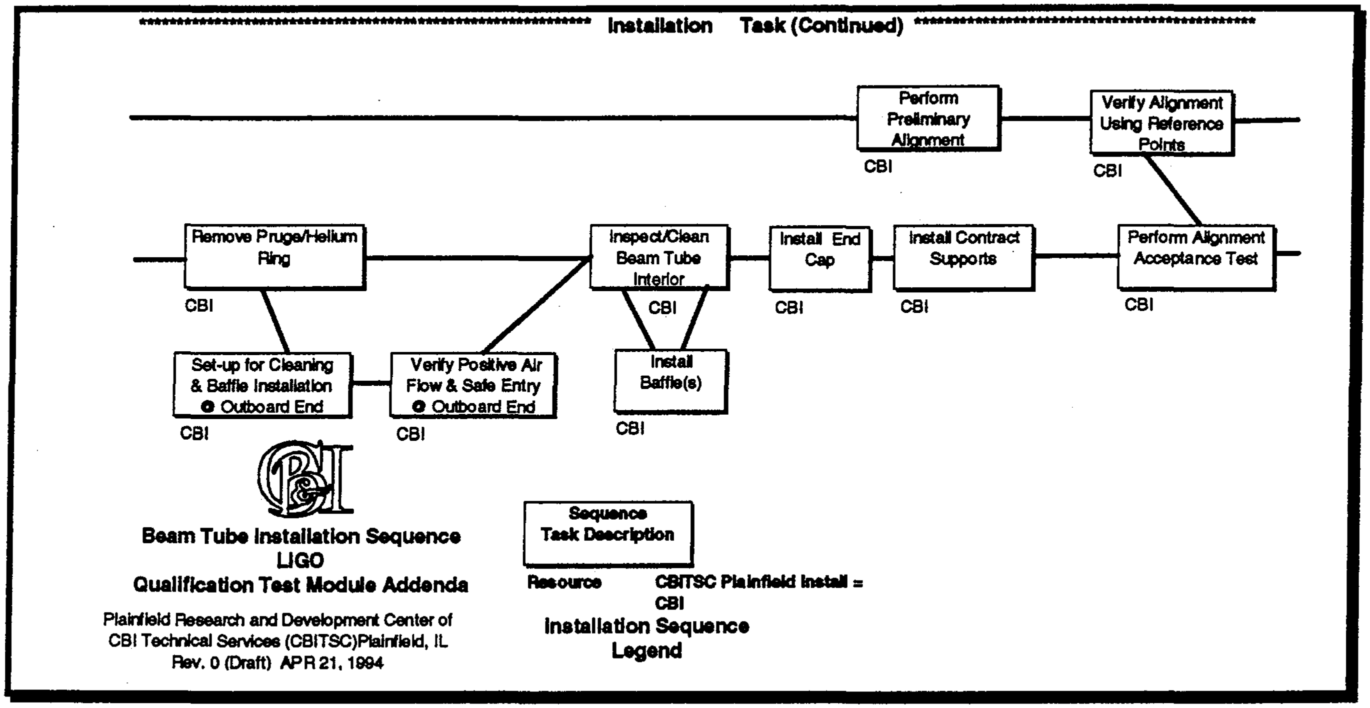
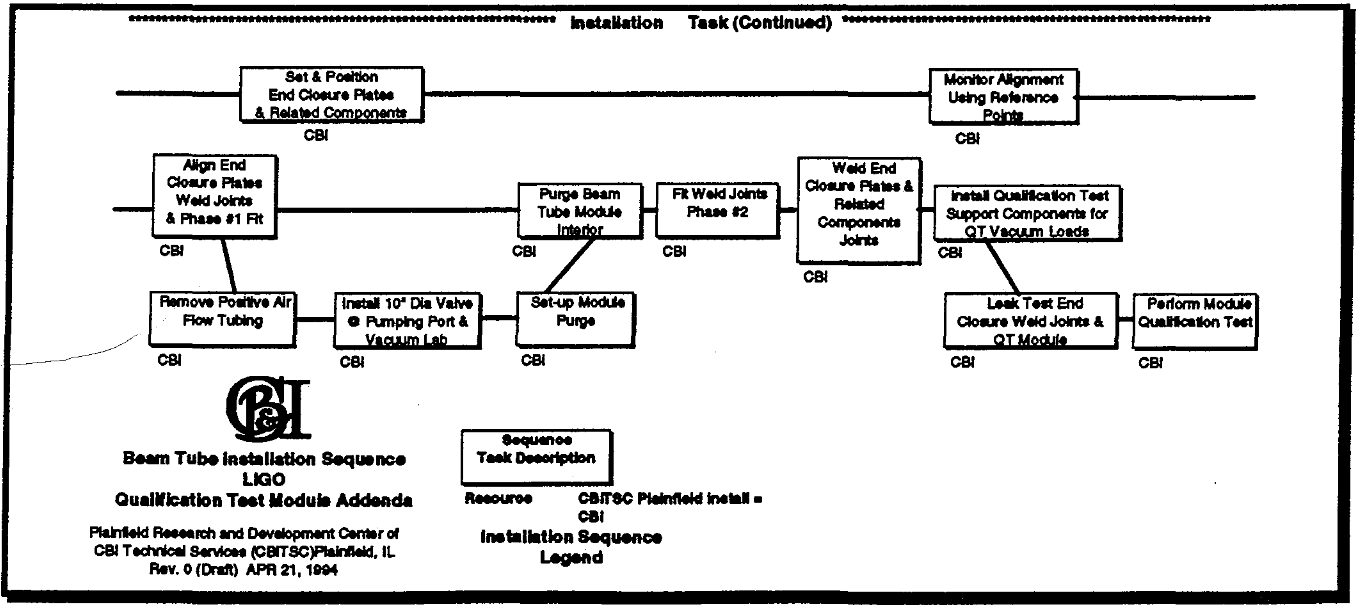
IDENTIFICATION ISQT			
TITLE	BEAM TUBE CAN SECTION INSTALLATION SEQUENCE FOR LIGO QT ADDENDA	REFERENCE NO. 930212	SHT 16 OF 16
		OFFICE RCE	REVISION 0
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP
		DATE 4/21/94	DATE 4/21/94
		MADE BY	CHKD BY
		DATE	DATE

ATTACHMENT – BEAM TUBE INSTALLATION SEQUENCE LOGIC DIAGRAM
QUALIFICATION TEST MODULE ADDENDA





CBI PROPRIETARY

IDENTIFICATION **DCQT**					
TITLE	**DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA**	REFERENCE NO. **930212**		SHT 1 OF 10	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES** **QUALIFICATION TEST** **CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/22/94**	DATE **4/22/94**	DATE	DATE

This procedure addends DC as follows:
Omitted for the Qualification Test - ~~Project Manager~~.
Changed for the Qualification Test - *italics*

Not up to 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.

~~1.2 This procedure is intended to be revised after the Qualification Test data has been reviewed.~~

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 *ASME QCS, Division 3 & 4, Section 9* ~~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 *Welding & QC Supervisor* ~~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.

QT?

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.).

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IDENTIFICATION DCQT				
TITLE	DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA	REFERENCE NO. 930212	SHT 2 OF 10	
		OFFICE RCE	REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY
		DATE 4/22/94	DATE 4/22/94	DATE

CHKD BY	
DATE	

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.).

