THE UNIVERSITY OF ARIZONA
TUCSON ARIZONA

Budgetary Proposal for the SAO 1.2-m Mirror Polishing

September 8, 2010

The Steward Observatory Mirror Lab (SOML) is pleased to offer this Budgetary Proposal for the SAO 1.2-m mirror polishing. A cast blank will be provided by SAO for the polishing from previous purchase order numbers 09-CNT-400-SK909007 and 10-CNT-400-SK010006. SOML will polish the mirror to the technical specification document *SAO 1.2-m Primary Mirror Technical Specification and Requirements* dated September 8, 2010 Version 1 that is attached.

Price:

The proposed price is $400,000 dollars as a fixed price contract.

Schedule:

The period of performance is 10 months after receipt of order.

List of deliverables:

1.) 1.2-m mirror blank figured to specification

2.) Final acceptance report

This activity proposed will be carried out at the University of Arizona Steward Observatory Mirror Lab (SOML) under the supervision of Jeffrey S. Kingsley as the Principal Investigator.

This is a budgetary proposal for estimating technical requirements, schedule and costs that has not been officially approved by UA officials. If this meets the technical, budgeting and scheduling requirements of the SAO then an officially approved proposal can be produce in two weeks.

SAO 1.2-m Primary Mirror

Technical Specifications and Requirements

Document Number: UASO 30125-TS-1

Version 1

September 8, 2010

Revision History

Version: 1
Date: September 8, 2010
Authors: J. Kingsley, B. Martin, R. Lutz & M. Rascon
Comments: Documentation creation

1. General Description

The SAO1.2-m primary mirror is to be a direct replacement mirror for the Fred Lawrence Whipple Observatory (FLWO) 48" telescope on Mount Hopkins near Amado, Arizona. The optical design calls for a concave hyperboloid mirror 1.2 meters in diameter. This document contains specifications for the fabrication and testing of the mirror.

2. Optical Prescription

2.1 Surface Figure

The ideal mirror surface is expressed in terms of its vertex radius of curvature, R_C, and its conic constant, k. The Cartesian coordinate of a point on the mirror surface is given by:

$$Z = \frac{(c)\,\mathrm{r}^2}{1+\sqrt{1-(1+k)(c)^2\,\mathrm{r}^2}}$$

Z = Height above Vertex

r = Distance from Optical Axis

c = 1/Radius of Curvature = 1/R

k = Conic Constant

The vertex radius of curvature (R) and conic constant (k) shall meet the specifications on drawing number 20253 on sheet 1, in note 1.

2.2 Clear Aperture

An annular shaped region centered on the front surface of the mirror will be used for imaging. The inner and outer diameters are specified as:

Inner clear aperture, ICA:	356 mm
Outer clear aperture, OCA:	1,194 mm

3. Physical Parameters

3.1 Design

The primary mirror design is given by Steward Observatory drawing number 20253 revision C dated June 15, 2010 that is attached.

3.2 Material

The mirror shall be cast of low expansion borosilicate E6 glass from Ohara Corporation.

4. GENERATION

4.1 General Procedure

The mirror shall be generated from the as-cast shape with a combination of grinding wheel and loose abrasive grinding.

4.2 Microfractures

The process of using successively finer grit sizes and removing sufficient material with each grit size is the process that controls the subsurface damage.

4.3 Vertex Thickness

The vertex thickness of the finished mirror is defined in drawing number 20253 on sheet 2.

4.4 Wedge Angle

The maximum wedge angle of the front surface with respect to the back surface is on drawing number 20253 on sheet 1 in note 8.

5. POLISHING

5.1 Polish Area

The entire front face between the inner and outer edge bevels shall be polished. Surface quality shall be measured in the area defined by the clear aperture.

5.2 Back plate

The back plate shall be polished to remove subsurface damage caused by generating.

5.3 Centration Tolerance

The optical center shall be concentric with the mechanical center of the blank as specified on drawing number 20253 on sheet 1, in note 7.

