Particle Physics Division 12-01-01

Mechanical Department Engineering Note

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Project: DESI

Project Internal Reference:

Title: DESI Shroud Load Calculations

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Key Words: DESI Shroud

Abstract/Summary: Calculations to show conformance with AISC steel construction manual for the Shroud section subjected to axial compression loads.

Applicable Codes: AISC.

Givens:

Max Axial load 900 kN

Introduction

"DESI" stands for Dark Energy Spectrographic Instrument. This scientific instrument will be installed on the Mayall telescope at Kitt Peak, Arizona. Kitt Peak is located about 50 miles southwest of Tucson. DESI is used to capture light from deep space and conduct research on dark energy.

During the assembly process of DESI corrector barrel it would be very useful to be able to rest some if not all the weight of the barrel, lenses, hexapod, etc. This document provides calculations for the allowable loading of the Shroud Section supporting the weight on a flat and horizontal surface, see Figure.1.

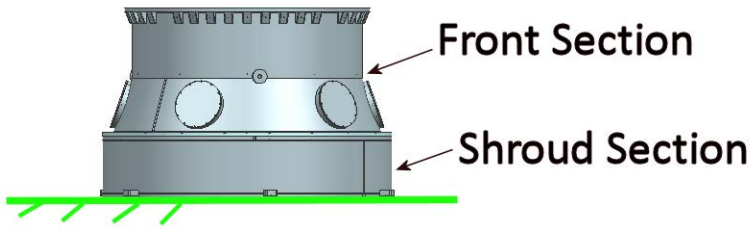


Figure.1 - Shroud Section located on a flat and horizontal surface.

Shroud Parameters

The Shroud is a thin cylindrical shell with two flanges welded on each end. The outer diameter of the Shroud is 1294 mm with 9.5 mm wall thickness and the length is 277 mm, see Appendix I. The Shroud is made from ASTM A36 steel which has a Yield Tensile strength of 250 MPa (36,3 ksi) and the Young Modulus of 200 GPa (29,000 ksi).

Calculations

The calculations assumes an axial compression load evenly distributed on the top flange while the entire bottom flange of the Shroud Section is sitting on a flat and horizontal surface. Below are reported the calculation based on the AISC Steel Construction Manual.

Shroud Calculations

Properties

$OD := 1294mm$ outer diameter

$TH := 9.5mm$ thickness

$L := 277mm$ length

$ID := OD - 2 \cdot TH$

$ID = 1.275\,m$ inner diameter

$$A_shroud := \frac{\pi}{4} \cdot \left(OD^2 - ID^2\right)$$

$E := 200GPa$ Young Modulus

$Fy := 250MPa$ Yield Tensile Strength

$K := 1.3$ effective length factor

$$r := \frac{\sqrt{OD^2 + ID^2}}{4}$$

$r = 0.454\,m$ radius of gyration

$$\frac{K \cdot L}{r} = 0.793$$

SECTION 1.5 ALLOWABLE STRESSES

1.5.1 Structural Steel

1.5.1.3 Compression

1.5.1.3.1 Axially loaded compression members

$$Cc := \sqrt{\frac{2\pi^2 \cdot E}{Fy}}$$

$Cc = 125.664$

$$Fa_15131 := \frac{\left[1 - \frac{\left(\frac{K \cdot L}{r}\right)^2}{2 \cdot Cc^2}\right] \cdot Fy}{\frac{5}{3} + \frac{3 \cdot \left(\frac{K \cdot L}{r}\right)}{8 \cdot Cc} - \frac{\left(\frac{K \cdot L}{r}\right)^3}{8 \cdot Cc^3}}$$

$Fa_15131 = 1.498 \times 10^8\,Pa$

Allowable stress according with section 1.5.1.3.1

1.9.2 Stiffened Elements Under Compression
1.9.2.3 Circular Tubular elements subject to axial compression

$$\frac{OD}{TH} = 136.211$$

The diameter-to-thicknss ratio is greater than 3300/Fy (91.7) but less than 13,000/FY (361), see Appendix C.