3.8 Cut Line -- The layout marking that shows the centerline of the circumferential weld joint. The marking is removed during the machining operation that faces the weld edge preparation.

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 *Qualification Test* ~~Option~~ Components -- The following list describes the beam tube component and a brief outline of the dimensional control or measurement method used.

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. Spiral 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.

	CBI PROPRIETARY	IDENTIFICATION DCQT			
TITLE	DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 3 OF 10	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY	CHKD BY
		DATE 4/22/94	DATE 4/22/94	DATE	DATE

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).

J. Qualification Test Module End Closures -- Inspection by supplier, documentation review, receiving inspection with random checks for general dimensions shown on vendor shop drawings.

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 (D_o) within ½ " to 2" from each end and at baffle locations.
   1. End Outside Diameter (D_o) -- D_o *max.* = 49.004"& D_o *min.* = 48.890"
   2. Baffle/Support Outside Diameter (D_o) -- D_o *max.* = 49.004"& D_o *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 the spiral weld joint and 180° from the spiral 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 sag and tension factors taken into consideration.
   1. Tolerance: Ordered Length -- ± ½ "

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TITLE	**DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA**	IDENTIFICATION **DCQT**			
		REFERENCE NO. 930212		SHT 4 OF 10	
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PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/22/94**	DATE **4/22/94**	DATE	DATE

D Measure and record reference deviation (e_R, 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 -- e_R max. = 0.114"

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 (D_o).
   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 (D_i). 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 (e_R, 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 -- e_R 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.

5.3.6 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.

5.3.9 Qualification Test Module End Closures have random measurements verified during receiving inspection with random checks for general dimensions shown on vendor shop drawings.

5.4 Assemblies Fabrication

The Qualification Test Fabricated Assemblies have circumferential weld joints that the Option beam tube can sections do not have. The final length and straightness of the assembly shall be measured after the circumferential weld joint joining the short beam tube can section to the longer beam tube can section has been completed. The finished lengths and straightness are similar to the finished length after installing the expansion joint in the Option. The measurement record and check list shall document the specific lengths for the Qualification Test.

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 (D_o) within ½" to 2" from each end and at baffle and support ring locations.
   1. End -- D_o *max.* = 49.004" & D_o *min.* = 48.890"
   2. Baffle & Support -- D_o *max.* = 49.004" & D_o *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 (e_R) 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 -- e_R max. = 0.114"

CBI PROPRIETARY

TITLE	**DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA**	IDENTIFICATION **DCQT**			
		REFERENCE NO. **930212**		SHT 6 OF 10	
		OFFICE **RCE**		REVISION 0	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **WLR**	CHKD BY **SWP**	MADE BY	CHKD BY
		DATE **4/22/94**	DATE **4/22/94**	DATE	DATE

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"

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. This measurement is used to correct an alignment acceptance test.

   1.Tolerance: over projection -- +0"

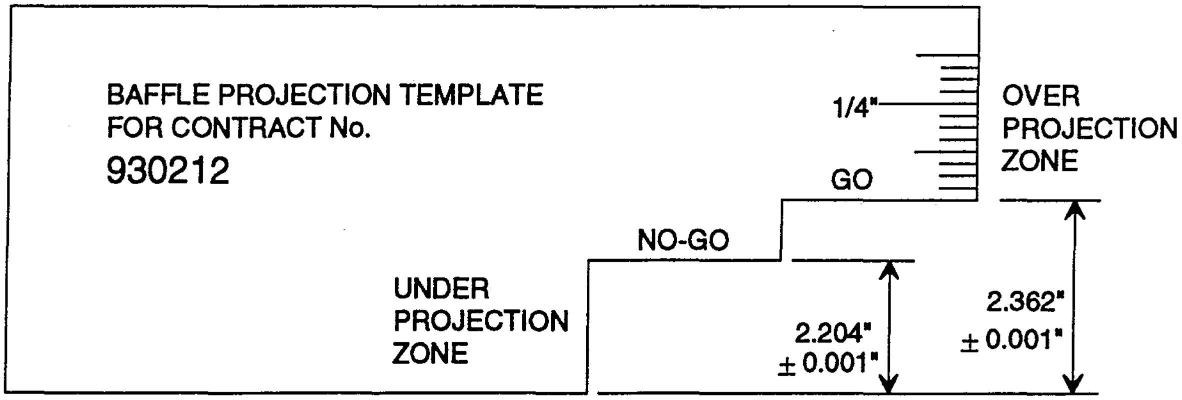


Figure 5.5.1.H

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 (D_o).
   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 (D_i). Take measurements at reference points and calculate the inside diameter.
   1. Inside Diameter (D_i) Tolerance -- ± 0.005"

C. Measure and record deviation (e_R, 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 -- e_R max. = 0.010"

5.4.3 Beam Tube Stiffener Rings have measurements verified during assembly fabrication.

5.5 Construction Installation

The Qualification Test (QT) Installation Module has a circumferential weld joint at the closure ends that the Option beam tube module does not have. The final length of the QT module shall be taken before and after the end closures and related components are welded. The measurement record and check list shall document the specific lengths for the Qualification Test. The alignment acceptance test will be performed before the end closures are installed.

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.

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 baffle end within ½" to 2"
   2. At each side of baffle weld joint within ½" to 2"
   3. At section mid points
1. Tolerance: Over projection -- + 0"

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.

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 *Engineering* 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**

CBI PROPRIETARY

TITLE	DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA	IDENTIFICATION DCQT			
		REFERENCE NO. 930212		SHT 9 OF 10	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY	CHKD BY
		DATE 4/22/94	DATE 4/22/94	DATE	DATE

ATTACHMENT 1

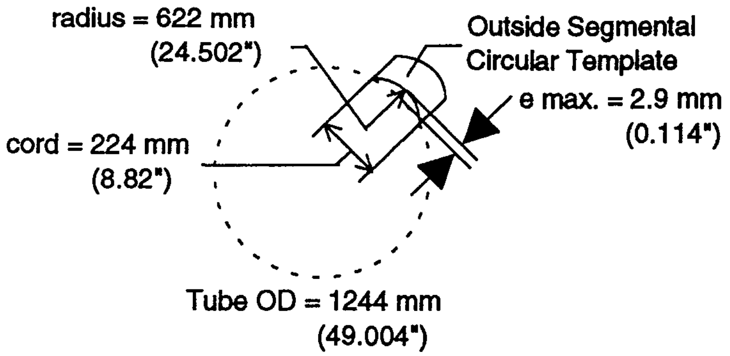
A.1.1 **UG 80 – Permissible Out-of-roundness of Cylindrical Shells**

"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."

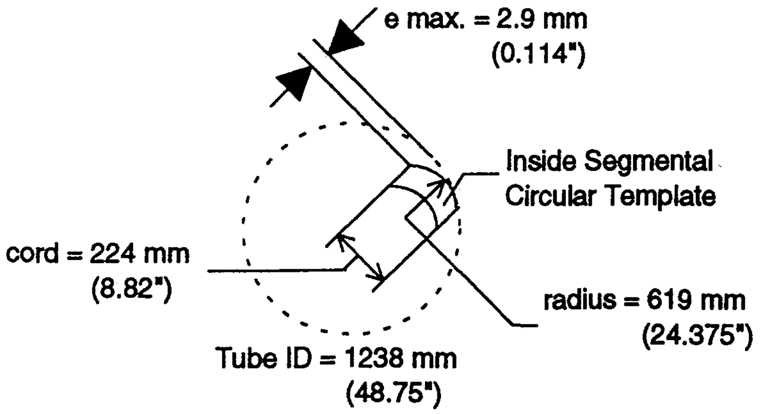
A.1.2 Paragraph UG-80 (b) (1) [Out-of- roundness limitations] -- At any cross section, D max. - D min. = 24.76 mm (0.975") within 1.238 m (48.75") from the center of an opening and 12.38 mm (0.487") at any other location.

