Dimensions for Large Borosilicate Honeycomb Mirrors

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Abstract

In this memo I have attempted to collect all the relevant dimensions for the first four large borosilicate honeycomb blanks to be cast at the Mirror Lab. These blanks will be a 6.5 m for the MMT Conversion and a 6.5 m for the Magellan Project followed by 8.4 m blanks for the Large Binocular Telescope Project. Listed here are the desired finished dimensions for the blanks in the telescope as well as the target dimensions for the casting. We have also listed estimates for the variations of the dimensions caused by the casting process. These dimensions are already frozen for the 6.5 meter and are now freezing for the 8.4 meter blanks. After the honeycomb cell design is finalized for each mirror, the Mirror Lab will produce dimensioned drawings of the as cast and finished blanks.

Changes since October 2, 1989

A few new dimensions and tolerances have been added, particularly for the finished blanks. (None of the previous dimensions have changed.) Explanatory notes to make the dimensions and tolerances more clear have also been provided. Thanks to Randy Lutz, estimated weights of the blanks have also been provided. I have also included dimensions for a possible 8.4 meter casting. An error in the finished edge thickness of the Columbus mirror was corrected. The as-cast blank thicknesses were corrected to allow for the 5 mm to be generated off the backplate.

Changes since May 2, 1990

Magellan has changed to a 6.5 m and LBT to an 8.4 m with an 0.9 m Cass hole. The MERPs fillet radius has increased to 25 mm. Cross pin holes have been added. Mass estimates have been revised.

Changes since September 24, 1993

Details of the Cass hole of the 8.4 meter mirror have been changed to ease some fabrication problems and to correct some typos. LBT has a different amount of overhang on the inner edges of both faceplates. All generated surfaces including bevels are to be polished (see drawing for bevel details). Added chamfer spec for backplate ventilation holes. Adjusted finished 6.5 meter mass to account for mold shrinkage. LBT also has a new honeycomb pattern not addressed in this memo.

1 Dimensions for All Large Honeycomb Blanks

Item	Finished Dimension			Tolerance	Cast Dimension		Tolerance
Hexagonal rib thickness	12 mm	0.5 in	as cast	±2 mm	12 mm	0.5 in	±2 mm
Hexagon center spacing	192.2 mm	7.567 in	as cast	±0.5 mm	*192.2 mm*	7.567 in	±0.5 mm
Outer edge wall thickness	15 mm	0.6 in	as cast	±2 mm	15 mm	0.6 in	±2 mm
Inner edge wall thickness	12 mm	0.5 in	as cast	±2 mm	12 mm	0.5 in	±2 mm
Front faceplate thickness	28 mm	1.1 in	polish	±1 mm	42 mm	1.7 in	±5 mm
Back faceplate thickness	25 mm	1.0 in	generate*	±1 mm	30 mm	1.2 in	+2 −0 mm
Back ventilation hole diameter	88.9 mm	3.50 in	chamfer	±2 mm	*88.9 mm*	3.50 in	±2 mm
Outer front faceplate overhang	20 mm	0.8 in	generate*	±2 mm	25 mm	1.0 in	±2 mm
Outer back faceplate overhang	20 mm	0.8 in	generate*	±2 mm	25 mm	1.0 in	±2 mm
Projected width of faceplate bevel	5 mm	0.2 in	generate*	±1 mm	none		
Fillet radius on faceplate bevel	8 mm	0.30 in	generate*	±1 mm	none		
Fillet radius on ribs	12 mm	0.5 in	as cast	±4 mm	12 mm	0.5 in	±4 mm
Fillet radius on MERPs	25 mm	1.0 in	as cast	±4 mm	25 mm	1.0 in	±4 mm
Chamfer width on backplate holes, 45°	3 mm	0.12 in	grind	±1 mm	none		
Cross pins below frontplate	120 mm	4.75 in	as cast	±10 mm	120 mm	4.75 in	±10 mm

