UNIVERSITY OF CALIFORNIA

LICK OBSERVATORY TECHNICAL REPORTS

No. 49

MOSAIC PROJECT

Jack Osborne, Dave Hilyard, and Bruce Bigelow

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ABSTRACT

We designed, built, and tested a mosaic of four grating blanks at several position angles relative to gravity. The blanks were adjusted to within 1 arcsec of each other and stayed within that tolerance. The testing instrument was a Zygo Model GH interferometer with Polaroid camera attachment for permanent output.

The project was begun during the design phase of the spectrographs for the Keck 10-Meter Telescope. The so-called MODRES Spectrograph needed a 2 × 2 array of 6 in. × 8 in. gratings. The HIRES Spectrograph needed a 1 × 3 array of 12 in. × 16 in. gratings and several 2 × 1 arrays of 12 in. × 16 in. gratings. The test consisted of a 2 × 2 array of 6 in. × 8 in. grating blanks. The blanks that were ordered were fine ground Zerodur from Schott Glass Company in Duryea, Pennsylvania. Pockets were machined into the blanks and Invar attachments glued in. The polished blanks were supported from an aluminum subplate and the subplate was supported by a two-axis rotating head.

The Keck instruments were still being designed and so the actual performance specifications were not well established. One year later, it now appears that all possible camera configurations and scientific goals can be met using a passive support such as we have built. We briefly describe alternative designs.

We also show the work in progress for the HIRES mosaics.