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").



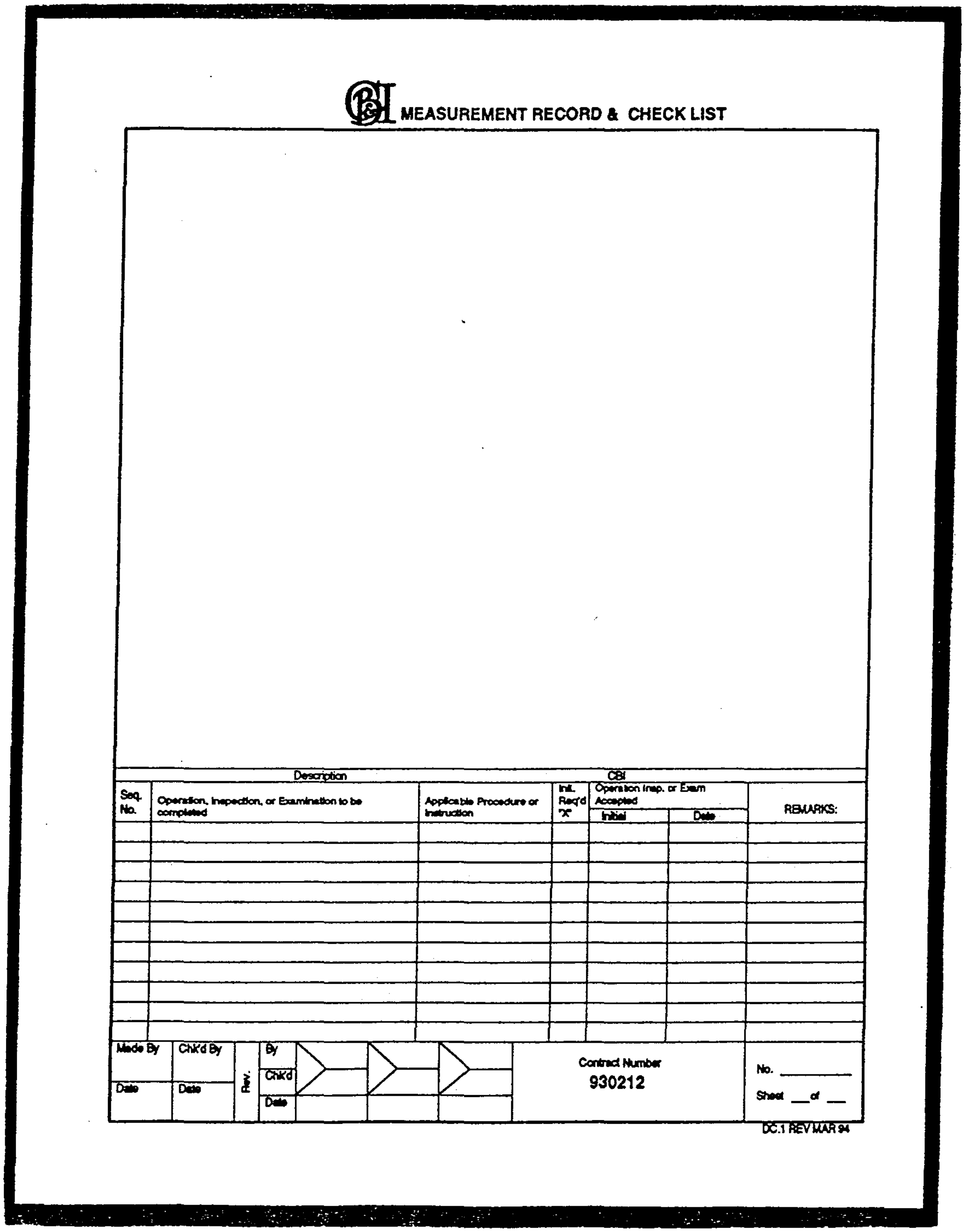
2. Inside segmental circular template dimensions, radius = 619 mm (24.375"), cord length = 224 mm (8.82") & *e* max. = 2.9 mm (0.114")



CBI PROPRIETARY

IDENTIFICATION DCQT					
TITLE	DIMENSIONAL CONTROL PROCEDURE FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 10 OF 10	
		OFFICE RCE		REVISION 0	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY WLR	CHKD BY SWP	MADE BY	CHKD BY
		DATE 4/22/94	DATE 4/22/94	DATE	DATE

ATTACHMENT 2



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		REMARKS:
				Initial	Date	

Made By	Chk'd By	Rev.	By				Contract Number 930212	No. ______
Date	Date		Chk'd				Sheet ___ of ___
			Date				

DC.1 REV MAR 94

CBI PROPRIETARY

IDENTIFICATION LIGOCPQT					
TITLE	PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 1 OF 2	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/8/94	DATE 4/19/94	DATE	DATE

This procedure addends LIGOCP as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

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 ***CL2QT*** 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 ***Softened*** 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.

CBI PROPRIETARY

IDENTIFICATION
LIGOCPQT

TITLE	**PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO QUALIFICATION TEST ADDENDA**	REFERENCE NO. **930212**		SHT 2 OF 2	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
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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 <u>DOCUMENTATION</u>:

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 ***CL1QT*** for each beam tube can section.

5.2.2 Satisfactory cleaning maintenance during construction per procedure ***CL2QT*** 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.

CBI PROPRIETARY

IDENTIFICATION **CL1QT**			
REFERENCE NO. **930212**		SHT 1 OF 4	
OFFICE RCE		REVISION 1	
MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
DATE 4/19/94	DATE 4/19/94	DATE	DATE

TITLE **CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES**
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

> This procedure addends CL1N as follows:
> Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
> Changed for the Qualification Test - ***Bold italics***

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 ***LIGOCPQT***.

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 ***LIGOCPQT***.

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 apparatus with adjustable tensioning legs for each can section cleaning station.~~

3.4 One manual tugger with cable for each cleaning station for pulling the jet cleaning apparatus through the can sections.

3.5 One jet steam cleaning apparatus. See Sketch SK-01.

~~3.6 Propane gas or natural gas for firing the steam cleaner.~~

~~3.7 A minimum of two high volume air movers at each cleaning station.~~

3.8 No Smoking and Flammable Gas signs.

3.9 Plastic covers for sealing the ends of each can section after satisfactory final cleaning and drying.

CBI PROPRIETARY

TITLE
CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA
PRODUCT
LIGO BEAM TUBE MODULES QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

IDENTIFICATION CL1QT			
REFERENCE NO. 930212		SHT 2 OF 4	
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DATE 4/19/94	DATE 4/19/94	DATE	DATE

3.10 Two inch (2") wide duct tape.

3.11 Four thermocouples used for recording temperatures of the beam tube during the steam cleaning process.

4.0 <u>GENERAL PROCEDURE</u>:

See the cleaning set-up at the end of the procedure for a conceptual sketch (SK-02) 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 Fasten the thermocouples to the beam tube at 180° apart, and approximately at the starting and center of the can section to be steam cleaned.