2 Mirror specific parameters – for MMT Conversion, Magellan

Item	Finished Dimension			Tolerance	Cast Dimension		Tolerance
Front faceplate hole diameter	889.0 mm	35.00 in	generate*	±0.5 mm	879.0 mm	34.6 in	±3 mm
Back faceplate hole diameter	939.8 mm	37.00 in	generate*	±0.5 mm	929.8 mm	36.6 in	±3 mm
Outer faceplate diameter	6512 mm	256.4 in	generate*	±0.5 mm	6522 mm	256.8 in	±3 mm
Outer wall mid-diameter	6457 mm	254.2 in	as cast	±3 mm	6457 mm	254.2 in	±3 mm
Inner wall mid-diameter	961 mm	37.83 in	as cast	±3 mm	961 mm	37.83 in	±3 mm
Inner front faceplate overhang	30 mm	1.2 in	generate*	±2 mm	35 mm	1.4 in	±2 mm
Inner back faceplate overhang	5 mm	0.2 in	generate*	±2 mm	10 mm	0.4 in	±2 mm
Clear optical aperture	6502 mm	256.00 in	polish				
Focal length (F/1.25, parabola)	8128 mm	320.00 in	polish	±2 mm	8128 mm	320.0 in	±2 mm
Focal length of core tops	8142 mm	320.55 in	as cast	±2 mm	8142 mm	320.55 in	±2 mm
Inner thickness at R=445 mm	391.2 mm	15.40 in	generate*	±2 mm	410 mm	16.1 in	+8 – 6 mm
Outer thickness at R=3256 mm	711.2 mm	28.00 in	generate*	±2 mm	730 mm	28.7 in	+8 – 6 mm
Sagitta for R=3256 mm	326.0 mm	12.83 in	calculate				
Sagitta for R=3250 mm	325.0 mm	12.80 in	calculate				
Sagitta for R=444.5 mm	6.08 mm	0.24 in	calculate				
Approximate Mass	8435 kg	18600 lbs	generate	±300 kg	9550 kg	21059 lbs	±200 kg

For finished dimensions see, Mirror Lab Drawing Number 1168 (Rev B, 9/93)
For cast dimensions see, Mirror Lab Drawing Number 3560 (Rev A, 5/91)

3 Mirror specific parameters – for LBT

Item	Finished Dimension			Tolerance	Cast Dimension		Tolerance
Front faceplate hole diameter	889.0 mm	35.00 in	generate*	±0.5 mm	879.0 mm	34.6 in	±3 mm
Back faceplate hole diameter	889.0 mm	35.00 in	generate*	±0.5 mm	879.0 mm	34.6 in	±3 mm
Outer faceplate diameter	8417 mm	331.4 in	generate*	±0.5 mm	8428 mm	331.8 in	±3 mm
Outer wall mid-diameter	8362 mm	329.2 in	as cast	±3 mm	8362 mm	329.2 in	±3 mm
Inner wall mid-diameter	941 mm	37.04 in	as cast	±3 mm	941 mm	37.04 in	±3 mm
Inner front faceplate overhang	20 mm	0.8 in	generate*	±2 mm	25 mm	1.0 in	±2 mm
Inner back faceplate overhang	20 mm	0.8 in	generate*	±2 mm	25 mm	1.0 in	±2 mm
Clear optical aperture	8408 mm	331.0 in	polish				
Focal length (F/1.14, parabola)	9600 mm	378.0 in	polish	±0.25 mm	9600 mm	378.0 in	±2 mm
Focal length of core tops	9614 mm	378.5 in	as cast	±2 mm	9614 mm	378.5 in	±2 mm
Inner thickness at R=445 mm	437.4 mm	17.2 in	generate*	±2 mm	456 mm	18.0 in	+8 – 6 mm
Outer thickness at R=4209 mm	893.6 mm	35.2 in	generate*	±2 mm	913 mm	35.9 in	+8 – 6 mm
Sagitta for R=4209 mm	461.35 mm	18.2 in	calculate				
Sagitta for R=4204 mm	460.25 mm	18.1 in	calculate				
Sagitta for R=445 mm	5.16 mm	0.20 in	calculate				
Approximate Mass	15582 kg	34358 lbs	generate	±600 kg	17753 kg	39146 lbs	±500 kg