$$Fa_C33 := \frac{662 \cdot ksi}{\frac{OD}{TH}} + 0.4 \cdot 36ksi$$

$$Fa_C33 = 1.328 \times 10^{8}\,Pa$$

Allowable stress according with section 1.9.2.3

$$f_load := Fa_C33 \cdot A_shroud$$

$$f_load = 5.091 \times 10^{6}\,N$$

allowable axial load based on the smallest allowable stress

The smallest value of the allowable stress between the two previous equation is 133 MPa (19.3 ksi) where the allowable axial load is 5,000 kN (500 metric tons).

A Finite Element Model is developed to evaluate the stresses caused by an evenly distributed axial compression load while the bottom flange is sitting on (3) steel blocks (150mm X 150mm X 150mm). Based on the boundary and load conditions listed above the average V-Mises stress estimated is 39 MPa with some local peaks located on the support region also called “Saint-Venant area”, see Figure.2.

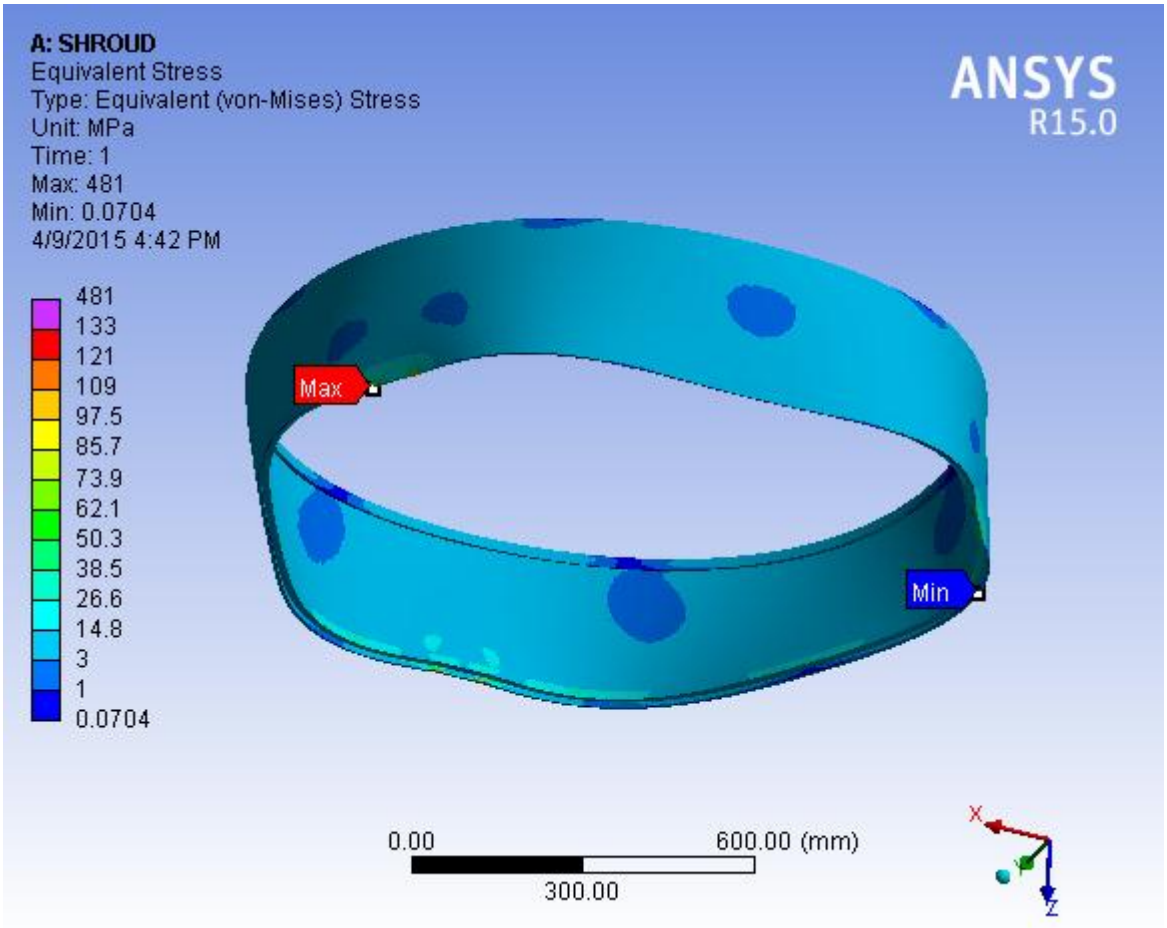


Figure.2 – Distribution of the V-Mises stress on the Shroud Section

Data Analysis

The failure model analyzed are the yield of the material and the buckling. For short columns yielding of the material is the failure mode, for intermediate and long column the failure can occur before the material yields. Based on the calculations the Shroud failure mode is the buckling where the allowable axial compression load is 5,000 kN (500 metric tons) when the load is evenly distributed and the bottom flange of the Shroud Section is placed on a flat and horizontal surface. An alteration of the support system can be the installation of (3) blocks underneath the Shroud Section which is a practical use in most cases and for that reason a FEM is made. According with the FEM analysis the average of V-Mises stress on the most part of the Shroud is below the yield point (~39MPa) but local peak of stress on the contact region might cause a local yield.