5.0 BLACKLIGHT INSPECTION AND SOLVENT CLEANING PROCEDURE:

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.

5.2 Put on white nylon coveralls, white shoe covers, white head cover and white gloves before entering the can section to be cleaned.

5.3 Starting at the end of the can section, 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.

5.4 Document completion of the initial spot cleaning of each can section by entry in the cleaning log book.

6.0 STEAM CLEANING PROCEDURE:

~~6.1 Connect the CBI cleaning skid to a source of potable tap water (soften as necessary) (See 4.1 of procedure LIGOCP).~~

6.2 At the low end of the can section to be final cleaned, install a receiving tank with a valved connection.

CBI PROPRIETARY

IDENTIFICATION
CL1QT

TITLE	CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 3 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

6.3 To the valve on the receiving tank, install a drain hose to the sanitary sewer.

6.4 Turn on the steam cleaner. When the steam cleaner reaches the operating temperature of (110°C-230°F) and the operating pressure of 50 psi, proceed to step 6.5.

6.5 Connect a clean steam hose from the steam cleaner to the jet cleaning apparatus.

6.6 Place the jet cleaning apparatus at the high end of the can section to be cleaned. Adjust the jet cleaning apparatus so that it is centered in the can.

6.7 Connect the cable from the manual tugger to the end of the jet cleaning apparatus.

6.8 When the jet cleaning head on the apparatus starts to rotate at a speed of 1 rps with a flat spray pattern of 6 inches, pull the manual tugger to start the jet cleaning apparatus 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 hose as the jet cleaning apparatus proceeds toward the low end. Monitor the temperature readings of the thermocouples and record them in the laboratory notebook.

6.9 When the jet cleaning apparatus reaches the low end of the can section, disconnect the jet cleaning apparatus from the manual tugger.

6.10 Vacuum all standing condensed steam from the expansion joint convolutions. Wipe the convolutions 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.

6.11 If an internal visual inspection of the can section indicates the cleaning is not adequate, repeat steps 6.8 through 6.10 as necessary until the internal visual inspection indicates the cleaning is adequate.

6.12 When the internal visual inspection of the can section indicates that the cleaning is adequate, proceed to step 6.13.

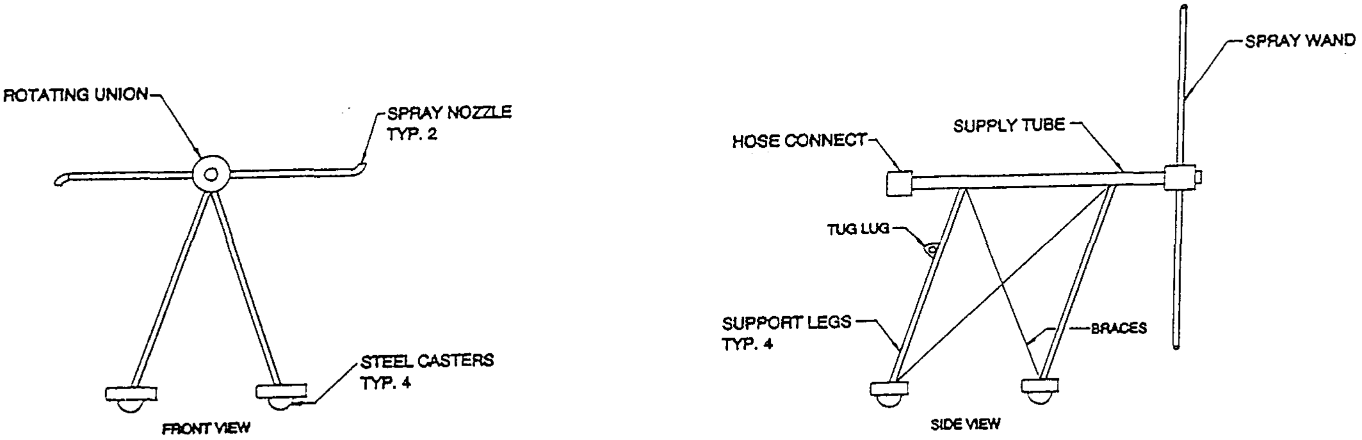
6.13 As soon as the can section has air dried, install plastic covers over the ends and seal the covers to the outside of the can with duct tape to keep out all dirt and other contaminates. The helium mass spectrometer leak test can now be performed on the can section.

7.0 DOCUMENTATION:

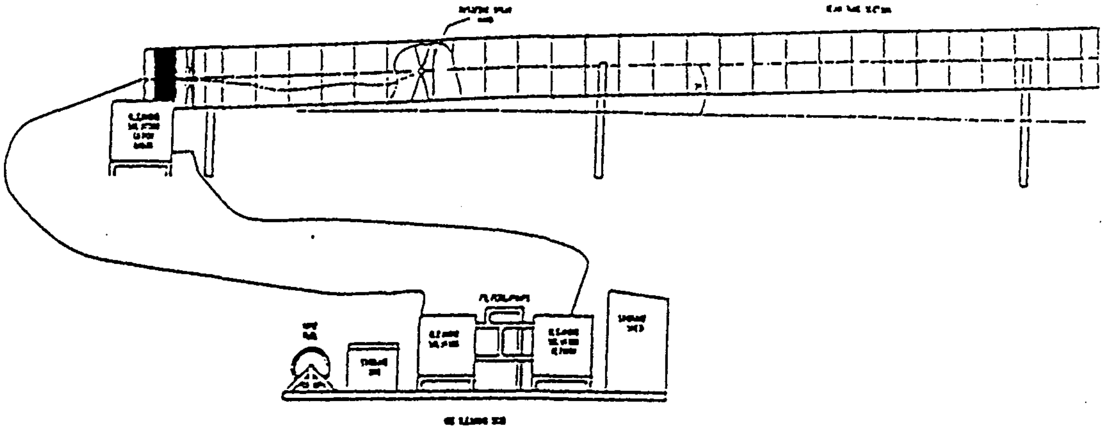
Document as outlined in 5.0 of procedure ***LIGOCPQT*** the satisfactory completion of both the preliminary solvent cleaning and the final steam cleaning operations.

CBI PROPRIETARY

TITLE	**CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA**	IDENTIFICATION **CL1QT**			
		REFERENCE NO. **930212**		SHT 4 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE



SK-01



SK-02

CBI PROPRIETARY

TITLE **CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES QUALIFICATION TEST**
CALIFORNIA INSTITUTE OF TECHNOLOGY

IDENTIFICATION **CL2QT**			
REFERENCE NO. **930212**		SHT 1 OF 3	
OFFICE RCE		REVISION 1	
MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
DATE 4/19/94	DATE 4/19/94	DATE	DATE

This procedure addends CL2N as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

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 ***LIGOCPQT***.

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 The vacuum clean room shall continually maintain a positive flow of clean dry air through the port pump end of the beam tube module to ensure that no contaminants enter the beam tube module during installation.

~~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.~~

CBI PROPRIETARY

IDENTIFICATION CL2QT			
REFERENCE NO. 930212		SHT 2 OF 3	
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DATE 4/19/94	DATE 4/19/94	DATE	DATE

TITLE CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA

PRODUCT LIGO BEAM TUBE MODULES
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

~~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:

This procedure has been adapted for the qualification test procedures.