5.4 Surface Accuracy

The mirror must be good enough that it does not limit seeing-limited performance in excellent seeing. The specification is a structure function, which gives the allowed error as a function of spatial scale in the pupil. More precisely, it is the mean square wavefront difference between points in the pupil as a function of their separation. The form of the structure function is chosen to match the seeing-limited wavefront in Kolmogorov seeing, with an additional allowance for small-scale structure. It is characterized by the FWHM image size and the loss due to small-scale structure, both at a wavelength of 500 nm. The specification for the SAO primary mirror corresponds to 0.12 arcsecond seeing and 2% scattering loss at 500 nm. The large-scale end of this structure function allows an rms wavefront error equal to about half that of the atmosphere in 0.25 arcsecond seeing. The small-scale end limits the small-scale structure to 5.6 nm rms surface error. We also list a goal that is roughly 20% more accurate than the specification. Table 1 lists the parameters and Figure 1 shows plots of the rms wavefront difference as a function of separation. The specified structure function is the performance acceptance criteria for the optical test.

	FWHM (arcsecond)	scattering loss
Specification	0.12	0.020
Goal	0.10	0.015

Table 1. Structure function parameters for specification and goal for wavefront accuracy

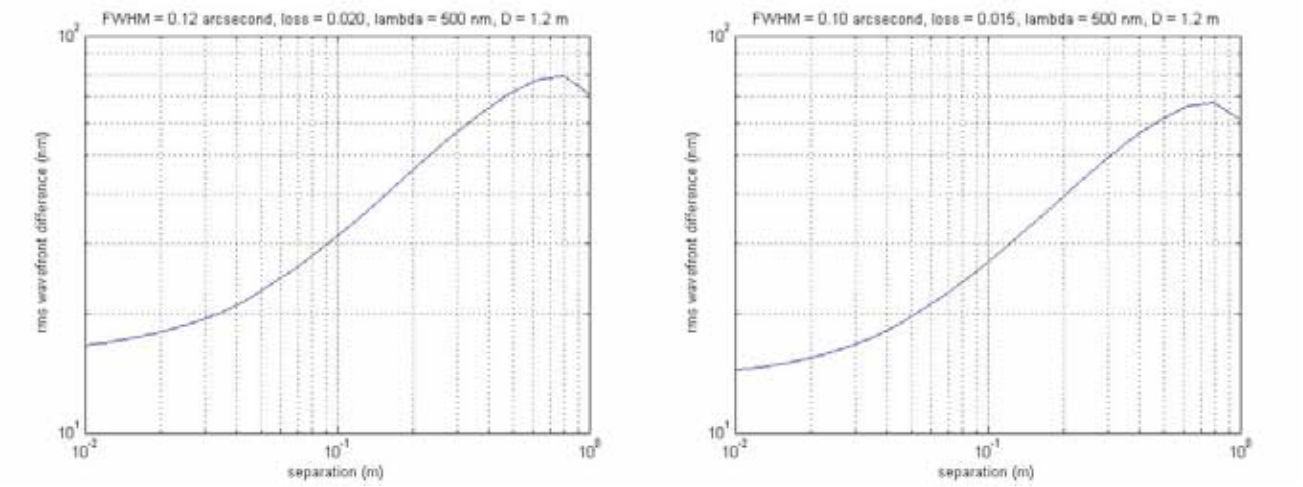


Figure 1. Plots of rms wavefront difference (square root of the wavefront structure function) for the specification (left) and goal (right).

5.5 Print-through

The mirror cells shall be pressurized during polishing and tool pressure shall be adjusted to minimize print through of the internal rib structure.

5.6 Microroughness

The polished surface is defined on drawing number 20253 on sheet 1, in note 6.