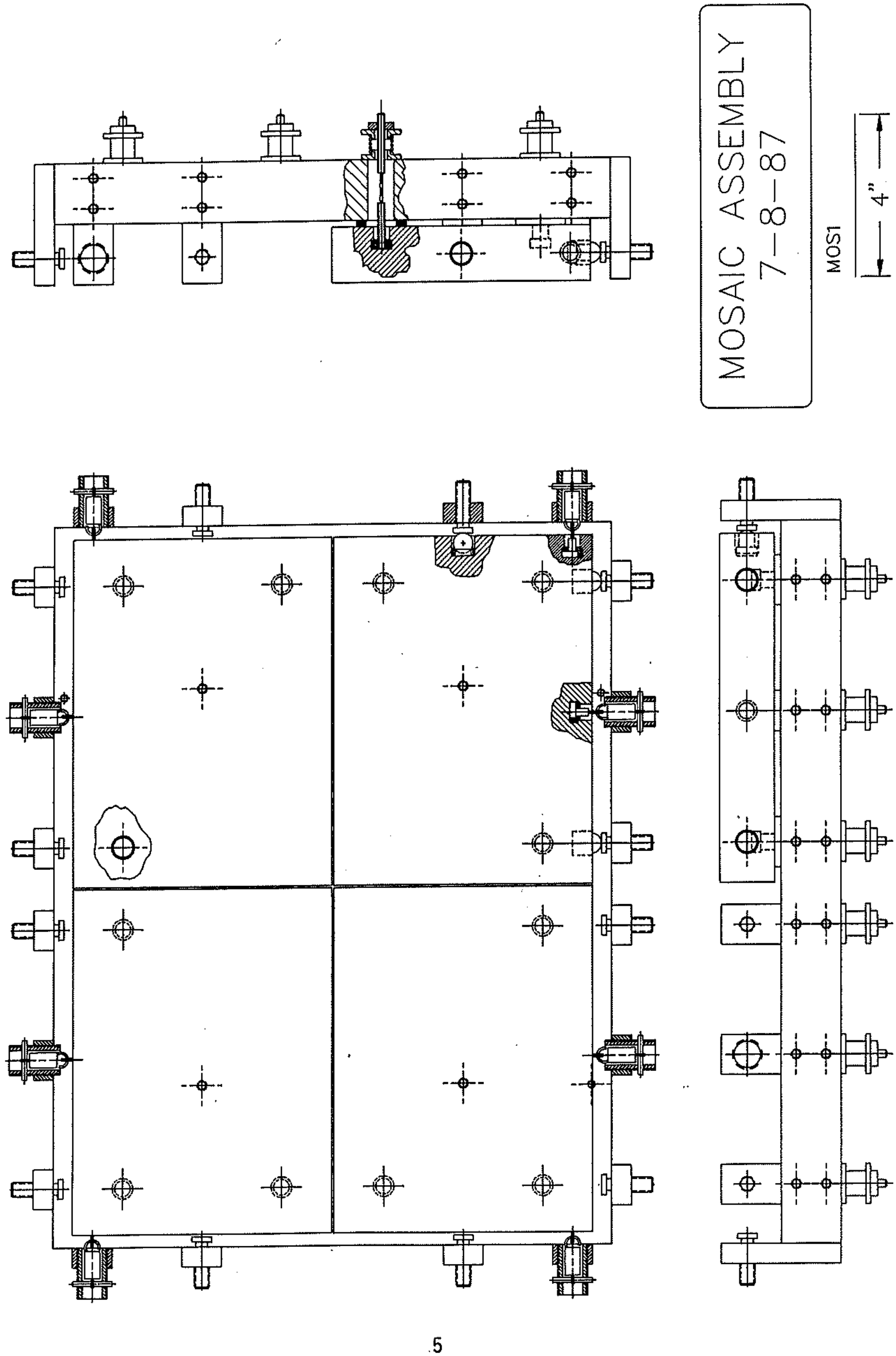
CONTENTS

1. THE FINAL DESIGN

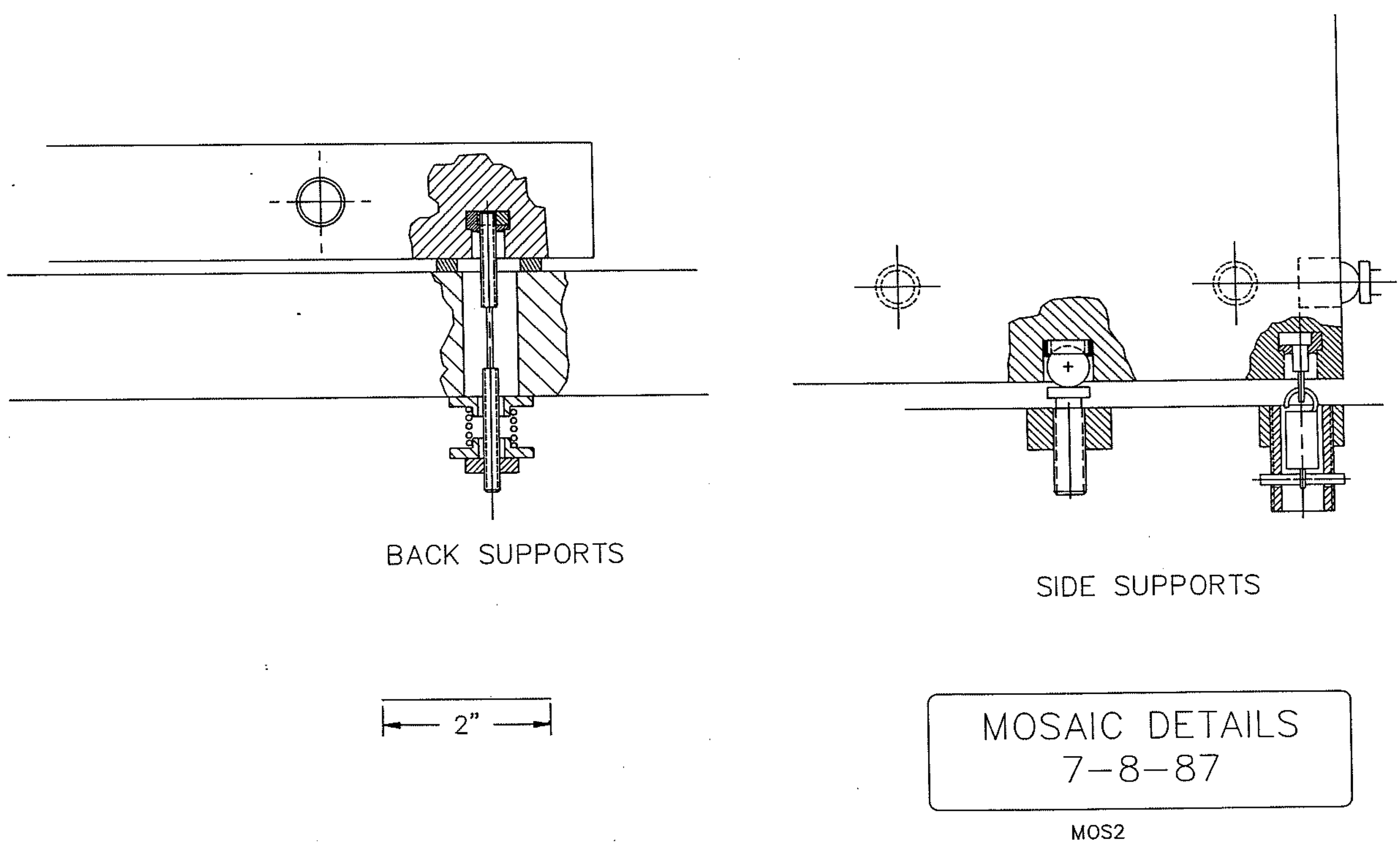
The figure on the next page shows the final assembly drawing. The gratings are arranged in a 2 × 2 mosaic. The gratings (blanks) are separated from the subplate by round Zerodur spacers. Although we used shims under the spacers, the spacers could have been custom lengths. The spacers are optically contacted to the gratings. The gratings are held against the subplate by flexible members and coil springs. The detail drawings show this. The Invar inserts in the grating pockets are glued in place with 5-minute epoxy. The side support is a steel ball against an adjusting screw. This is detailed too. Tension springs pull the grating against the side supports. The design load at each support interface is set so that the minimum is 1 g and the maximum is 2 g.

