UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY TECHNICAL REPORTS

NO. 43

TMT PRIMARY MIRROR COVERS

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Santa Cruz, California

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Jack Osborne, October 1984

PURPOSE:

1. The covers should substantially reduce dust getting on the primary mirror when the telescope is not in use.
2. The covers should not degrade telescope performance while open.
3. The covers should offer a measure of protection from falling objects when closed.
4. The covers won't do the following:
   a. allow walking.
   b. allow the primary mirror to be stopped (i.e. they don't function as an iris)
   c. provide a tight thermal package around the primary mirror and cell.
   d. capture a great amount of water.
5. Further, the covers should be lightweight, simple and inexpensive.
6. Also, the cover system should include a mechanism for maintaining correct tube balance at all times.
7. The covers must be closeable during a power failure.
8. The covers will be closed or opened only when the telescope is at the zenith, and will retain their integrity as the telescope is moved to the horizon.

CONCLUSIONS:

We have invented a primary mirror cover system which will be described in this report. It meets all the above requirements. This report details the features of the system, points out areas where further work might be done, and briefly mentions alternative cover systems.

List of Figures:

10. Panel weights and link loads.
12. Alternate cover system.

GENERAL DESCRIPTION:

The primary mirror cover is made up of six panels. Each panel is a parallelogram linkage with a thin skin of aluminum on its top surface. See Figures 1,2,&2B. The folding panels will be stowed between the elevation ring and the mirror cell. Figures 3,4. The packaging is rather tight and part of the folded panel remains inside the elevation ring at the two Nasmyth sides of the elevation ring. This is 4 cm from a 1 degree off-axis light beam. The covers are driven by air motors. One motor drives each of the six panels (six motors). This air system must have enough stored compressed air to close the cover during a power failure. Each motor drives a shaft located just above the mirror cell. This shaft extends across the base of the panel and drives all six guide rail rollers. Figure 7. The middle two guide rail slides control the moving ends of 7-bar linkages. The next two guide rail slides (one on either side of the two central ones) control the moving ends of 5-bar linkages. The outer two guide rail slides control the moving ends of 3-bar linkages. The motion of all six panels can be simultaneous since no overlap at the joints is intended. Opening or closing time will be on the order of 1 minute. Once closed, twelve latches on the Cassegrain tower will engage the extended cover (Figure 6). Suitable limit switches and control logic will be provided. The latches will be pneumatic since power-failure mode is required. The opening and closing sequences are done while the telescope is pointed at the zenith. This reduces the loads on the drive components. Once latched to the central tower, the telescope may be moved to the horizon for storage or whatever. The mirror covers are shown with the top pivot of the parallelogram moving down (and hence the center of gravity also moves down) as the covers are closed. See Figure 5. An inversion of this scheme is possible, that is the top pivot can be fixed and the lower pivot can be moved up to close the covers. There may be thermal or other reasons for doing this. The design is flexible in this area. Each panel of the cover will weigh 330 lbs and the required guide rails and motors will weigh 500 lbs. There are six sets, so the total weight of the cover system is 5000 lbs. The moving weight 2000 lbs moves 20 inches and so a counter-moving weight must be provided. If this weight is mounted on the elevation ring, where 10 feet of travel is available, then the weight is 330lbs.(3300 ft-lb)

The covers never come closer than 2.5 cm to the primary mirror segments. The nominal skin thickness is .06 in (1.5 mm). A very crude drop test was done on a 30"x30" panel on a raised wooden support. A 12" crescent wrench was dropped 50 feet and did not penetrate this panel (12" crescent wrenches weigh 2 lbs). The kinetic energy was converted to accoustical energy and a slight puncture in the aluminum panel . This material was 6061-T6, a fairly brittle aluminum alloy. Further study should be done to select a softer material. Also, since the weight of the skin is much of the cover weight, and dictates the loads on the guide rail supports, a thinner skin might be investigated. .06" was picked arbitrarily. Figure 10 lists weights.

The panels use piano hinge strips for the top and middle pivots for the linkages. These have air gaps (dust gaps) and since the panels fold up when opening, provision has been made to catch any dust falling down into the three valleys. See Figure 8. These channels must be periodically cleaned.

An alternate geometry for mirror covers was proposed in July 1980 (TMT Report 39) which had 6 panels hinged inside the top of the elevation ring. See Figure 12. It is now felt that in the open position, these will have adverse effects on the telescope due to wind loading. The covers stowed just above the primary mirror cell (and only 1/3 as long when folded up) minimize this effect although they are considerably more complicated structures. Figure 4 illustrates this.

Water: The geometry of this cover design has a flaw. That is, if the joints are all water tight and the covers get rained on, the valleys will fill up with water. This added weight will damage the structure. Therefore, the covers will not protect the mirrors from rain. The mirrors will be protected from a light fog and occasional oil or cryogens falling from above. If rain water protection is essential, then the telescope should be stored horizontally when not in use.

Future work: No attempt was made to optimize the linkage elements, but instead, larger members were selected for this first design. The elements of the parallelogram are statically indeterminate. If possible, an analysis should be made to set the size of the members and the pivots. As mentioned above, the upper skin might be optimized, both material and thickness. The guide rail supports are nominally 4" x 4" built-up "I" beams. This gives a section moment of about 19 in_4. The central 7-bar linkage imposes a 300 lb lateral load to the guide rail and the deflection of the rail is .05" (.5" at the latch) The upper attachment is a bolted bracket to the underside of the elevation ring and the lower attachment is a sliding joint, see Figures 7a, 7b. These elements are a large fraction of the mirror cover system and could stand some optimizing.

Interface: The vertical elements which make up the guide rails must support lateral forces at mid span and must resist bending. The upper connection to the elevation ring can be rigid but the connection at the bottom, to the mirror cell can be a sliding joint. That is, it won't attach to the mirror cell so that loads are transmitted from the cell to the ring in a direction parallel to the optical axis of the telescope tube. They will however, transfer some of the weight of the covers directly to the mirror cell, when looking at the horizon. The structural engineers should be aware of this, since this affects optical collimation. About 3000 lbs is now added to the top set of mirror cell nodes when the telescope is horizontal.