5.7 Scratches

Scratches on the mirror surface within the clear aperture may not exceed 200 microns in measured width. Scratches less than 200 microns but greater than 100 microns in width will be cataloged over the entire clear aperture of the mirror. The summed area (length x width) of all scratches between 100 microns and 200 microns may not exceed 0.01% of the area of the clear aperture. Scratches outside of the clear aperture will be ignored. Scratches smaller than 100 microns in measured width will be ignored.

5.8 Surface Polish

The entire mirror surface will be polished with no evidence of gray areas (broad areas of residual pits from loose abrasive grinding). Individual pits on the mirror surface within the clear aperture may not exceed 500 microns in (measured) greatest dimension. Pits less than 500 microns but greater than 200 microns will be cataloged over the entire clear aperture of the mirror. The summed area of all pits between 500 microns and 200 microns may not exceed 0.01% of the area of the clear aperture. The area of a pit will be calculated as the area of a circle with a diameter equal to the greatest dimension of the pit. Pits outside of the clear aperture will be ignored. Pits smaller than 200 microns in measured width will be ignored provided that they are sparse and not representative of insufficient polishing.

5.9 Bubbles

Bubbles less than 10 mm in diameter will be treated by stoning (smoothing the edges with an abrasive stone). All residual polishing compounds will be removed from open bubbles prior to delivery of the mirror.

6. METROLOGY

6.1 Support During Testing

The mirror shall be supported during optical testing in a manner that uses the same support pads as in the telescope and duplicates, to the extent possible, the support force distribution at zenith pointing in the telescope.

6.2 Mirror Thermal Control

A blower system shall be provided to promote rapid thermal relaxation and equilibration of the blank during testing.

6.3 Test Methods

Surface quality shall be measured interferometrically using a null computer generated hologram (CGH) with sufficient spatial resolution and sensitivity to demonstrate compliance with the specification of Section 5.3. A full aperture test is required.

A tolerance analysis shall be performed on the test optics to demonstrate the ability to measure to the accuracy required to meet the polishing specification. Procedures shall be specified for removing wavefront errors introduced by auxiliary optics in the test.

Microroughness shall be measured from 6 replicated samples uniformly distributed over the mirror surface.

The radius of curvature will be measured using a laser tracker system with sufficient accuracy for the measurement.

