



IDENTIFICATION

DC

LIGO-E950056-02-B

TITLE	DIMENSIONAL CONTROL PROCEDURE	REFERENCE NO.		SHT	1	OF	8
		930212		REVISION			
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	OFFICE		2			
		PCR					
		MADE BY	CHKD BY	MADE BY	CHKD BY		
		WLR	SWP	KSD	SWP		
		DATE	DATE	DATE	DATE		
		4/22/94	4/22/94	11/6/95	11/7/95		

1.0 SCOPE

- 1.1 This procedure describes the dimensional measurements that are required to be performed and recorded to meet the requirements of American Petroleum Institute (API) "Bulletin on Stability Design of Cylindrical Shells" (BUL 2U), the requirements of fabrication and construction, and the requirements of Caltech Specification No. 1100004.

2.0 DIMENSIONAL CONTROL EQUIPMENT

- 2.1 Calibration of specific types of equipment used for final acceptance of Code items shall meet the requirements of the LIGO QAM. A list of equipment with reference to a Calibration Certificate (CC) with traceability to the National Institute of Science and Technology (NIST), the applicable internal calibration procedure(s) or policy statement, as applicable shall be maintained by the Project Manager.

3.0 DEFINITIONS

- 3.1 Beam Tube Module: -- A beam tube that is approximately 2 kilometers (km) in length and terminated with a weld joint end preparation at the following locations.
1. The ends may be at a corner station and a mid station.
 2. The ends may be at a corner station and a mid point joint.
 3. The ends may be at a mid point joint and an end station.
 4. The ends may be at a mid station and an end station.
- 3.2 Beam Tube Section: -- Approximately 20 m length of fabricated beam tube with expansion joint, pumping port, and related equipment as applicable that are field assembled without intruding into the clear aperture.
- 3.3 Beam Tube Section Dimensional Test: -- A test demonstrating acceptable geometry before each beam tube section gets installed. The contractor shall provide documentation that records actual measurements and provides calculations that demonstrate acceptable geometry and traceability to each beam tube section (See Caltech Specification No. 1100004, Section 4.3.3.).
- 3.4 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.

APPROVED

M. Jellison 11/10/95
DRT 11/10/95

J. Jones 11/10/95
LIGO



TITLE DIMENSIONAL CONTROL PROCEDURE		IDENTIFICATION DC				
		REFERENCE NO. 930212		SHT 2 OF 8		
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY		OFFICE PCR		REVISION 2		
		MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP	
		DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95	

- 3.5 Cardinal reference point: -- (Clocking reference point) -- 0°, 90°, 180°, & 360° centerline punch mark at beam tube ends used during fabrication and installation for alignment control points.
- 3.6 Random Measurements: -- A set of measurements with the number and location at the discretion of the inspector.
- 3.7 Wrap-around Template: -- A rectangular sheet, 12" min. width with the edge straight within 1/8", made of paper, steel or plastic that is wrapped around the beam tube (approximately two times) for the purpose of establishing a straight and square layout line. This layout line will be used to establish the locations of cut lines, stiffeners and pump ports.

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 Method to establish 0°, 90°, 180°, & 360° cardinal reference points and cut lines.
 1. Set the beam tube on horizontal rollers or rails
 2. Using the wrap-around template, establish a straight and square reference line around the beam tube approximately 2" from one end.
 3. Layout the cut line locations, overall length of beam tube.
 4. Locate the pump port position, when applicable. The pump port reinforcing ring must clear the spiral weld. This establishes the 90 deg. cardinal line.
 5. Pi tape the end of the beam tube that has the wrap-around template. Calculate the arc dimensions for the cardinal points.
 6. Mark the cardinal points on end of beam tube within a tolerance of +/- 1/32". When applicable, the 90 deg. line, on which the pump port is located, will be used as the starting point.
 7. Mark cut line at cardinal line locations.
 8. Plumb the 0 deg. & 180 deg. cardinal points.
 9. Pi tape the other end of the beam tube. Calculate the arc dimensions for the cardinal points.
 10. Mark the cardinal lines on this end of the tube without rotating the tube. The 0 deg. & 180 deg. cardinal points are to be plumb to within +/- 1/32".
 11. Using the wrap-around template establish and mark the cut line on this end.
 12. Punch mark the final cut lines and cardinal reference points. Cardinal points to be punched (1") from the finished cut lines.



TITLE DIMENSIONAL CONTROL PROCEDURE		IDENTIFICATION DC			
		REFERENCE NO. 930212		SHT 3 OF 8	
PRODUCT LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY		OFFICE PCR		REVISION 2	
		MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP
		DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95

5.0 COMPONENT INSPECTION

5.1 Components:-- The following list describes the beam tube components and a brief outline of the required inspections and reviews.