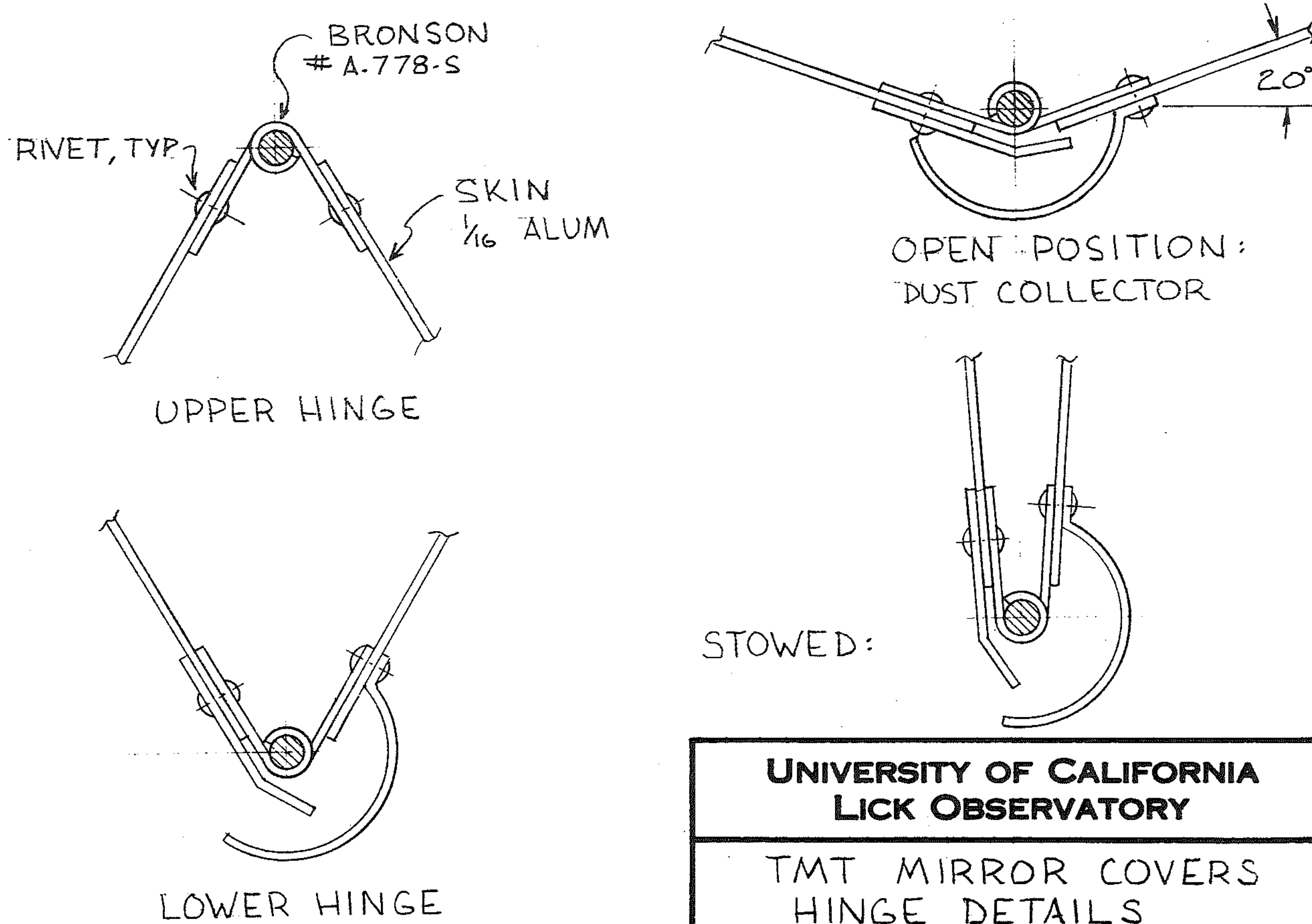
Dynamics: While the covers are folded up during observing, there may be unwanted natural frequencies (rattles) present. It may be necessary to provide a device or system to force the covers closed against rubber stops. This is easier to handle as a retro-fit than to predict what the resonances will be before hand.

Re-aluminizing: Since the covers don't overlap each other or "nest" when closed, it may be possible to open only one panel while mirrors are removed and replaced for re-aluminizing, thus offering some protection for the other mirrors.

Cassegrain tower: It is not clear whether there will be a permanent structure outside of the tower. This awaits the design of the Cassegrain baffle design. If it is decided to have some permanent stuff outside the tower (partially shadowing the inner ring of segments) then the design of the covers becomes simpler. That is, the furthest link of the parallelogram gets shorter and stowing becomes more compact.

Optimizing the linkage: Figure 9 shows how the parallelogram linkage angle affects the guide rail loads and the cover extension. Guide rail loads (lateral) are plotted versus extension. 20 degrees (40 degrees between 2 links) was selected because the loads get very much higher for very little increase in extension. This value then determined the extra extension added to the last panel in the linkage. This extra part is what is stowed inside the elevation ring (only at the elevation axis flats).

See Disc I12 mirror cover



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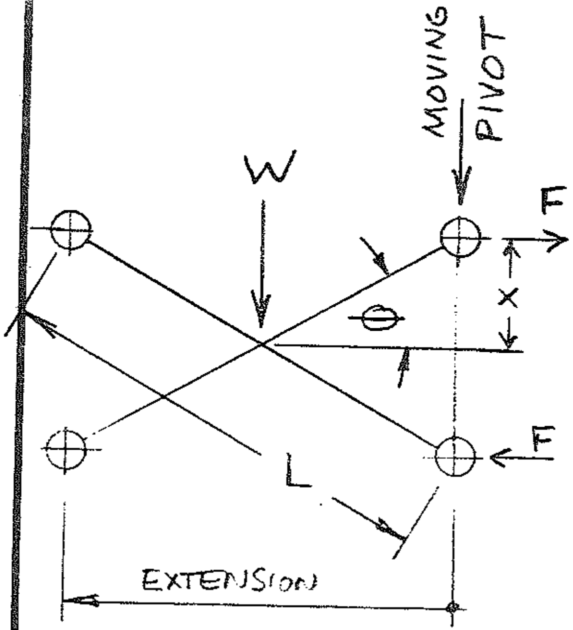
TMT MIRROR COVERS
HINGE DETAILS

DES'N JO	10/16/84	SCALE: FULL	DWG. NO. FIG. 8
DRW'N	/ /		



EXTENSION = L cos θ

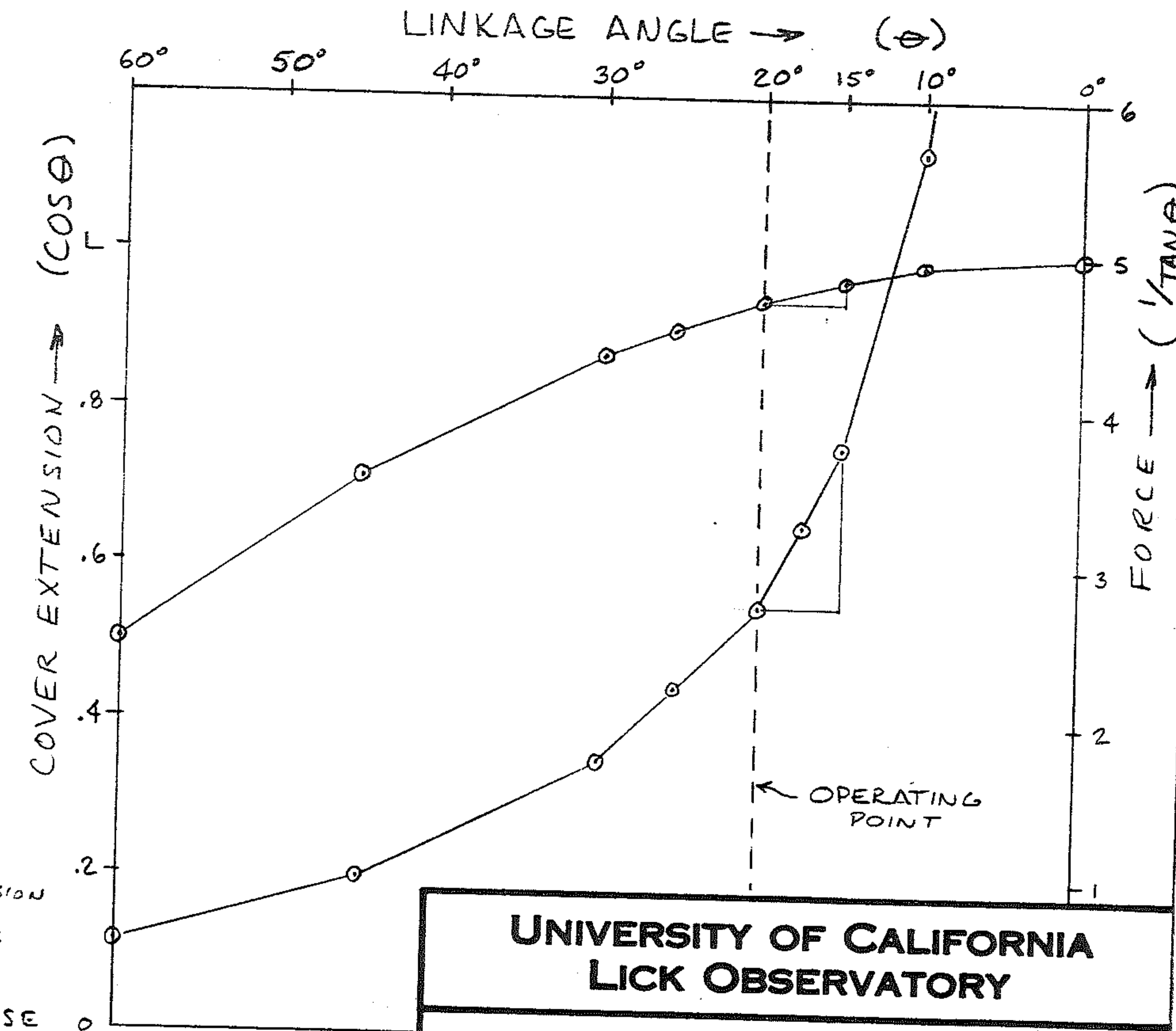
$$F(2X) = W\left(\frac{L}{2}\right)\cos\theta$$