6.4 Test Records

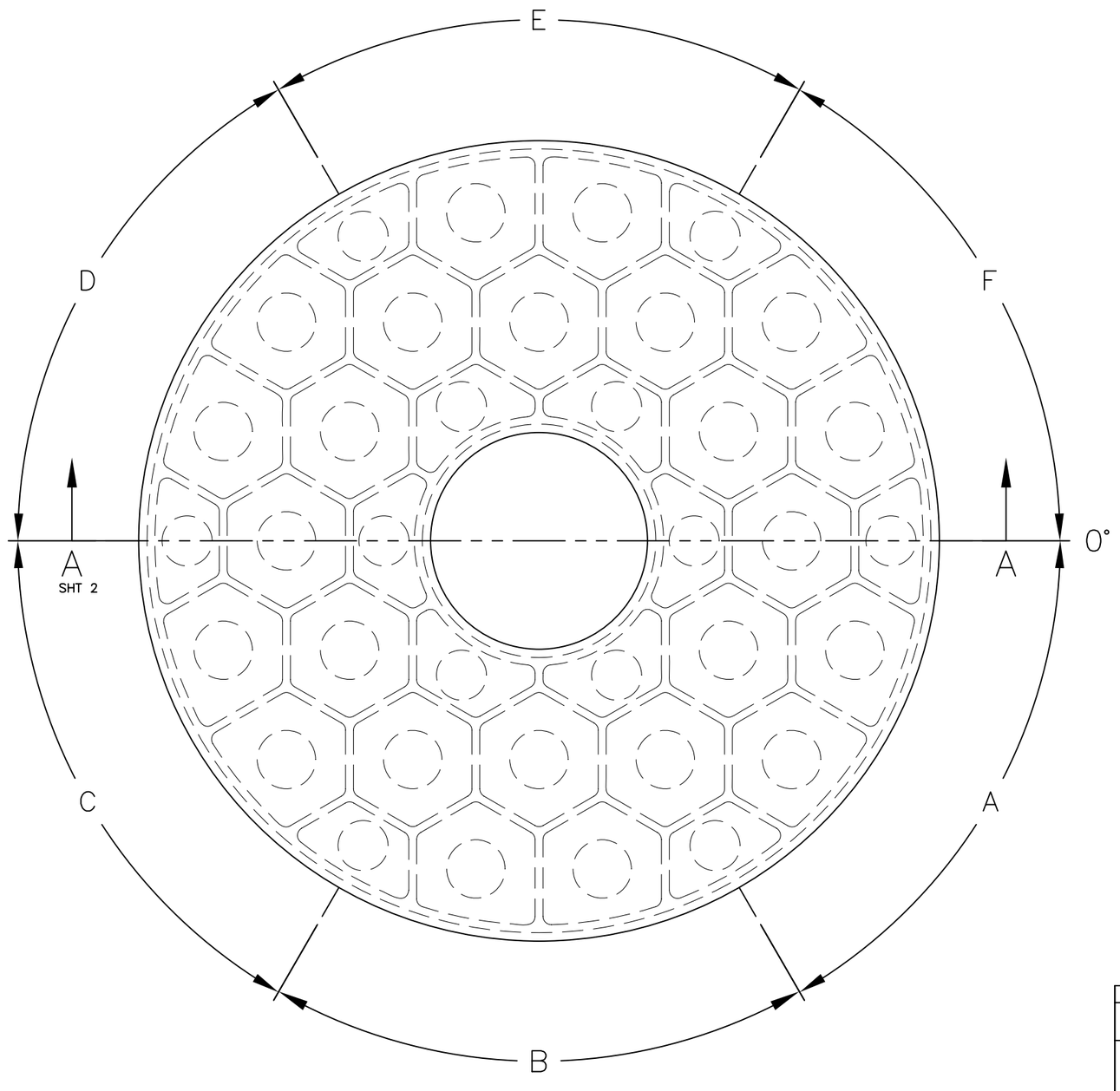
Records shall be maintained for both in-process and acceptance testing. The records shall contain the date of test, test conditions, and results.

Surface maps from interferometric tests shall be made available to SAO in digital format following final polishing.

7. HANDLING

The mirror shall be removed from the polishing machine with a handling fixture provided by SAO. UA shall be responsible for the removal operation.

REVISION HISTORY				
REV	DESCRIPTION	DATE	REVISED BY	APPROVED
A	INITIAL RELEASE	2/10/2010	A. FERN	M. RASCON
B	UNPDATED NOTES 1, 3 & 5.	4/23/2010	A. FERN	M. RASCON



SAO 1.2m MIRROR

(MIRROR BEING VIEWED WITH FRONT, CONCAVE SURFACE TOWARD VIEWER)

NOTES:

1. SURFACE 1 IS GIVEN BY:

$$Z = \frac{(c)\,r^2}{1+\sqrt{1-(1+k)(c)^2\,r^2}}$$

Z = Height above Vertex

r = Distance from Optical Axis

c = 1/Radius of Curvature = 1/R

k = Conic Constant

PARAMETER	DESIGN
R	180.743 [4590.87 mm]
k	-1.040231

2. THIS SURFACE TO BE MACHINIED ONLY. FINISH ACCORDING TO POLISHING LAB PROCESS SPECIFICATION 2101A CLASS 320 GRIT.

3. RADIUS INDICATED EDGES OF FRONT SURFACE AND BACK SURFACE TO .24±.04 [6mm±1mm] RADIUS. THE RADIUS SHOULD HAVE A PROJECTED WIDTH OF .16 [4mm]. THE ANGLE OF THE RADIUS SHOULD BISECT THE CORNER.