Shroud Load Test Documentation

A load test for DECam Shroud was made. The DECam Shroud section was loaded with 21.8 kN (4,800 lbs) as measured by the hoist scale and a ¾" foam was placed under the shroud. During the test was noticed an uneven load due to the soft resilience of the foam.

The conclusions of the DECam shroud test with 21.8 kN were the no observation of adverse effects.

A reasonable comparison can be made using as reference the allowable load calculated with the procedure listed into the AISC manual where the test load for DESI Shroud section is estimated, see Table.1.

	Allowable axial load	Test Load	Actual Load
DECam	121 kN	21.8 kN	22.7 kN
DESI	5000 kN	909 kN	41.5 kN

Table.1 – DECam and DESI Shroud loads.

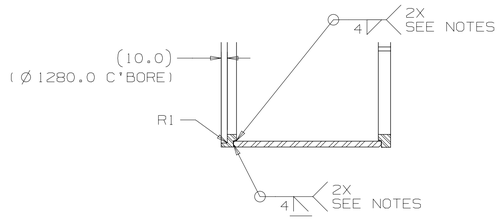
An estimated test load of 909 kN for DESI Shroud section could not cause adverse effects.

Conclusions

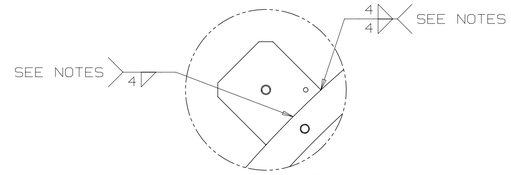
Since the actual load of DESI corrector barrel, the lenses, the ADCxs, the hexapod are ~41.5 kN (~9,200 LBS) smaller than the estimated test load there should not be any concern on the failure of DESI Shroud section supported over a flat and horizontal surface. Side loads and support blocks must be avoided, so shipping the telescope while being supported on the shroud is not recommended. Also, when aligning the lenses/cells while being supporting from the shroud might cause small deflections in the barrel assembly which would be different than supporting of the flange as it will be in the final configuration.