$$X = \left(\frac{L}{2}\right)\sin\theta$$

$$F = \left(\frac{W}{2}\right)\frac{1}{\tan\theta}$$

AT 20°, 430 cm EXTENSION & F ~ 300 lbs

AT 15°, 12 cm INCREASE BUT F ~ 400 lbs.



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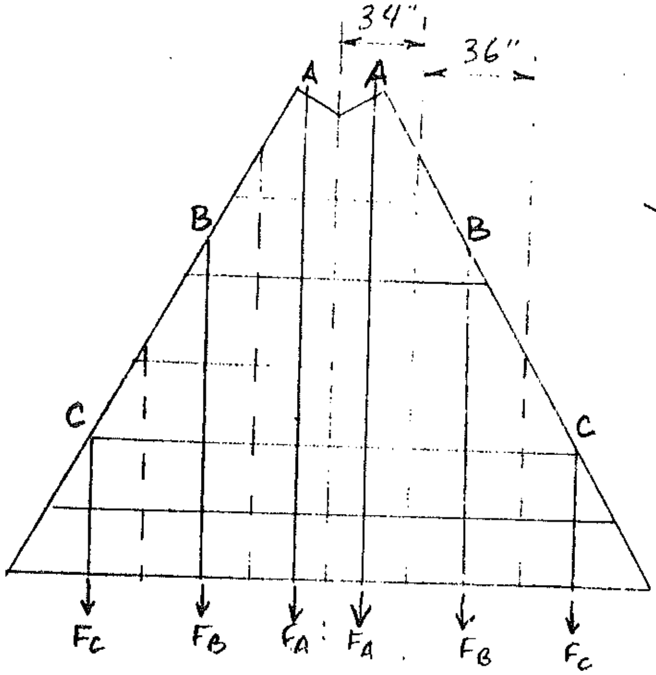
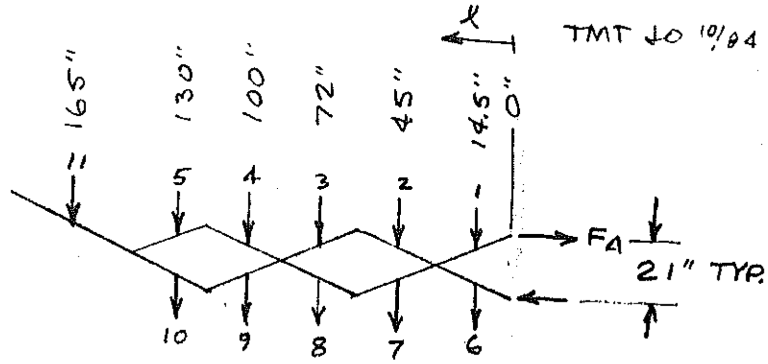
TMT MIRROR COVER
GUIDE RAIL FORCE VS. EXTENSION

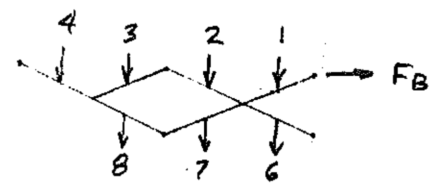
DES'N JO	10/16/84	SCALE: N/A	DWG. NO. FIG 9
DRW'N	/ /		

TMT 10/04

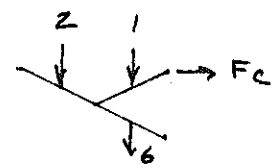




Linkage A, 7-bar linkage



Linkage B, 5-bar linkage



Linkage C, 3-bar linkage

PANELS: 1/16" Alum: #1-5 are 34"x30" = 6.4 lbs
#11 is 34"x42" = 8 lbs.

Links: 3"x 1/2" x30" = 4.5 lbs. #1, 6-10
2" x 1/2" x 48" = 4.8 #11 only.
3"x 1/2" x30" TAPERED TO 0" ◺
#2,3,4 2.4 lbs.

Derivation of F_A: $F_A \times 21" = \sum W_i \cdot \ell_i$

	Panels			Links	
1	6.4# x 14.5" =	93 in-lb	1	4.5# x 14.5" =	65 in-lb
2	6.4 x 45 =	288	2	2.4 x 45 =	108
3	6.4 x 72 =	461	3	2.4 x 72 =	173
4	6.4 x 100 =	640	4	2.4 x 100 =	240
5	6.4 x 130 =	832	5	0 x 130 =	0
11	8 x 165 =	1320	6	4.5 x 14.5 =	65
	40 lbs.	3634 in-lb	7	4.5 x 45 =	203
			8	4.5 x 72 =	324
			9	4.5 x 100 =	450
			10	4.5 x 130 =	585
			11	4.8 x 165 =	743
				39 lbs	2956 in-lb

Panels ↑
(50% of weight
55% of moment)

Links ↑

WEIGHT SECTION A ≅ 80 lbs
Moment " ≅ 6600 in-lb

$F_A = 6600 \div 21 = 314$ lbs

F_B:

26 lbs + 1500 in-lb panels
25 lbs + 1200 in-lb links

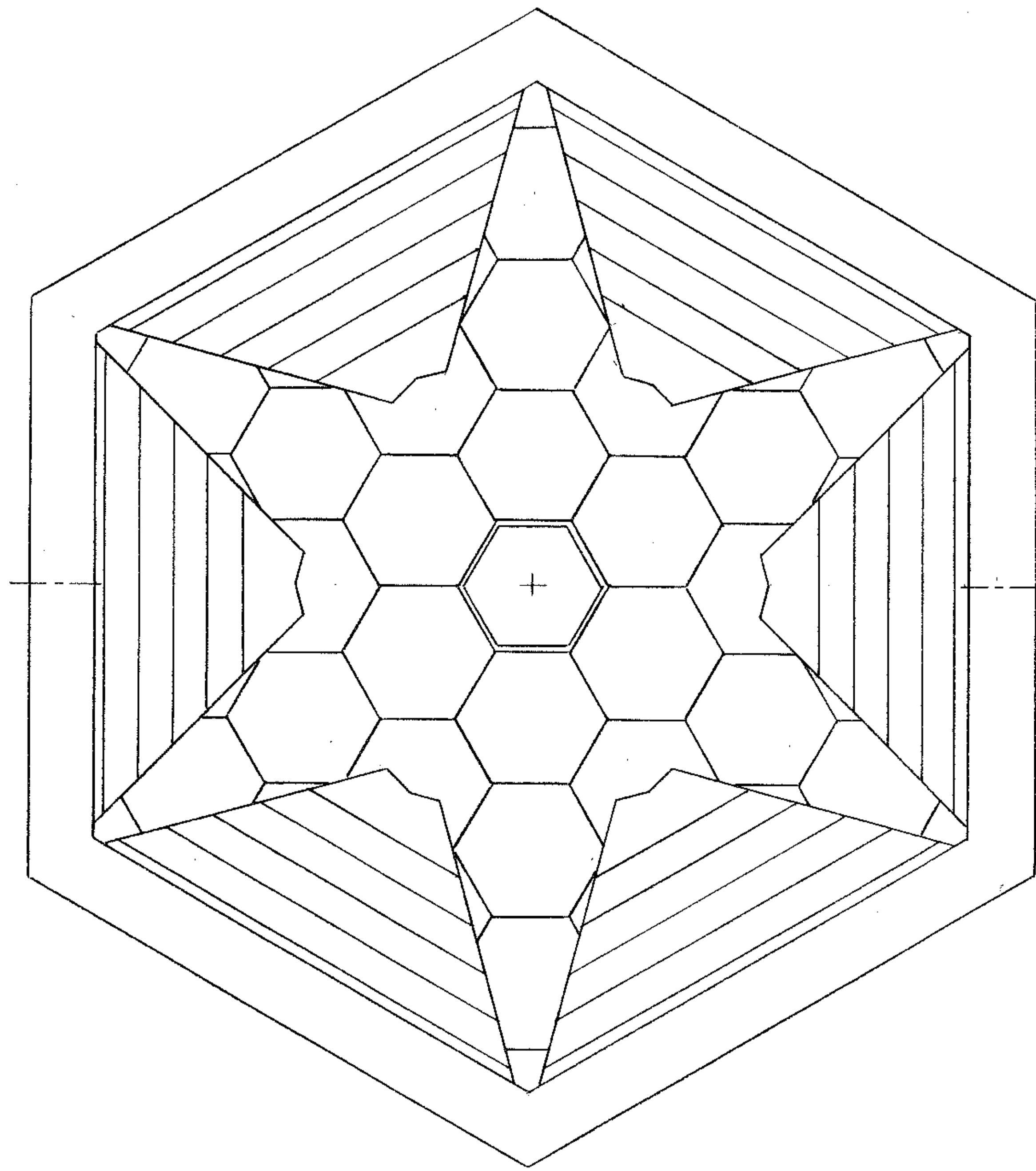
Weight Section B = 51 lbs
MOMENT " = 2700 in-lb

F_B = 129 lbs.

F_C: 24 lbs, 620 in-lb totals, F_C = 30 lbs.

TOTAL COVER: (2A+2B+2C) x 6 = (310 lbs) x 6 = 1860 lbs, all 6 covers

FIG. 10 PANEL WEIGHTS & FORCES



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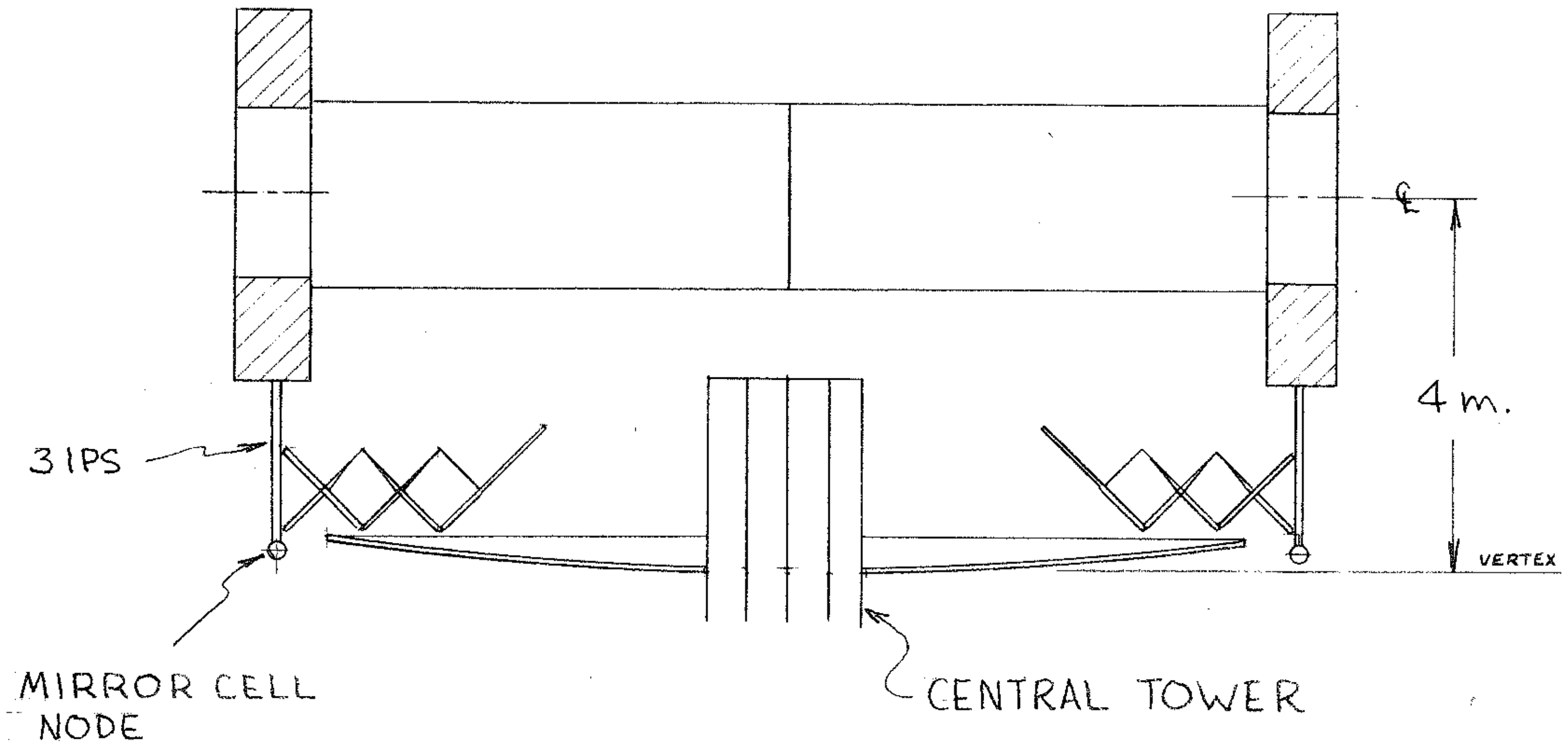
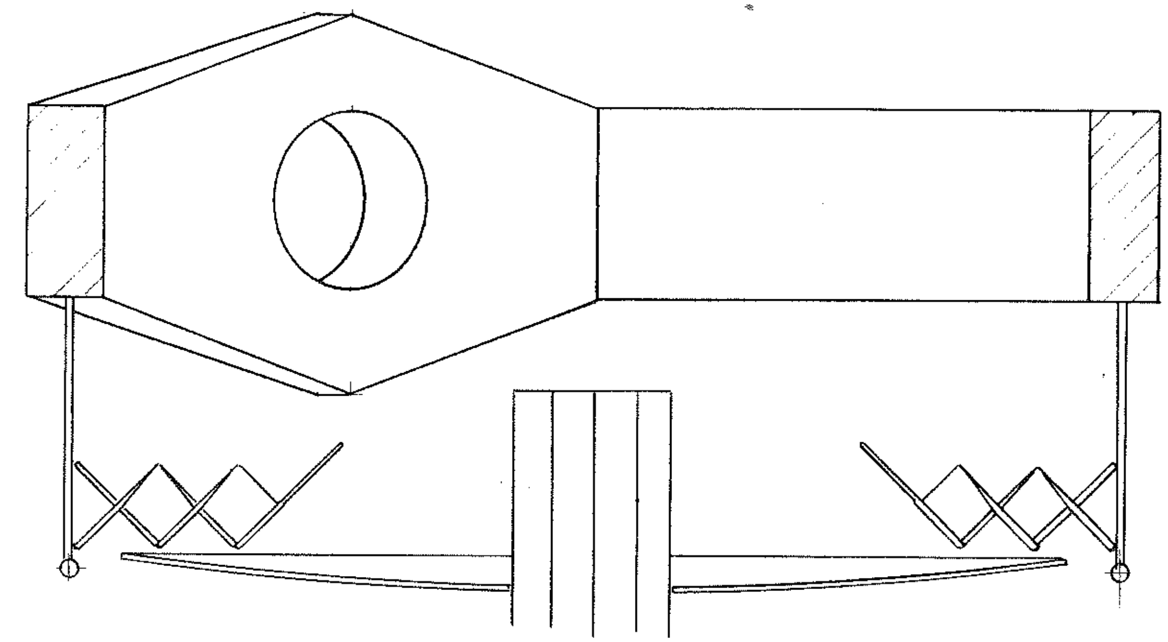
TMT MIRROR COVERS
PARTIALLY OPEN