OR

CHAMFER INDICATED EDGES OF FRONT SURFACE AND BACK SURFACE TO .24±.04 [6mm±1mm] AT 35°±6°. WHERE SHOWN.

4) AS CAST: BACK SURFACE HOLES FINISH 45° CHAMFER, .45 [11.43mm] WIDE ON OUTSIDE SURFACE.

5. SPECULAR POLISH OVER 99% OF SURFACE AREA.

6. THE POLISHED SURFACE SHALL BE SMOOTH AT SPATIAL FREQUENCIES << 1cm SUCH THAT MICROROUGHNESS SHALL NOT EXCEED 20A RMS.

DO NOT SCALE DRAWING

INTERPRET DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH ASME Y14.5M-94

TOLERANCES
UNLESS OTHERWISE SPECIFIED

LINEAR	ANGULAR
.X = ± -----	± 1°
.XX = ± .15	
.XXX = ± -----	

DIAMETRICAL: SEE SPEC S-002

DIMENSIONS ARE IN INCHES / DIMENSIONS IN [ ] ARE METRIC

MATERIAL:
OHARA E6
BOROSILICATE

FINISH:
N/A

THIS DRAWING CREATED IN:

ACAD	MECH	IDEAS	INV
☐	☐	☐	■

N/A	SAO
NEXT ASSY	USED ON
ASSEMBLY APPLICATION	

Steward Observatory, University of Arizona
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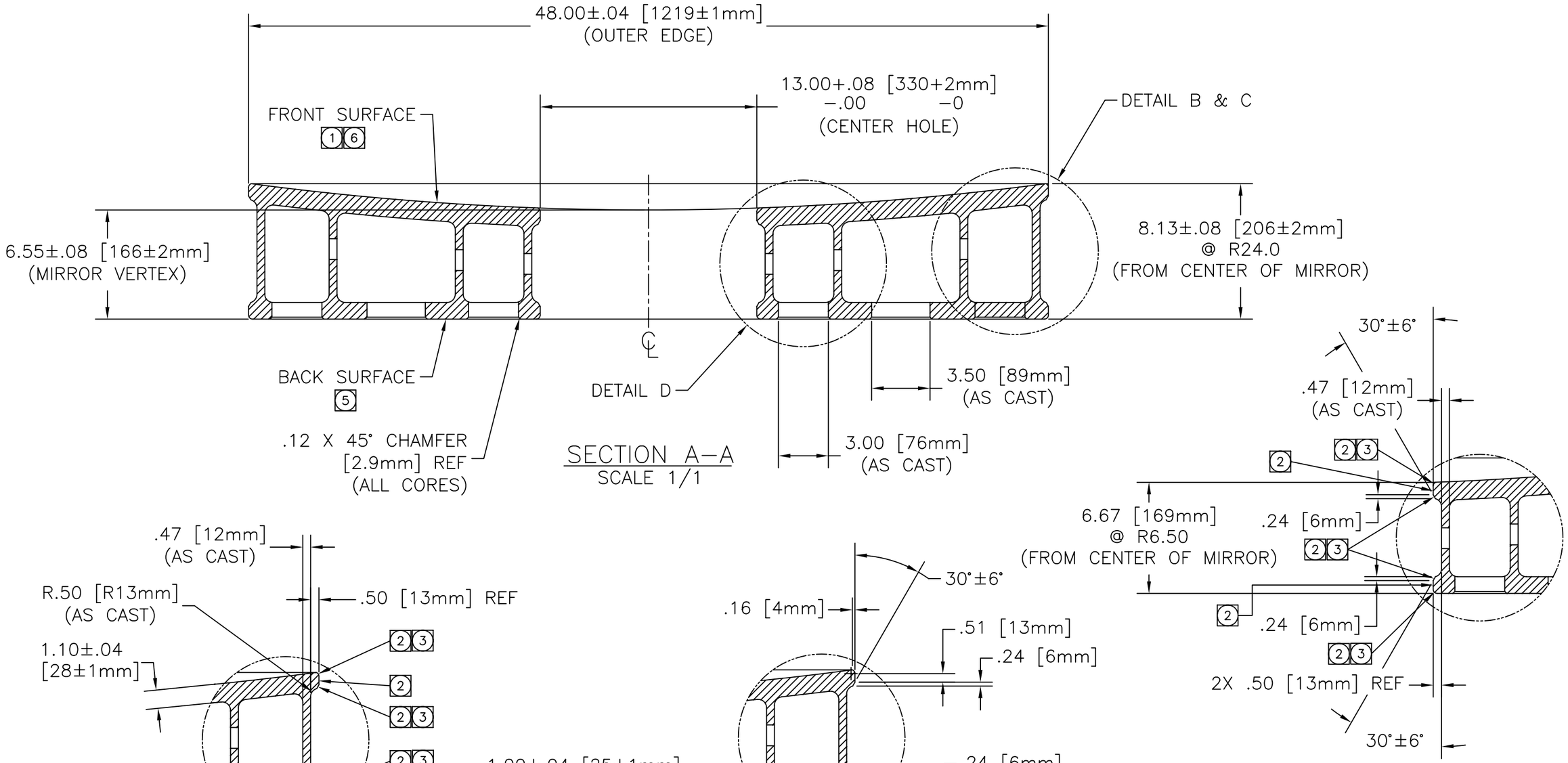
ENGINEER: M. RASCON	DATE: 2/10/2010	CATEGORY: SAO
DESIGNED BY: A. FERN	DATE: 2/10/2010	PROJECT: 1.2m MIRROR
DRAWN BY: A. FERN	DATE: 2/10/2010	TITLE: SAO 1.2m MIRROR FINISHED DIMENSIONS
CHECKED BY: A. FERN	DATE: 2/10/2010	
APPROVED: M. RASCON	DATE: 2/10/2010	
APPROVED:	DATE:	
APPROVED:	DATE:	DRAWING NUMBER: 20253
APPROVED:	DATE:	SHEET 1 OF 2