DESCRIPTION: C1 SHROUD AND FLANGE WELDMENT
CATEGORY: WELDMENT PROJECT: DESI

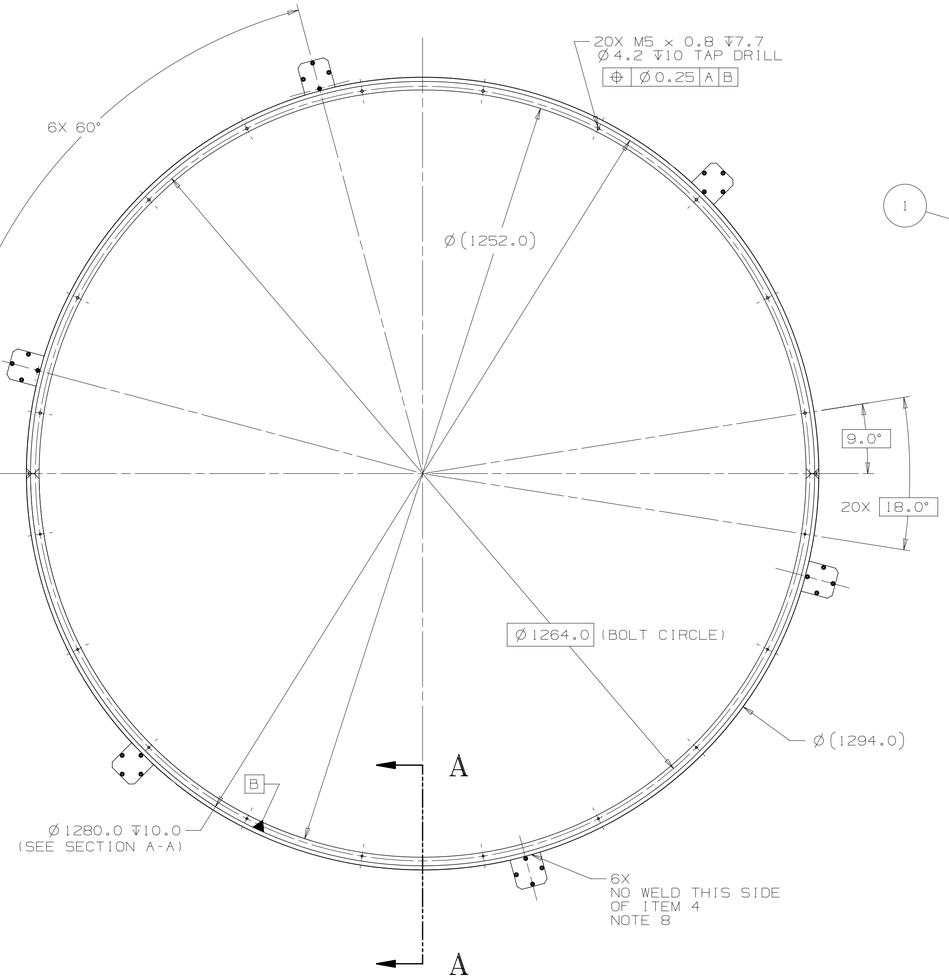
REV	REVISION CONTROL DOCUMENT	DATES	SIGNATURES	
-	F10028559---RCD		DRAWN	
			APPROVED	