MARK	DATE	DRW'N	CH'KD	REVISION

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/16/84	SCALE 1/2" = 1 m	FIG. 1
CHK'D BY	DATE	



VIEW 1 - THROUGH ELEVATION AXIS



VIEW 2 - ROTATED 60° TO VIEW 1

MARK	DATE	DRW'N	CH'KD	REVISION

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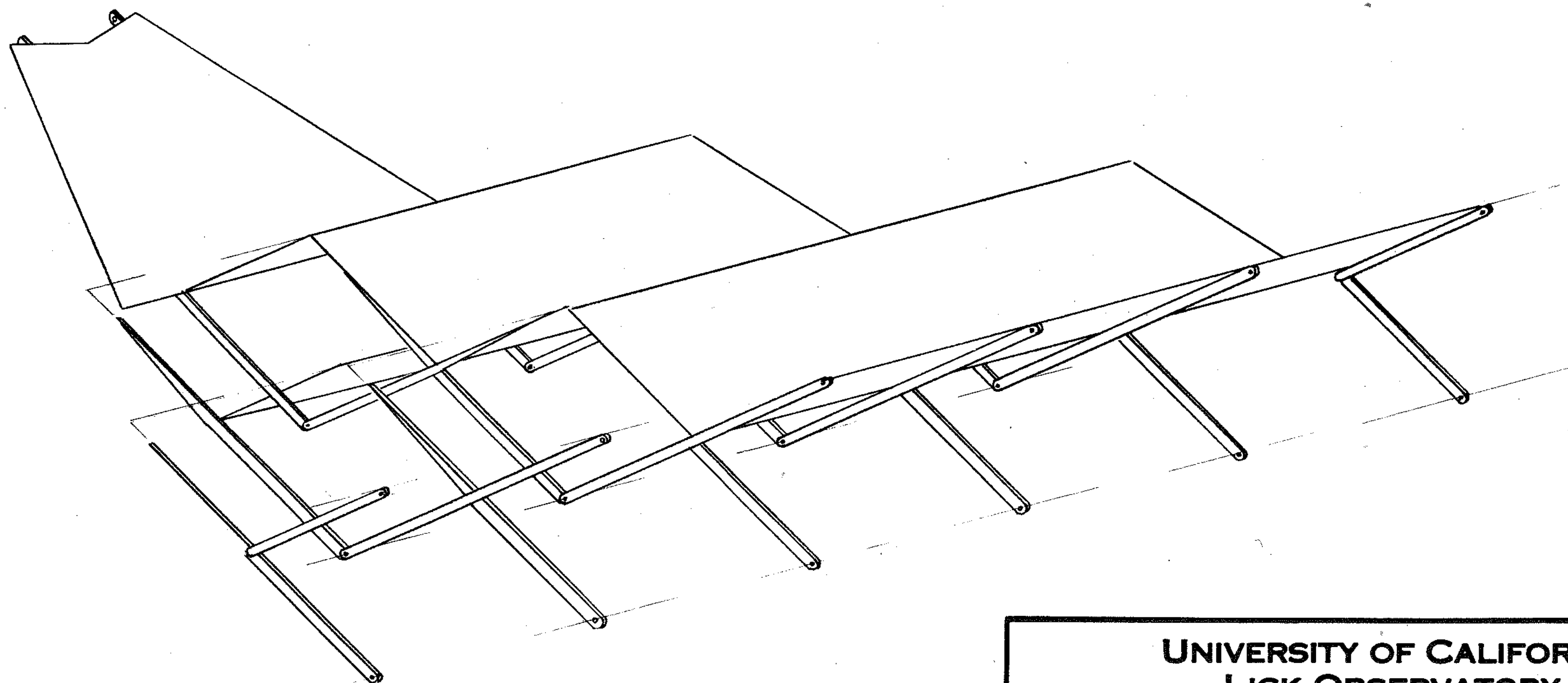
TMT MIRROR COVERS
SIDE VIEW

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/16/84	SCALE ½" = 1 m.	FIG. 2
CHK'D BY	DATE	



MARK	DATE	DRW'N	CH'KD	REVISION

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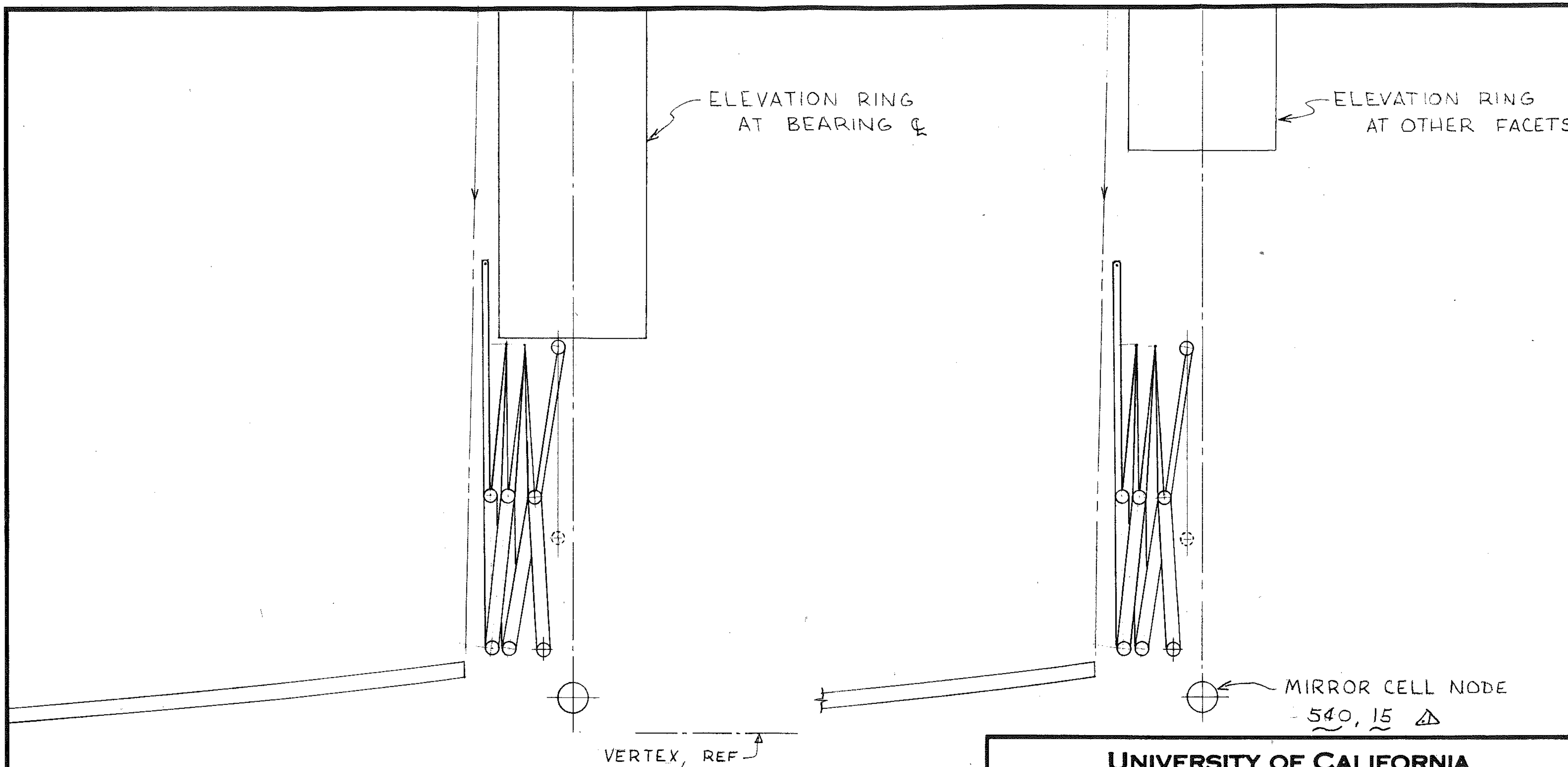
TMT MIRROR COVER
~ OBLIQUE VIEW