4.1 As soon as the beam tube can section is placed in the vacuum room, do not remove the plastic cleaning cover on the outboard end of the 6 inch pump port.

~~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 Install the next beam tube can section to the pump port's outboard end of the beam tube module.

CBI PROPRIETARY

		IDENTIFICATION CL2QT			
TITLE	CLEANING OF COMPLETED BEAM TUBE CAN SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QT ADDENDA	REFERENCE NO. 930212		SHT 3 OF 3	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

~~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 Move the second can section within 6" to 8" from the outboard end of the first beam tube can section for fit-up of the weld. Remove both the plastic covers for fit-up of the weld and cut slits in the plastic cleaning cover of the second cans outboard's end to allow the vacuum room filtered air to pass through the second beam tube can section.

4.7 Weld the joint formed by the two beam tubes can sections.

4.8 After the weld joint is welded complete, move the fit-up and welding equipment down to the outboard end of the can section.

4.9 Move the helium mass spectrometer and leak test equipment into position over the welded joint. Perform the helium mass spectrometer leak test.

4.10 After successful completion of the helium mass spectrometer leak test, locally clean the inside of the completed 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 are being performed on the welded joint, move the next can section to be installed in line.

4.12 Repeat steps 4.6 through 4.11 for each of the can sections as they are installed.

5.0 <u>DOCUMENTATION</u>:

Document the completion of all events associated with this procedure in accordance with 5.0 of procedure ***LIGOCPQT***.

CBI PROPRIETARY

IDENTIFICATION **CL3QT**			
REFERENCE NO. **930212**		SHT 1 OF 5	
OFFICE RCE		REVISION 1	
MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
DATE 4/19/94	DATE 4/19/94	DATE	DATE

TITLE **FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES QUALIFICATION TEST**
CALIFORNIA INSTITUTE OF TECHNOLOGY

This procedure addends CL3N as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

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 ***CRWAQT***.

~~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: ***LIGOCPQT***; "PLANNED APPROACH FOR CLEANING AND CLEANING MAINTENANCE FOR LIGO QUALIFICATION TEST ADDENDA".

3.4 CBI Cleaning Procedure CL1QT; "CLEANING OF COMPLETED BEAM TUBE SECTIONS BEFORE AND AFTER LEAK TESTING AND FINAL ASSEMBLY FOR LIGO QUALIFICATION TEST MODULE ADDENDA".

3.5 CBI Cleaning Procedure CL2QT; "MAINTENANCE OF PARTIALLY COMPLETED BEAM CAN SECTIONS FOR LIGO QUALIFICATION TEST MODULE ADDENDA".

CBI PROPRIETARY

		IDENTIFICATION **CL3QT**			
TITLE	**FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA**	REFERENCE NO. 930212		SHT 2 OF 5	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

3.6 CBI Procedure BI1N, "BLACKLIGHT INSPECTION TECHNIQUE AND SOLVENT CLEANING PROCEDURE".

~~3.7 CBI Procedure LIGOCR1; "CLEAN ROOM TRANSPORTING, STORAGE AND MAINTENANCE."~~

3.8 CBI Procedure CRWAQT; "CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST MODULE ADDENDA".

4.0 EQUIPMENT:

4.1 See CBI Procedure CRWAQT for complete listing or wearing apparel for Beam Tube 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

CBI PROPRIETARY

TITLE	**FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA**	IDENTIFICATION **CL3QT**			
		REFERENCE NO. **930212**		SHT 3 OF 5	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

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, page 4.

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, page 5.

6.4 These records will be turned in to the QC Manager at the end of the workday. The final inspection turnover documents shall include these reports.

CBI PROPRIETARY

IDENTIFICATION CL3QT			
REFERENCE NO. 930212		SHT 4 OF 5	
OFFICE RCE		REVISION 1	
MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
DATE 4/19/94	DATE 4/19/94	DATE	DATE

TITLE FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA

PRODUCT LIGO BEAM TUBE MODULES QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

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				
Line 14				
Line 15				
Line 16				
Line 17				
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Line 28				
Line 29				
Line 30				
Line 31				
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 _____

Printed in USA

GO 1688 FEB 91

CBI PROPRIETARY

IDENTIFICATION CL3QT				
TITLE	FINAL CLEANING AND INSPECTION OF LIGO BEAM TUBE INNER SURFACES INCLUDING BAFFLES FOR LIGO QUALIFICATION TEST MODULE ADDENDA	REFERENCE NO. 930212	SHT 5 OF 5	
		OFFICE RCE	REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

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:

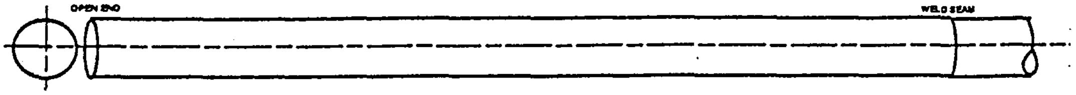
INSPECTION OF BEAM TUBE AS NOTED ABOVE HAS BEEN FOUND TO BE CLEAN AND ALL EQUIPMENT AND MATERIALS REMOVED. INITIALS

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

CBI PROPRIETARY

TITLE	CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION CRWAQT			
		REFERENCE NO. 930212		SHT 1 OF 6	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

This procedure addends CRWA-1 as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

1.0 SCOPE:

This procedure covers protective wearing apparel for Beam Tube Access. All personnel entering the Beam Tube shall be properly clothed.

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 required 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.

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 cleaning 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 LIGO. Project.

3.3 CBI Cleaning Procedures.

4.0 EQUIPMENT & MATERIALS:

The following is a listing of Safety Equipment and Wearing Apparel required for final access into the Beam Tube.

~~4.1 CBI Hard Hat Meeting CBI Safety Standards.~~

~~4.2 Disposable Hard Hat Protective Cover.~~

CBI PROPRIETARY

TITLE	**CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA**	IDENTIFICATION **CRWAQT**			
		REFERENCE NO. **930212**		SHT 2 OF 6	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

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 permanently sewn closed. Zipper front and elastic, cinch, 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 PROPRIETARY