For finished dimensions see, Steward Observatory Drawing Number 5184 (4/94)
LBT drawing number to be assigned.
(replaces obsolete Mirror Lab Drawing Number 3465)
For cast dimensions see, Steward Observatory Drawing Number 5185 (pending)
For mold dimensions see, Steward Observatory Drawing Number 5186 (pending)

Explanatory Notes

Finished Dimension refers to the final dimensions of the blank after casting and generating have been completed (to this precision, polishing has no effect). Dimensions are specified in millimeters with rounded inch translations for all mirrors other than the 6.5 meter, where inches are the native units.

Cast Dimension refers to the condition of the blank when it emerges from the furnace. Note that these are specified in a mixture of inches and millimeters. Cast dimensions are similar to the mold dimensions, but not necessarily identical due to shrinkage and thermal expansion.

Hexagonal rib thickness is the mean thickness of the ribs between the hexagonal honeycomb cells. This dimension is controlled by the stability of the cores in the casting process. The tolerance of $\pm$ 2 mm includes variations from rib to rib as well as variations within a single rib. This tolerance is driven by the desire for predictable mass and stiffness distribution in the mirror blank.

Hexagon center spacing is the repeat dimension of the honeycomb cells across the flat dimensions of the hexagons. This dimension is set by the hexagonal tiles that make up the bottom of the mold and thus must be the same for all of the large castings. For historical reasons, this number was set to 7.567 inches. The tolerance is set by the expected errors in the mold assembly process with $\pm$0.5 mm referring to the mean spacing geometry.

(on rib tolerances) It says above that the rib thicknesses tolerance is $\pm$2 mm, but it also says that the hexagon center spacing is $\pm$0.5 mm. The idea is that the base of the core is positioned to 0.5 mm to give a good overall shape. The rest of the 2 mm is allowance for core tilt and shrinkage and deflection under load. If the core tilts so one rib is thin, a neighbor will be thick, so the overall honeycomb strength is preserved.

Outer edge wall thickness is the mean thickness of the edge wall or skirt around the perimeter of the honeycomb pattern. This wall is thicker than the average honeycomb rib to provide safety in handling and stiffness at the edge of the blank.

Inner edge wall thickness is the mean thickness of the edge wall or skirt around the honeycomb pattern at the Cassegrain hole. This wall is the same thickness as the average honeycomb rib.

Front faceplate thickness is the thickness of the front faceplate (frontplate) of the mirror as measured normal to the surface. The 28 mm thickness is set to provide a tolerable amount of quilting during the final stages of polishing. (Recent polishing advances have made this a very conservative number; the WIYN 3.5 m achieved 6 nm p-v quilting.)

Roughly 14 mm of extra glass is added at casting time to be sure that there will be enough glass to remove when the optical surface is generated. Errors in the finished faceplate thickness come from variations in blank geometry and variations in the height of individual cores, and are thus set by the casting process. The tolerance of ± 1 mm is for the core heights and does not represent the quality of the finished surface. Again, this tolerance is driven by the desire for uniform mass distribution and stiffness. The as-cast surface is a parabola to 0.3 mm rms, but the thickness uncertainty is ± 5 mm.

Back faceplate thickness is the thickness of the back faceplate (backplate) of the mirror measured normal to the nominally flat surface. If blank geometry forces back faceplate thickness outside the specified tolerance, we may choose to generate in a very long radius sphere rather than the nominal flat surface to improve backplate thickness uniformity.

Back ventilation hole diameter is the size of the hole in the back faceplate at the bottom of each honeycomb cell. This hole is used for air ventilation of the finished mirror. The hole is cast around the area used for the SiC bolts that prevent the cores from floating in the molten glass. The holes are cast with a 3.5 inch diameter. A 45 degree chamfer, 1/8 inch deep is applied to the outside face while the mirror is being finished. There many be special holes in partial hexagon cores at the edge of the mirror.