DES'N BY	APPROVED BY	DWG. NO. FIG. 2B
DRW'N BY JO 10/19/84	SCALE N/A	
CHK'D BY	DATE	



MARK	DATE	DRW'N	CH'KD	REVISION
.1	10-31-84	JO		540, 15 WAS 550, 17.5

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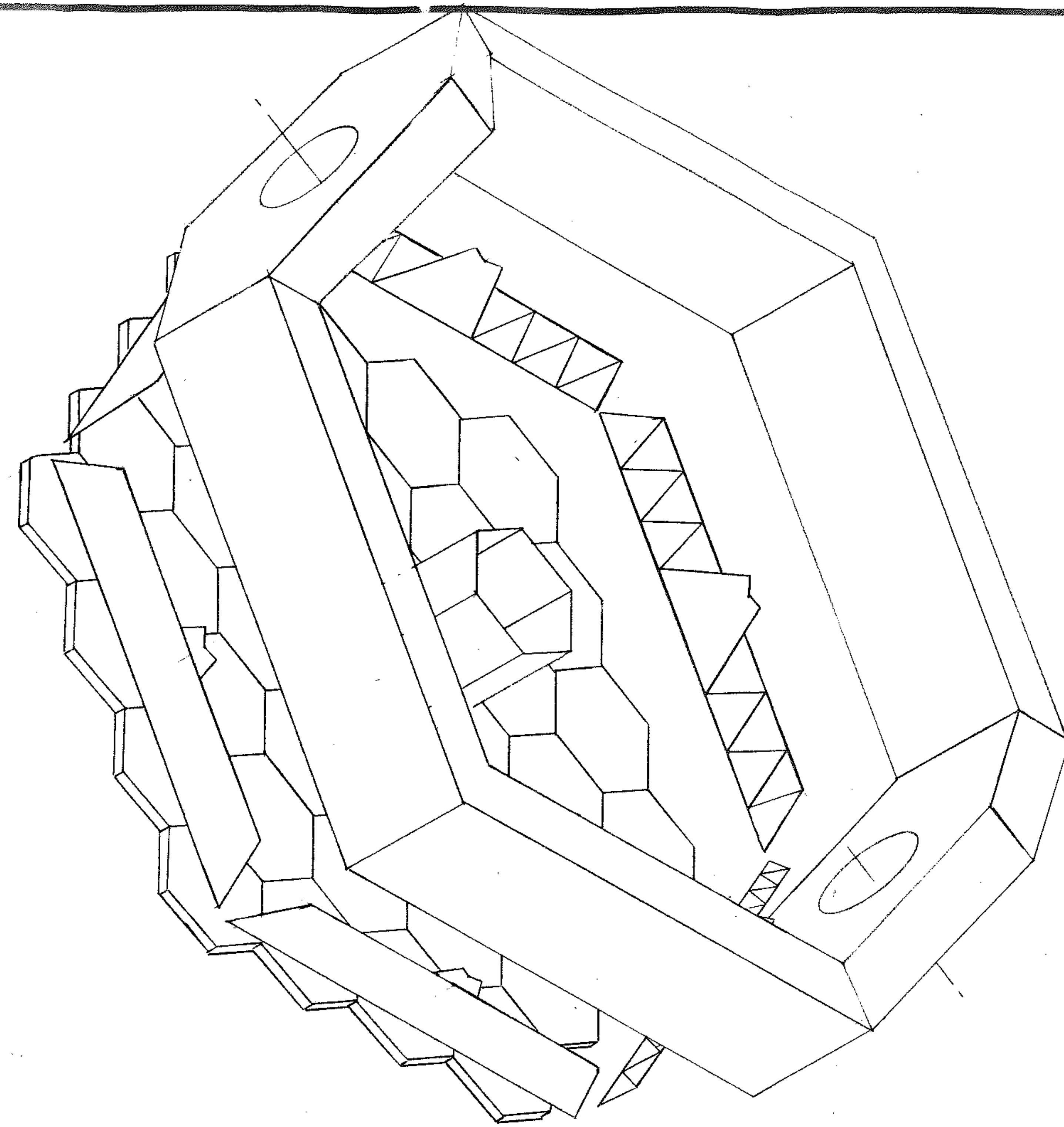
TMT MIRROR COVER
OPEN ("STOWED")

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/19/84	SCALE: 1/20TH	FIG. 3.1
CHK'D BY	DATE	