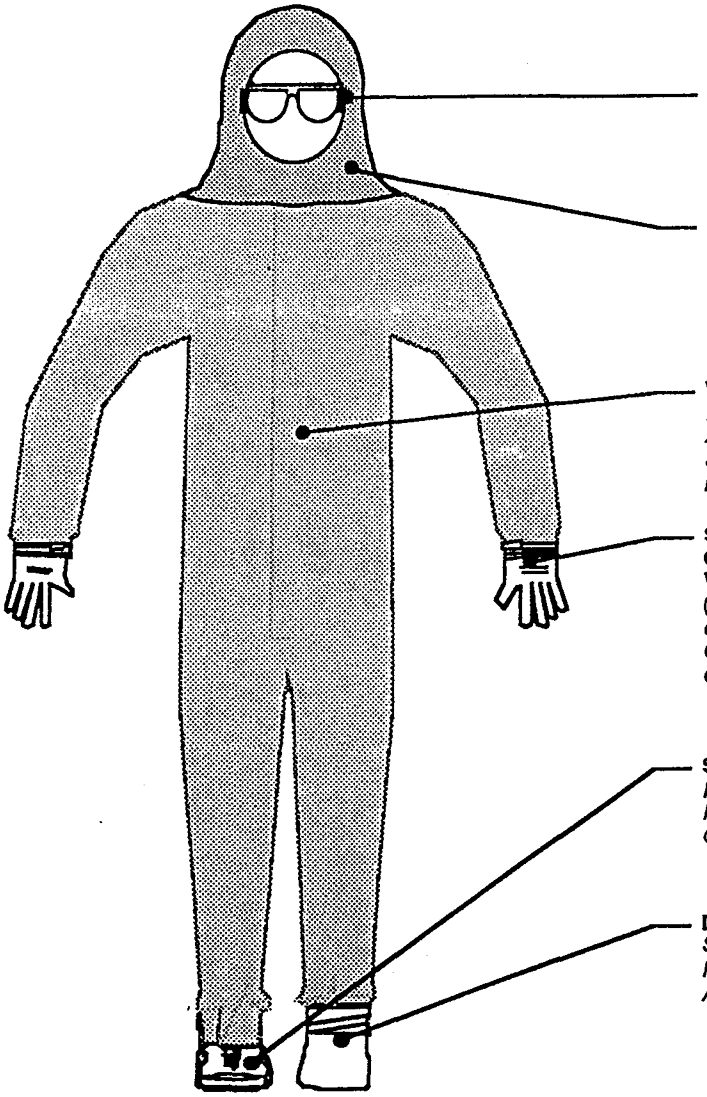
IDENTIFICATION
CRWAQT

TITLE CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA

PRODUCT LIGO BEAM TUBE MODULES
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO.		SHT 3 OF 6	
930212			
OFFICE		REVISION	
RCE		1	
MADE BY	CHKD BY	MADE BY	CHKD BY
MJG	PM		
DATE	DATE	DATE	DATE
4/19/94	4/19/94		

FIGURE 4.1



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

CBI PROPRIETARY

		IDENTIFICATION CRWAQT			
TITLE	CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 4 OF 6	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

5.0 APPAREL INSTRUCTIONS REQUIRED FOR BEAM TUBE ACCESS

Beam Tube Access instructions are described in procedure CL3QT. The following is a detailed set of instructions for wearing clean compatible 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 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, repair 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 disposal.

~~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 Flammable 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 CBI Safety requirements.~~

CBI PROPRIETARY

TITLE	CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION CRWAQT				
		REFERENCE NO. 930212		SHT 5 OF 6	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY MJG	CHKD BY PM	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

6.0 INSTRUCTIONS REQUIRED FOR VACUUM ROOM EXIT

The following is a detailed set of instructions for the removing, storing and cleaning of Beam Tube Access compatible 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 flammable waste container. Clean and dry gloves shall be stored in the Flammable Materials Cabinet for re-use.~~

6.2 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 stockinged 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.

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 "through 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.~~

CBI PROPRIETARY

IDENTIFICATION
CRWAQT

TITLE	**CLEAN ROOM WEARING APPAREL FOR BEAM TUBE ACCESS FOR LIGO QUALIFICATION TEST ADDENDA**	REFERENCE NO. **930212**		SHT 6 OF 6	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **MJG**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 4/19/94	DATE 4/19/94	DATE	DATE

~~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.,).~~

CBI PROPRIETARY

IDENTIFICATION LIGOTPQT			
REFERENCE NO. 930212		SHT 1 OF 4	
OFFICE RCE		REVISION 1	
MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
DATE 4/5/94	DATE 4/19/94	DATE	DATE

TITLE **PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES**
QUALIFICATION TEST
CALIFORNIA INSTITUTE OF TECHNOLOGY

This procedure addends LIGOTP as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

1.0 SCOPE:

This planned approach to leak testing LIGO (in chronological 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 ***HMST1QT***.

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 ***HMST2QT***.

~~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/performance test of each beam tube module in accordance with the current approved revision of procedure ***HMST4QT***.

~~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 Analysis" 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 PROPRIETARY

		IDENTIFICATION LIGOTPQT			
TITLE	PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 2 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 4/5/94	DATE 4/19/94	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 auxiliary 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, vacuum gauges, helium mass spectrometers (see item 4.1).

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

4.9 Clean lint free cloths or paper towels.

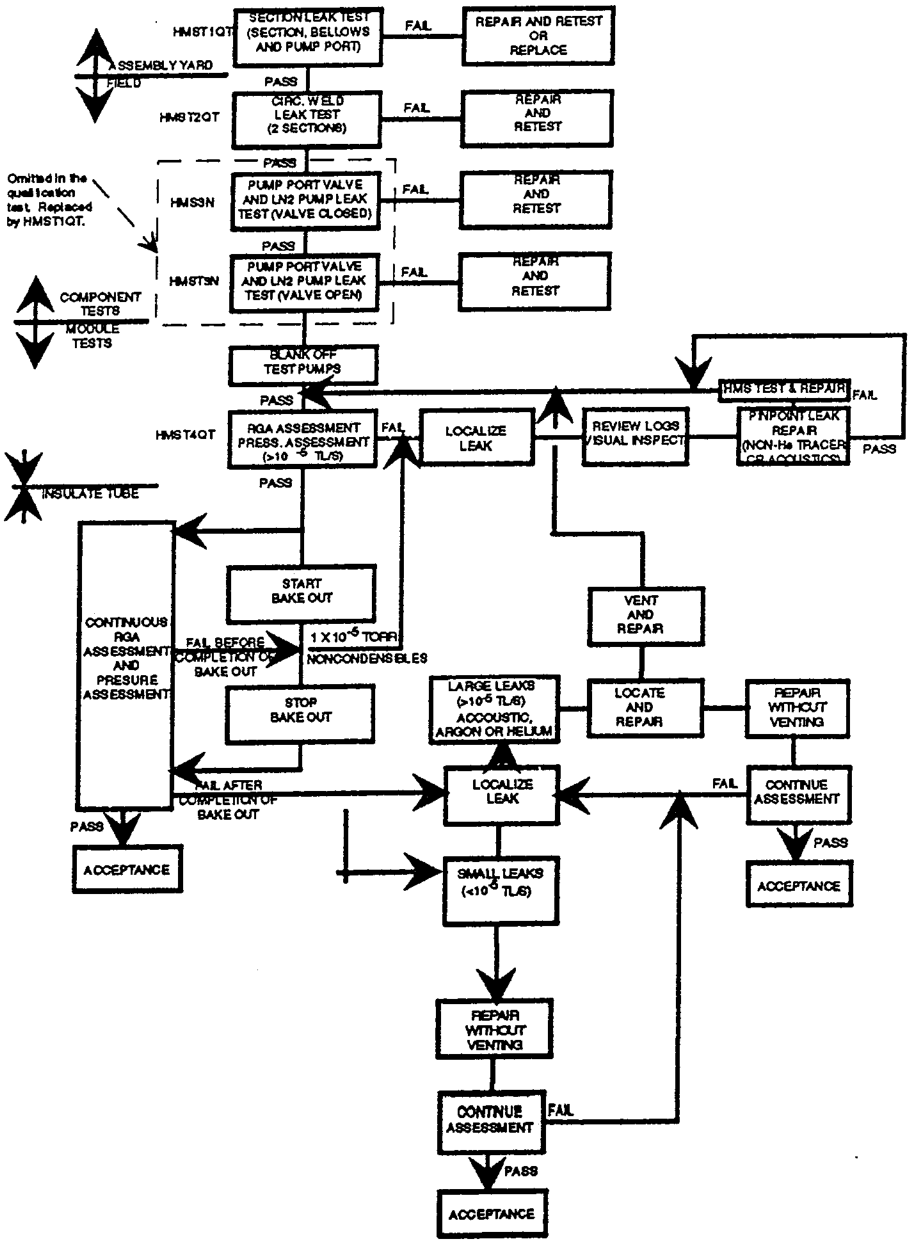
CBI PROPRIETARY

TITLE	PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION LIGOTPQT			
		REFERENCE NO. 930212		SHT 3 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 4/5/94	DATE 4/19/94	DATE	DATE