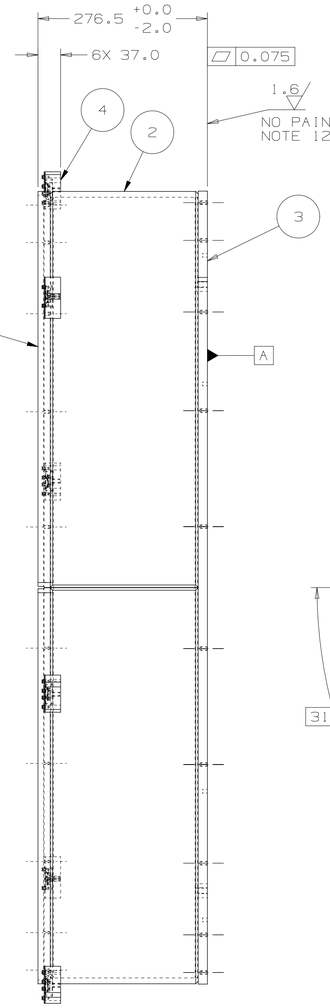
SECTION A–A

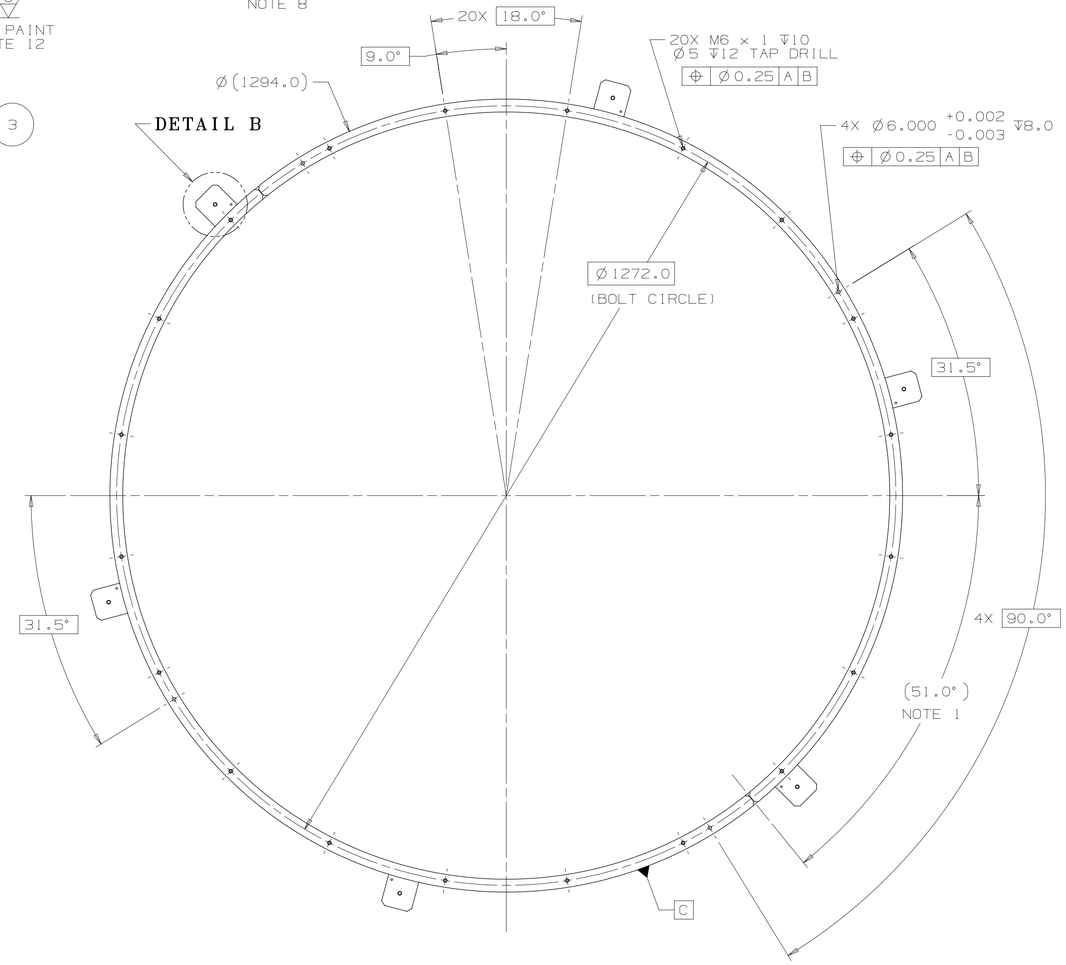


DETAIL B
SCALE 1:2
TYPICAL 6 PLACES
NOTE 8



END RING VIEW





FLANGE END VIEW

NOTES:

1. BEFORE WELDING, CLOCK ITEMS 1 AND 3 SO THAT THE WELD SEAMS WILL LIE BETWEEN FLANGE HOLES WHEN THEY ARE MACHINED. NO HOLES ARE TO BE DRILLED THRU WELD SEAMS.
2. STRESS RELIEVE WELDMENT BEFORE MACHINING IN ACCORDANCE WITH ANSI/AWS D1.1, "STRUCURAL WELDING CODE - STEEL".
3. ALL WELDS TO BE E7018 OR EQUIVALENT.
4. ALL WELDING SHALL BE IN ACCORDANCE WITH ANSI/AWS D1.1, "STRUCTURAL WELDING CODE - STEEL".
5. ALL WELDS SHALL BE MADE IN A SEQUENCE THAT WILL BALANCE THE APPLIED WELDING HEAT WHILE THE WELDING PROGRESSES. THE PROCEDURE AND SEQUENCE SHALL BE DESIGNED TO MINIMIZE DISTORTION AND SHRINKAGE STRESSES.
6. ALL WELDS SHALL BE VISUALLY AND MAGNETIC PARTICLE INSPECTED TO DETECT SURFACE AND SUBSURFACE CRACKS AND DISCONTINUITIES IN ACCORDANCE WITH ANSI/AWS D.1., "STRUCTURAL WELDING CODE - STEEL".
7. ALL WELDS THAT FAIL AN INSPECTION SHALL BE REPAIRED IN ACCORDANCE WITH ANSI/AWS D1.1, "STRUCTURAL WELDING CODE - STEEL".
8. ITEM 8, SHROUD MONUMENT ASSY (F10032822) TO BE DISASSEMBLED PRIOR TO WELDING. DO NOT WELD ON COVER SIDE OF ITEM 8. RETAINED PARTS TO BE RE-ASSEMBLED AFTER WELDING.
9. ALL PRIMARY DIMENSIONS ARE IN MILLIMETERS (mm). REFERENCE DIMENSIONS IN BRACKETS, IF SHOWN, ARE IN INCHES.
10. ALL WELDING SHALL BE COMPLETED PRIOR TO ANY DRILLING OR MACHINING.

NOTES: (CONT'D)

11. AFTER ALL WELDING AND MACHINING HAS BEEN COMPLETED, PAINT ASSEMBLY WITH 1 COAT OF CORROSION INHIBITING PRIMER, AND 2 COATS OF GLOSS PAINT, SAFETY BLUE IN COLOR. ALL HOLES TO BE TAPED OR PLUGGED TO PREVENT PRIMER OR PAINT ON INTERNAL SURFACES. ALL THREADED HOLES SHALL BE RE-TAPPED BY HAND TO ENSURE THREADS ARE FREE FROM PRIMER AND PAINT.
12. PROTECT FLANGE SURFACE FROM MARS, DENTS, SCRATCHES AND DISCOLORATION DURING FINAL SHIPPING.

APPROX WEIGHT: 96.6 Kg (213 LBS)

ITEM	PART NO	DESCRIPTION	QTY
4	F10032822	SHROUD MONUMENT ASSEMBLY	6
3	F10008502	SHROUD FLANGE	1
2	F10008503	C1 SHROUD	1
1	F10022820	SHROUD END RING	1

PARTS LIST

UNLESS OTHERWISE SPECIFIED				
±X	±X.X	±X.XX	±X/X	±X°
2	0.3	0.12	N/A	1°

BREAK ALL SHARP EDGES 0.5 MAX.
DO NOT SCALE DRAWING
DIMENSIONS BASED ON ASME Y14.5-2009
MAX. ALL MACH SURFACES 3.2
DRAWING UNITS: MM

DRAWN	T.SPERRY	DATE	27-Oct-2014
CHECKED	D.FRIEND	DATE	25-Feb-2015
APPROVED	- -	DATE	
USED ON	F10029910		
MATERIAL			
GROUP: Particle Physics Mechanical Support		CAGE CODE: 0U5R6	

FERMI NATIONAL ACCELERATOR LABORATORY
UNITED STATES DEPARTMENT OF ENERGY

NAME: SHROUD WELDMENT

SCALE	SIZE	DRAWING NUMBER	SHEET	REV
1:5	A1	F10028559	1 OF 1	-