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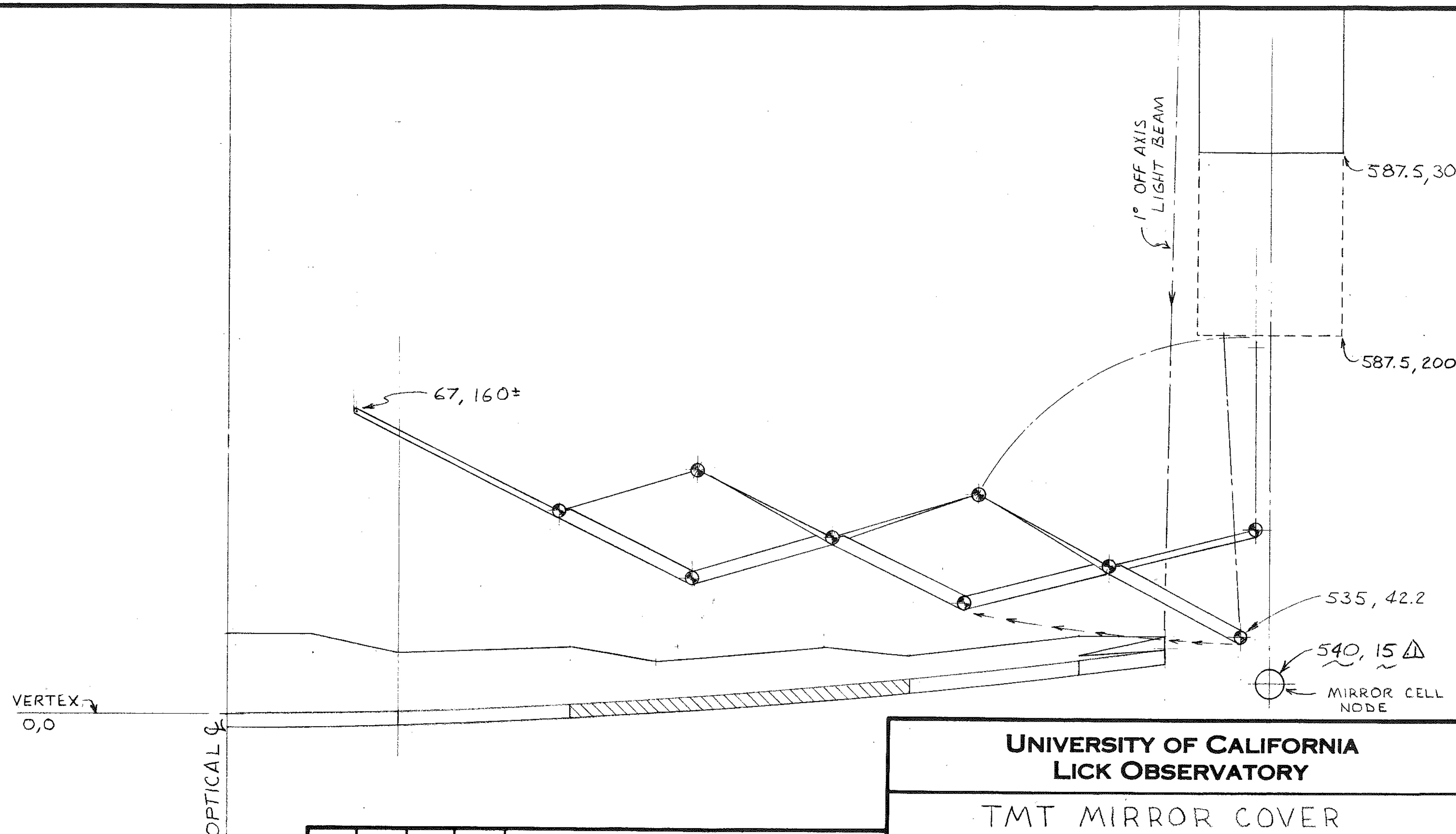
TMT MIRROR COVERS
~OBLIQUE VIEW~

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/18/84	SCALE: NONE	FIG. 4
CHK'D BY	DATE	



MARK	DATE	DRW'N	CH'KD	REVISION
.1	10-31-84	JO	JO	540, 15 WAS 550, 17.5.

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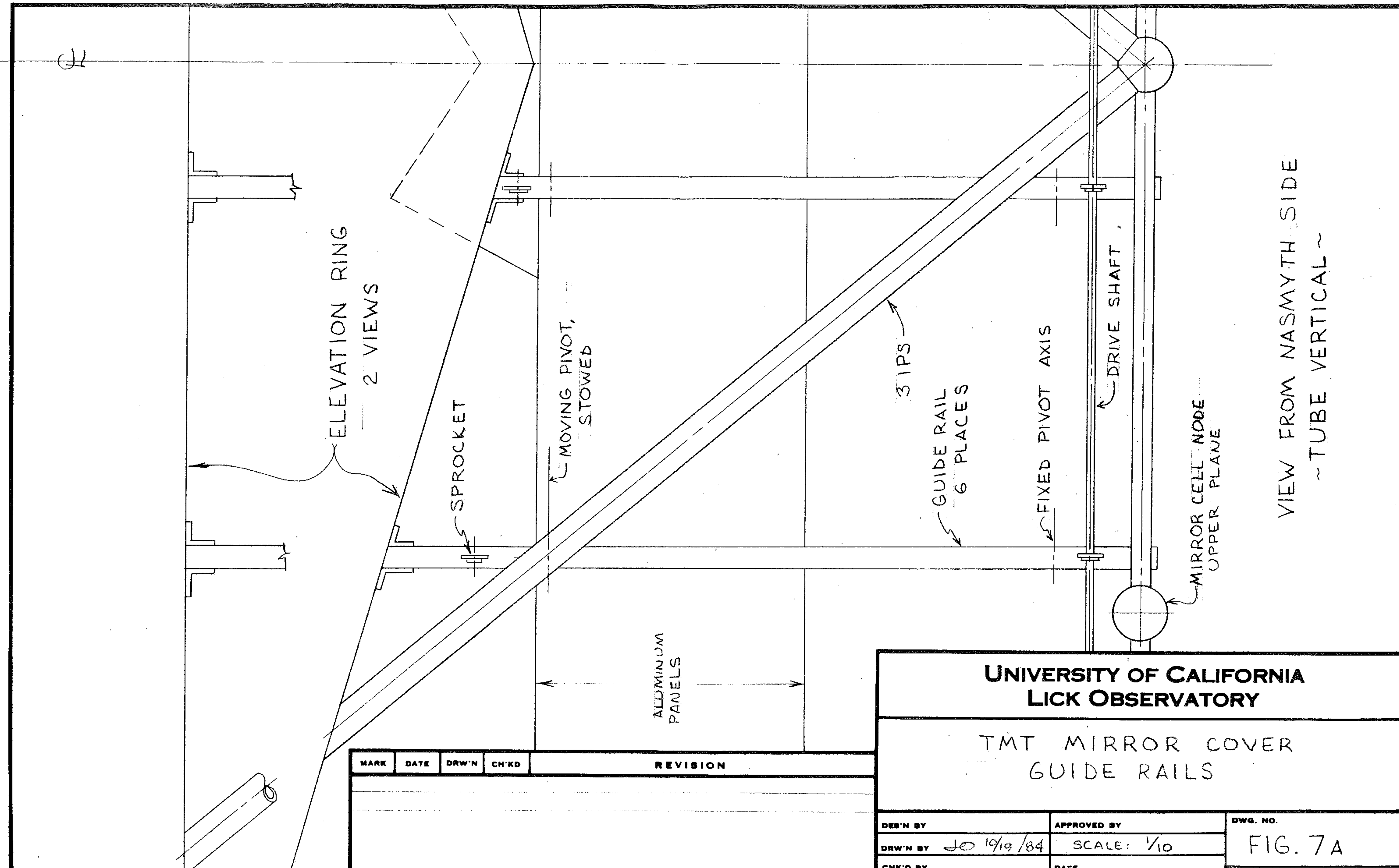
TMT MIRROR COVER
~CLOSED~

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/18/84	SCALE: 1/20 TH	FIG. 5.1
CHK'D BY	DATE	