5.0 DECISION TREE:

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

LEAK DETECTION DECISION TREE
QUALIFICATION TEST



CBI PROPRIETARY

		IDENTIFICATION LIGOTPQT			
TITLE	PLANNED APPROACH TO LEAK TESTING FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 4 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 4/5/94	DATE 4/19/94	DATE	DATE

6.0 DOCUMENTATION:

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

6.2 Maintain a ***construction record for the QT*** beam tube module and make entries of all noteworthy 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 entries 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 of each helium spectrometer instrument.*** Make entries in each of these logs for all:

6.5.1 Maintenance 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.

CBI PROPRIETARY

IDENTIFICATION HMST1QT					
TITLE HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 1 OF 7		
	OFFICE RCE		REVISION 1		
PRODUCT LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY	
	DATE 3-15-94	DATE 4/19/94	DATE	DATE	

This procedure addends HMST1N as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

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 ***LIGOTPQT.***

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 satis-factorily 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 x 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 The hood test enclosure will be replicated by fabricating an enclosure from sheet polyethylene and duct tape bag:

2.2.1 Venting will be accomplished by a hose and exhaust fan.

2.2.2 The hood (plastic bag) will be exhausted by attaching a hose to centrifical exhaust system.

CBI PROPRIETARY

IDENTIFICATION HMST1QT					
TITLE	HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 2 OF 7	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

~~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 This portion of the procedure will not be done since there is not an outer full-vacuum container. Location of leakage will be done either by painting the surface of the tube with a fine spray of helium or by isolating successive areas with plastic sheets, duct tape, and injection of helium into these areas.

~~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:~~

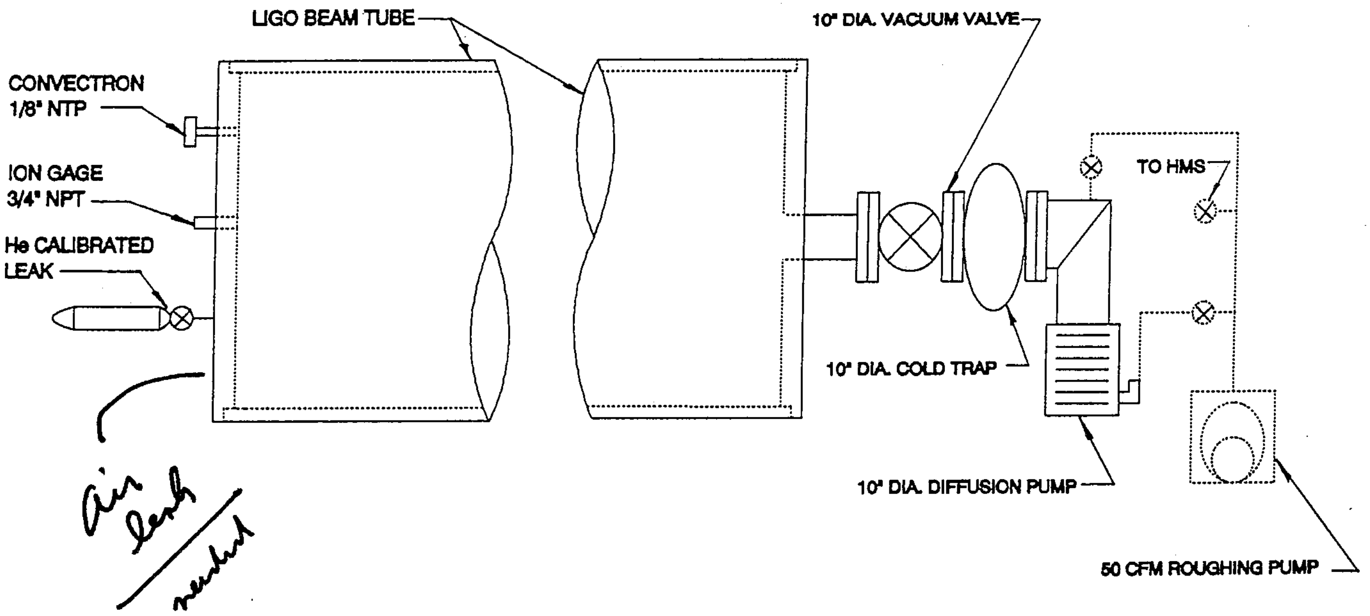
~~2.3.4 Three inch (3"Ø) valved nozzle to which is connected a mechanical vacuum pump unit such as a Leybold WAU501 Roots booster backed by a D65B rotary vane pump or unit of comparable or greater capacity. The pump unit connection line shall contain a valved 40 mm (1 1/2"Ø) crossover line to a diffusion 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.~~

CBI PROPRIETARY

TITLE	HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION HMST1QT			
		REFERENCE NO. 930212		SHT 3 OF 7	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

2.4 See the illustration below describing the beam tube and test apparatus.



air leak needed

~~2.4.1 A 160 K (6") ∅ nozzle with a 6"∅ 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"∅ cold trap at the inlet of the booster. The pump unit connection line shall contain a valved 100 mm (4"∅) crossover line to a diffusion pump foreline. It shall also contain a tee with a 40 KF (1 1/2" ∅) long flange valved for connecting the helium mass spectrometer.~~

~~2.4.2 A 500 K (20"∅) flanged port with a 20"∅ ASA flanged vacuum valve to which is mounted a flanged 20"∅ Balzer Model DIF 500A or equiva-lent diffusion pump. The 100 K (4"∅) 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"∅) 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"∅) 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.~~

CBI PROPRIETARY

IDENTIFICATION **HMST1QT**				
TITLE	**HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA**	REFERENCE NO. **930212**	SHT 4 OF 7	
		OFFICE RCE	REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **EEB** / CHKD BY **MJG**	MADE BY / CHKD BY	
		DATE 3-15-94 / DATE 4/19/94	DATE / DATE	

~~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"Ø) 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)Ø 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)Ø 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.

3.2 Engage the end-seal assembly at each of the beam tube can section. Seal these assemblies with electrical tape or vacuum putty.

CBI PROPRIETARY

IDENTIFICATION
HMST1QT

TITLE	HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212		SHT 5 OF 7	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

3.3 ***Energize the roughing pump and evacuate the can sections. Also evacuate the diffusion pump and foreline. When the absolute pressure in the beam tube can section reads about 1000 millitorr, begin cooling the LN2 cold trap.***

~~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 400 millitorr, energize the diffusion pump.***

3.6 ***When the absolute pressure in the can section reads 50 to 75 millitorr, close the roughing pump valve and open the 10"Ø diffusion pump valve.***

~~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 helium mass spectrometer instrument into operation and calibrate (peak tune) the instrument to ensure that it meets the instrument to ensure that it needs the optimum 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 ***10"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.