- A. Beam Tube Material Coils: -- Receiving inspection and review of material certifications for chemistry, mechanical tests and out gassing results and supplier dimensional reports for width, thickness and weight.
- B. Expansion Joints: -- Receiving inspection and review of material certifications for chemistry, mechanical tests and out gassing results and fabricator dimensional/inspection and leak test reports.
- C. Beam Tubes: -- Inspection after tube mill spiral welding to verify tube diameters, straightness and lengths.
- D. Beam Tube Final Assemblies: -- Inspection of assemblies after welding of stiffeners, pump ports and expansion joints when applicable, end machining and end expanding to record and verify drawing compliance.
- E. Beam Tube Support Rings: -- Receiving inspection and review of supplier material certifications and dimensional inspection reports.
- F. Pump Ports: -- Receiving inspection and review of supplier material certifications and dimensional inspection reports.
- G. Beam Tube Vacuum Stiffener Rings: -- Receiving inspection and review of supplier material certifications and dimensional inspection reports.
- H. Beam Tube Supports including related items: -- Receiving inspection and review of supplier material certifications and dimensional inspection reports when applicable.

5.2 Inspection by Supplier: -- The CBI Material Specification and Product Procurement Specification specify the dimensional measurements, inspections, and records to be provided by the vendor.

5.3 Receiving Inspection

- A. Beam Tube Material Coils: Random checks for width and thickness taken during mill operation.
- B. Expansion Joints: Outside diameter and length measurements taken and recorded during fabrication. The Purchaser will review the supplier documentation during receiving inspection.
- C. Beam Tube Support Rings: Random dimensions verified during receiving inspection. The measurements taken at receiving inspection are used for verification of procurement requirements. Review documentation provided by the supplier.



IDENTIFICATION DC			
REFERENCE NO. 930212		SHT 4 OF 8	
OFFICE PCR		REVISION 2	
MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP
DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95

TITLE	DIMENSIONAL CONTROL PROCEDURE
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY

- D. Support Welded Attachment Members: Random dimensions verified during receiving inspection. The measurements taken at receiving inspection are used for verification of procurement requirements. Review of documents provided by supplier.
- E. Beam Tube Supports including related items: Random dimensions verified during receiving inspection. The measurements taken during receiving inspection are used for verification of procurement requirements. Review of documents provided by supplier.
- F. Pump Ports: Random dimensions taken during receiving inspection. The measurements taken during receiving inspection are used for verification of procurement requirements. The Purchaser will review the vendor documentation during receiving inspection.

5.4 Inspection During Fabrication

5.4.1 Beam Tubes: The following inspections and measurements will taken after the spiral mill welding. The measurements will be taken with the tube supported by rolls or rails and with temporary metal round out fixtures installed, if required.

A. Measure and record the tube outside circumference to determine the effective diameter at the ends, quarter points and center. The measurements will taken with a precision Pi tape.

- Tolerance [Diameter]: $49.00'' + 0.28'' / - 0''$

B. Measure and record the length of the tube at approximately 90 deg. intervals The measurements will be taken with a steel tape.

- Minimum Cutoff Length = Final Specified Length of Welded Beam Tube Assembly + 0.75".
This provides 0.25" allowance for weld shrinkage and 0.50" stock for machining.

C. Make random checks for local deviation from a true circle using an outside segmental circular template and no-go gauge [see Section 6.1.2].

- No-go Gauge Size - 0.121" as measured using a 9.02" chord length circular template.

D. Make measurements and record straightness of tube axis using standoff blocks with music wire stretched from end to end. Measurements to be taken along four equal quadrant lines. Measure the distance from the wire to the tube at center and 1/4 points. Correct the data for the horizontal axis diameter variance to arrive at tube axis straightness

- Tolerance - +/- 1/8"

E. Make random measurements and record squareness and flatness of ends using wrap-around template. Measure the distance from edge of tube to wrap-around template.

- Rough Cut End - +/- 1/4

5.4.2 Beam Tube Final Assemblies: The following inspections and measurements will be taken after welding of stiffeners, supports, pump ports and expansion joints when applicable, and end expanding and end machining. Inspections will be performed at the end machining and expanding station and expansion joint weld station, when applicable. At the end cutting and expanding station, the tube will



IDENTIFICATION DC			
REFERENCE NO. 930212		SHT 5 OF 8	
OFFICE PCR		REVISION 2	
MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP
DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95

TITLE	DIMENSIONAL CONTROL PROCEDURE
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY

be positioned and supported so that the tube is square and aligned with end cutter. The station will be checked periodically to insure that alignment is maintained. At this station, after machining and expanding, end flatness and circumference and length will be measured. At the expansion joint weld station, the length of the tube will be measured after attaching the expansion joint.

- A. Measure and record the tube outside circumference [1"] from ends. The measurement will be taken with a precision Pi tape.
 - Tolerance: +/- 0.048"
- B. Measure and record the end flatness. The measurement will be taken using a dial indicator attached to the end cutter.
 - Tolerance: 0.010" MAX. TIR
- C. Measure and record the tube length. The measurements will taken with a steel tape. If necessary, temperature correction will be made per paragraph 4.2.
 - Tolerance: +/- 1/4"

5.4.3 Beam Tube Support Rings: Measurements will be verified during assembly fabrication. Take random measurements of the outside diameter using an outside caliper. The representative measurements taken for each support ring shall be recorded.