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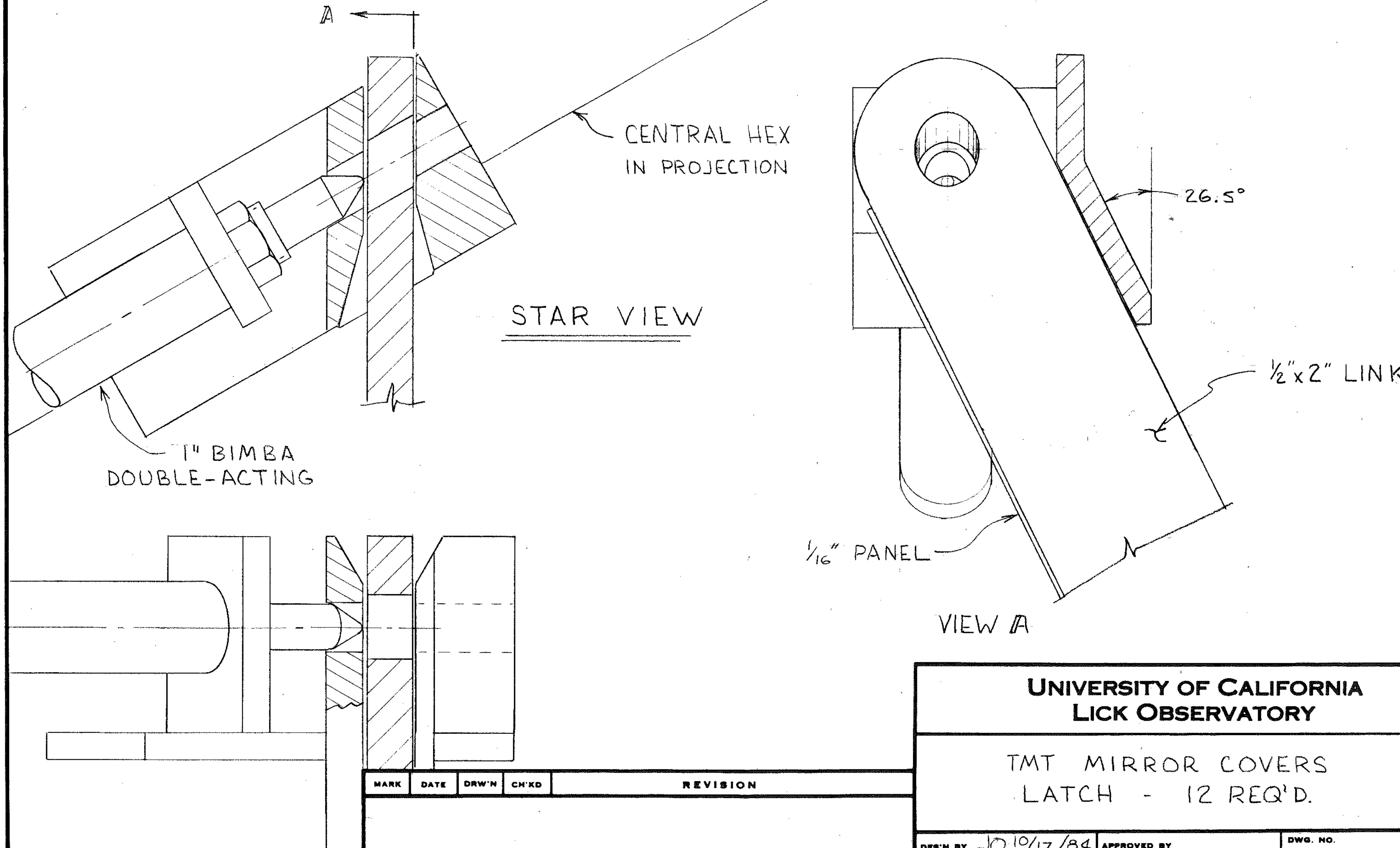
TMT MIRROR COVER
GUIDE RAILS

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/19/84	SCALE: 1/10	FIG. 7A
CHK'D BY	DATE	



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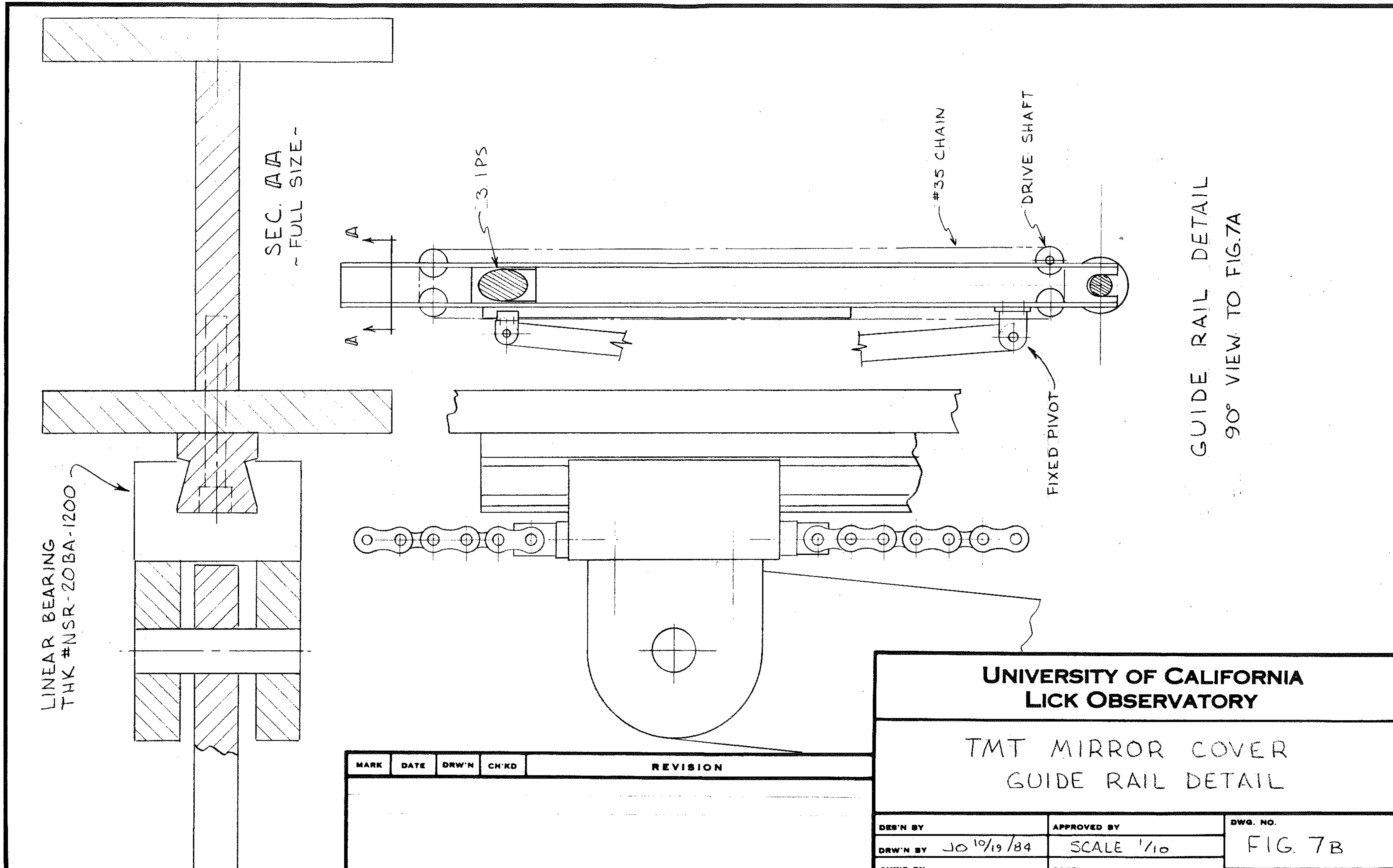
TMT MIRROR COVERS
LATCH - 12 REQ'D.

DES'N BY JO 10/17/84	APPROVED BY	DWG. NO. FIG. 6
DRW'N BY	SCALE: FULL	
CHK'D BY	DATE	



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TMT MIRROR COVER
GUIDE RAIL DETAIL

DES'N BY	APPROVED BY	DWG. NO.
DRW'N BY JO 10/19/84	SCALE 1/10	FIG. 7B
CHK'D BY	DATE	