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TITLE	HELIUM MASS SPECTROMETER HOOD TEST OF BEAM TUBE CAN SECTIONS FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION HMST1QT			
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		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY MJG	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

~~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 x 10^{-5} atm. cc/sec., open the test enclosure and pinpoint the location of the leak or leaks by the conventional helium probe technique.

~~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 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.

10^{-11} goal 10^{-10} req'd

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 x 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 x 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.

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 bag 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 x 10^{-10} atm. cc/sec. or larger or required total helium leakage rate of 1 x 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 x 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.

4.0 DOCUMENTATION

See procedure ***LIGOTPQT*** for documentation requirements.

CBI PROPRIETARY

IDENTIFICATION **HMST2QT**				
REFERENCE NO. **930212**		SHT 1 OF 4		
OFFICE RCE		REVISION 1		
MADE BY **EEB**	CHKD BY **PM**	MADE BY	CHKD BY	
DATE 3-15-94	DATE 4/19/94	DATE	DATE	

TITLE **HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS FOR LIGO QUALIFICATION TEST ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES QUALIFICATION TEST**
CALIFORNIA INSTITUTE OF TECHNOLOGY

This procedure addends HMST2N as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

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 ***LIGOTPQT***.

2.1 The helium mass spectrometers used to perform the leak testing outlined in this procedure shall be the Alcatel Model ASM 110TCL, Leybold Model UL400, Veeco Model 18AB or equivalent with an optimum high sensitivity in the range of 10^{-11} atm. cc/sec. of helium.

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 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.

CBI PROPRIETARY

TITLE	HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS FOR LIGO QUALIFICATION TEST ADDENDA	IDENTIFICATION HMST2QT			
		REFERENCE NO. 930212		SHT 2 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	MADE BY EEB	CHKD BY PM	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

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 insigni-ficant, 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.

CBI PROPRIETARY

TITLE	**HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS FOR LIGO QUALIFICATION TEST ADDENDA**
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**

IDENTIFICATION **HMST2QT**			
REFERENCE NO. **930212**		SHT 3 OF 4	
OFFICE RCE		REVISION 1	
MADE BY **EEB**	CHKD BY **PM**	MADE BY	CHKD BY
DATE 3-15-94	DATE 4/19/94	DATE	DATE

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 1×10^{-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.

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TITLE	**HELIUM MASS SPECTROMETER HOOD TEST OF CLOSING WELD JOINTS BETWEEN BEAM TUBE CANS FOR LIGO QUALIFICATION TEST ADDENDA**	IDENTIFICATION **HMST2QT**			
		REFERENCE NO. **930212**		SHT 4 OF 4	
		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **EEB**	CHKD BY **PM**	MADE BY	CHKD BY
		DATE 3-15-94	DATE 4/19/94	DATE	DATE

3.21 Repeat steps 3.3 through 3.19 for the remaining 170° segment of the closing weld joint.

4.0 DOCUMENTATION:

See procedure ***LIGOTPQT*** for documentation requirements.

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IDENTIFICATION
HMST4QT

TITLE	HELIUM MASS SPECTROMETER/ PERFORMANCE TEST OF BEAM TUBE MODULES FOR LIGO QUALIFICATION TEST ADDENDA	REFERENCE NO. 930212	SHT 1 OF 5	
PRODUCT	LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY	OFFICE RCE	REVISION 1	
		MADE BY EEB	CHKD BY PM	MADE BY
		DATE 3-15-94	DATE 4/19/94	DATE

This procedure addends HMST4N as follows:
Omitted for the Qualification Test - ~~3.3 Steam cleaner skid with circulation pumps,.....~~
Changed for the Qualification Test - ***Bold italics***

1.0 SCOPE:

1.1 This procedure covers the helium mass spectrometer/leak test of the qualification test tube module. Use this procedure in conjunction with the current revision of procedure LIGOTP-QT.

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 the qualification test module have been successfully HMS leak tested in accordance with procedure HMST1QT, final cleaned and installed.

1.2.2 All closing weld joints except the outboard end closure head 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"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 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 qualification test vacuum pump set 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"Ø) fittings for connecting the helium mass spectrometer to the test system.

2.3 The LN$_2$ panel will be supplied by CBI for this test.

2.4 CBI RGA will be used.

2.5 CBI turbo - molecular pump will be used in lieu of Caltech supplied equipment.

CBI PROPRIETARY

IDENTIFICATION
HMST4QT

TITLE **HELIUM MASS SPECTROMETER/ PERFORMANCE TEST OF BEAM TUBE MODULES FOR LIGO QUALIFICATION TEST ADDENDA**

PRODUCT **LIGO BEAM TUBE MODULES QUALIFICATION TEST**
CALIFORNIA INSTITUTE OF TECHNOLOGY

REFERENCE NO.		SHT	OF
930212		2	5
OFFICE		REVISION	
RCE		1	
MADE BY	CHKD BY	MADE BY	CHKD BY
EEB	PM		
DATE	DATE	DATE	DATE
3-15-94	4/19/94		

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 mechanical vacuum pump and turbomolecular pump sets. 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. Continue to plot absolute pressure versus time on semi-log paper during the entire pump down and test.

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.

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IDENTIFICATION **HMST4QT**			
TITLE	**HELIUM MASS SPECTROMETER/ PERFORMANCE TEST OF BEAM TUBE MODULES FOR LIGO QUALIFICATION TEST ADDENDA**	REFERENCE NO. **930212**	SHT 3 OF 5
		OFFICE RCE	REVISION 1
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **EEB**	CHKD BY **PM**
		DATE 3-15-94	DATE 4/19/94
		MADE BY	CHKD BY
		DATE	DATE

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 When the pressure in the beam tube is less than 1x10^{-5} Torr conduct an RGA analysis. Record the values for the following masses: 2, 12, 14, 15, 17, 18, 28, 32, 39, 40, 41, 42, 43, 44, 51, 52, 55, and 57. If at this step of the procedure the system appears to be pumping down as expected, proceed to step 3.16.

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 x 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 LIGOTPQT, conduct a pressure assessment of the beam tube module using the RGA readouts.

3.11.2 Record the absolute pressure simultaneously with the RGA readout.

~~3.11.3 Isolate the pump set at the far end of the beam tube module. Record the absolute pressure simultaneously readout at each RGA.~~

~~3.11.4 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.~~

~~3.11.5 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..~~

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		OFFICE RCE		REVISION 1	
PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **EEB**	CHKD BY **PM**	MADE BY	CHKD BY
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~~3.11.6 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.~~

~~3.11.7 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 Location of leakage will be done either by painting the surface of the tube with a fine spray of helium or by isolating successive areas with plastic sheets, duct tape, and injection of helium into these areas.

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.

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 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 if the following conditions are met:

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PRODUCT	**LIGO BEAM TUBE MODULES QUALIFICATION TEST CALIFORNIA INSTITUTE OF TECHNOLOGY**	MADE BY **EEB**	CHKD BY **PM**	MADE BY	CHKD BY
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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 should now be ready for bakeout.

3.20 If unacceptable leakage develops in the beam tube module during bake-out, remove the insulation and repeat applicable steps of this procedure.

3.21 After bakeout, 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 x 10^{-9} atm. cc/sec. or larger, repeat the applicable steps of 3.15.

4.0 DOCUMENTATION:

Document in accordance with item 5.0 of procedure ***LIGOTPQT***.