5.4.4 Beam Tube Vacuum Stiffener Rings: Measurements will be verified during assembly fabrication. Take random measurements of locations.

5.4.5 Pump Ports: Measurements will be verified during assembly fabrication. Measure the distance from the cut line to the center line of the pump port. Verify that the pump port is installed along the 90 deg. cardinal line.

5.5 Construction Installation

5.5.1 Welded Beam Tube Assemblies shall be installed in accordance with the contract drawings. The alignment procedure "ALI-1" is used to measure and record final installation dimensions.



TITLE	DIMENSIONAL CONTROL PROCEDURE	IDENTIFICATION			
		DC			
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY	REFERENCE NO.		SHT 6 OF 8	
		930212			
		OFFICE		REVISION	
		PCR		2	
MADE BY	CHKD BY	MADE BY	CHKD BY		
WLR	SWP	KSD	SWP		
DATE	DATE	DATE	DATE		
4/22/94	4/22/94	11/6/95	11/7/95		

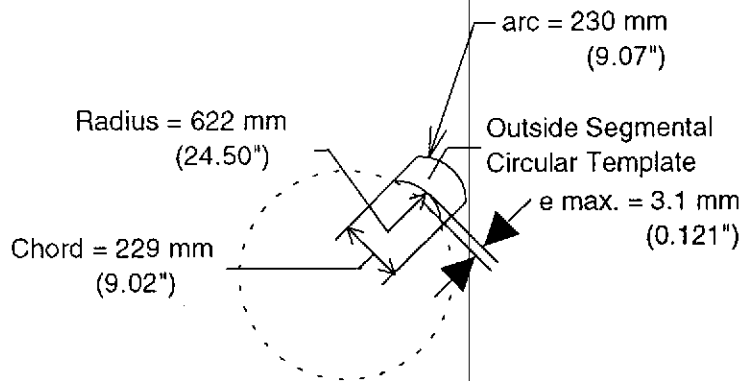
6.0 AMERICAN PETROLEUM INSTITUTE (API) "Bulletin on Stability Design of Cylindrical Shells" (BULL 2U) DIMENSIONAL TOLERANCES

6.1 BULL 2U -- 10. TOLERANCES

6.1.1 Maximum Differences in Cross-Sectional Diameters -- The difference should not exceed 1% of the nominal diameter at any cross section, $D_{max} - D_{min} = 12.44 \text{ mm (0.490")}$.

6.1.2 Local Deviation From True Circle -- Maximum permissible deviation = 0.121" as measured using a 9.02" chord length circular template. Additionally the difference between the actual radius to the shell at any point and the theoretical radius should not exceed $(0.005R) = 0.123"$

1. Outside segmental circular template dimensions, radius = 24.50", arc length = 9.07", & chord length = 9.02"





TITLE	DIMENSIONAL CONTROL PROCEDURE
PRODUCT	LIGO BEAM TUBE MODULES CALIFORNIA INSTITUTE OF TECHNOLOGY

IDENTIFICATION DC			
REFERENCE NO. 930212		SHT 7 OF 8	
OFFICE PCR		REVISION 2	
MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP
DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95

7.0 RECORDS

- 7.1 "Measurement Record & Check List" [see attachment 1] shall be initiated by the Welding & QC Manager for the component, beam tube, beam tube final assembly and installation inspections . The form will identify the piece or assembly to be inspected and the required number and location of measurements to be taken. Theoretical dimensions and tolerances will also be shown. The Welding & QC Supervisor, Engineer or a designated inspector will take the required measurements and complete the form. The identification of the measuring equipment shall be recorded on the form, if required.
- 7.2 The completed "Measurement Record & Check List" will be submitted to the Welding & QC Manager for inclusion into the final record package.

8.0 ATTACHMENTS

- 8.1 Attachment 1 -- (Typical) " Measurement Record & Check List" Form **DC.1**



IDENTIFICATION DC			
REFERENCE NO. 930212		SHT	8 OF 8
OFFICE PCR		REVISION 2	
MADE BY WLR	CHKD BY SWP	MADE BY KSD	CHKD BY SWP
DATE 4/22/94	DATE 4/22/94	DATE 11/6/95	DATE 11/7/95

TITLE DIMENSIONAL CONTROL PROCEDURE

PRODUCT LIGO BEAM TUBE MODULES
CALIFORNIA INSTITUTE OF TECHNOLOGY

ATTACHMENT 1



MEASUREMENT RECORD & CHECK LIST

--	--	--	--

Seq. No.	Description Operation, Inspection, or Examination to be completed	Applicable Procedure or Instruction	CBI		REMARKS:
			Int. Req'd 'X'	Operation Insp. or Exam Accepted	
			Initial	Date	
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					

Made By	Chk'd By	By		Contract Number 930212	No. _____
Date	Date	Chk'd Date			Sheet ___ of ___