REVISION: B



SECTION A–A
SCALE 1/1

DETAIL B
SCALE 1/1

DETAIL C
SCALE 1/1

DETAIL D
SCALE 1/1

DO NOT SCALE DRAWING INTERPRET DIMENSIONS AND TOLERANCES IN ACCORDANCE WITH ASME Y14.5M-94 TOLERANCES UNLESS OTHERWISE SPECIFIED LINEAR: .X = ± —, .XX = ± .15, .XXX = ± — ANGULAR: ± 1° DIAMETRICAL: SEE SPEC S-002 DIMENSIONS ARE IN INCHES. DIMENSIONS IN [ ] ARE METRIC MATERIAL: OHARA E6 BOROSILICATE FINISH: N/A	THIS DRAWING CREATED IN: ACAD ☐ MECH ☐ IDEAS ☐ INV ☐ N/A / SAO NEXT ASSY / USED ON ASSEMBLY APPLICATION	Steward Observatory, University of Arizona 933 N. Cherry Avenue, Tucson, AZ 85721 (520)621-7659 ENGINEER: M. RASCON — DATE: 2/10/2010 DESIGNED BY: A. FERN — DATE: 2/10/2010 DRAWN BY: A. FERN — DATE: 2/10/2010 CHECKED BY: A. FERN — DATE: 2/10/2010 APPROVED: M. RASCON — DATE: 2/10/2010 APPROVED: — DATE: APPROVED: — DATE: APPROVED: — DATE: CATEGORY: SAO PROJECT: 1.2m MIRROR TITLE: SAO 1.2m MIRROR FINISHED DIMENSIONS DRAWING NUMBER: 20253 SHEET 2 OF 2 REVISION: B