Outer front faceplate overhang is the amount the frontplate extends beyond the outside of the outer edge wall. Note that the overhang is specified from the outside of the edge wall and not the mid-thickness of the edge wall. The edge of the faceplate should be generated to the specified diameter not to the specified overhang. The overhang dimension is built in during the casting process.

Outer back faceplate overhang is the amount the backplate extends beyond the outside of the outer edge wall. Note that the overhang is specified from the outside of the edge wall and not the mid-thickness of the edge wall. The edge of the backplate should be generated to the specified diameter not to the specified overhang. The overhang dimension is built in during the casting process. The outer faceplate and backplate have the same overhang to facilitate handling with an edge band.

Inner front faceplate overhang is the amount the frontplate extends beyond the inside of the inner edge wall. Note that the overhang is specified from the inside of the edge wall and not the mid-thickness of the edge wall. The edge of the faceplate should be generated to the specified diameter not to the specified overhang. The overhang dimension is built in during the casting process.

Inner back faceplate overhang is the amount the backplate extends beyond the inside of the inner edge wall. Note that the overhang is specified from the inside of the edge wall and not the mid-thickness of the edge wall. The edge of the backplate should be generated to the specified diameter not to the specified overhang. The overhang dimension is built in during the casting process. The inner backplate overhang is made smaller to facilitate mounting of the wide field corrector.

Projected width of the faceplate bevel is the width of the strip at the edge of the mirror surface used for the bevel as viewed along the optical axis. Since we plan to use a radius bevel, the width implies that the bevel will cut less than 90 degrees out of the corner of the faceplate, compared to the included angle which is roughly 105 degrees.

Fillet radius on faceplate bevel is the radius of the diamond tool used to radius the inner and outer edges of the mirror faceplates. This radius will be placed to bisect the angle of the corner since it covers less than 90 degrees.

Fillet radius on ribs is cut on each of the hex cores before installation. Each core also has a slight taper toward the bottom of a rib.

Fillet radius on MERPs (mirror edge refractory pieces) is cut on each of the MERPs pieces before installation. This radius is larger than the core fillet to reduce the stress concentration if the mirror were ever lifted by the edge.

Front faceplate hole diameter is the physical diameter of the hole generated in the front faceplate of the mirror. The sides of the hole will be parallel to the optical axis. The faceplate bevel will make the useful area around the Cassegrain hole a slightly larger diameter. The faceplate hole should be centered to ± 0.5 mm with respect to the outer faceplate diameter (better if possible). The optical axis will in turn be centered on the faceplate hole.

Back faceplate hole diameter is the physical diameter of the hole generated in the back faceplate of the mirror. The sides of the hole will be parallel to the optical axis. The backplate hole is larger than the front to allow more clearance for the wide field corrector (on 6.5 meter only).

Outer faceplate diameter is the physical diameter of the outside edge generated on the front and back faceplates of the mirror. The edges will be parallel to the optical axis. The faceplate diameter should be centered on the mean honeycomb geometry.

Outer wall mid-diameter is the mid-thickness diameter of the outer wall of the honeycomb structure. Mid-thickness refers to the center of the glass rib rather than the mean of a variable diameter, nonetheless the outer wall should be circular to within the diameter tolerance.

Inner wall mid-diameter is the mid-thickness diameter of the inner wall of the honeycomb structure.

Clear optical aperture refers to the diameter of the polished surface of the mirror. The clear aperture is smaller than the Outer faceplate diameter because of the bevels on the faceplate.

Focal length refers to the parabolic surface or the vertex sphere.

Focal length of the core tops is longer than the focal length of the optical surface so the front faceplate will have a uniform thickness normal to the surface.

Inner and Outer thickness at R=... refers to the vertical thickness or depth of the blank at the specified radius from the optical axis. These dimensions do not account for material removed by the beveling operations. The cast dimensions are larger to allow for material removed from the front and back faceplates.

Generate indicates that the dimension will be determined by diamond grinding. All generated surfaces are planned to be polished for stress relief and inspection purposes. The front bevels also need polished to avoid trapping opticoat or other contaminants.

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