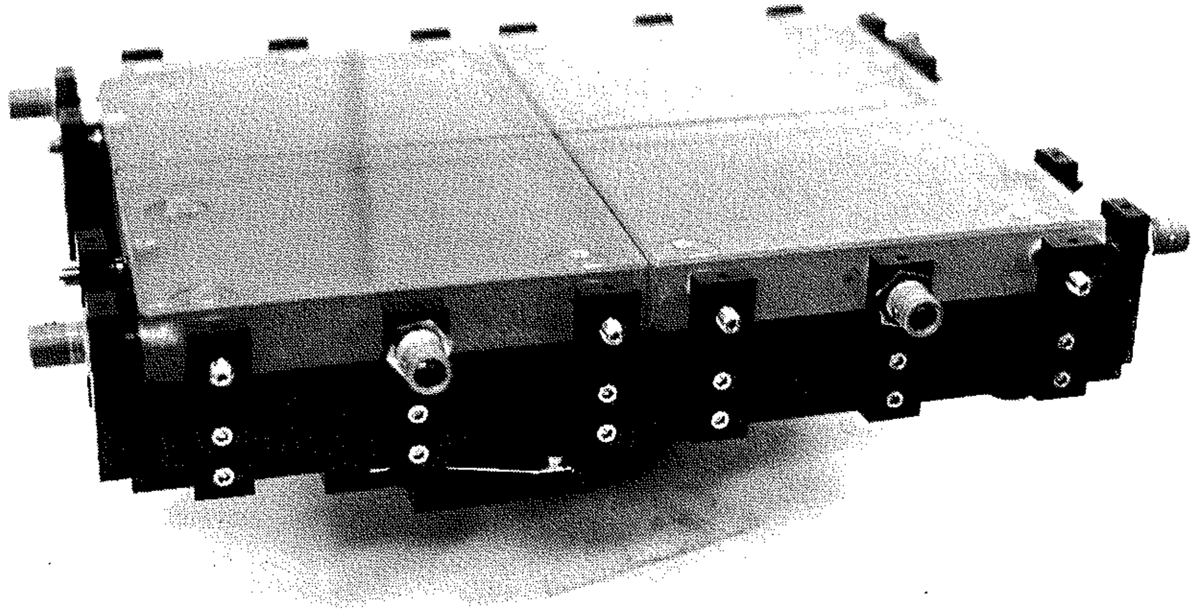
The photographs show the attachment to an adapter which mates with the two-axis rotator head.

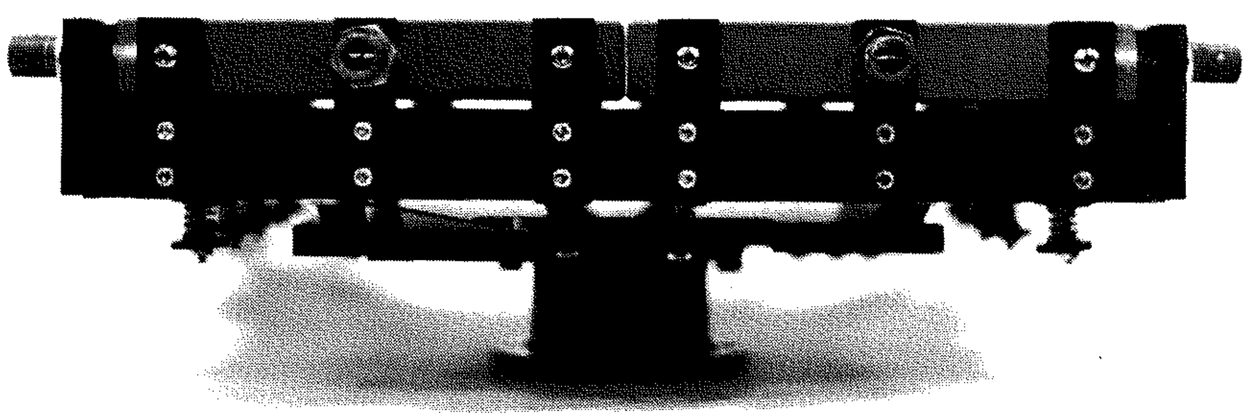
Section 4 describes the deflection of the subplate and the nature of the passive support system.



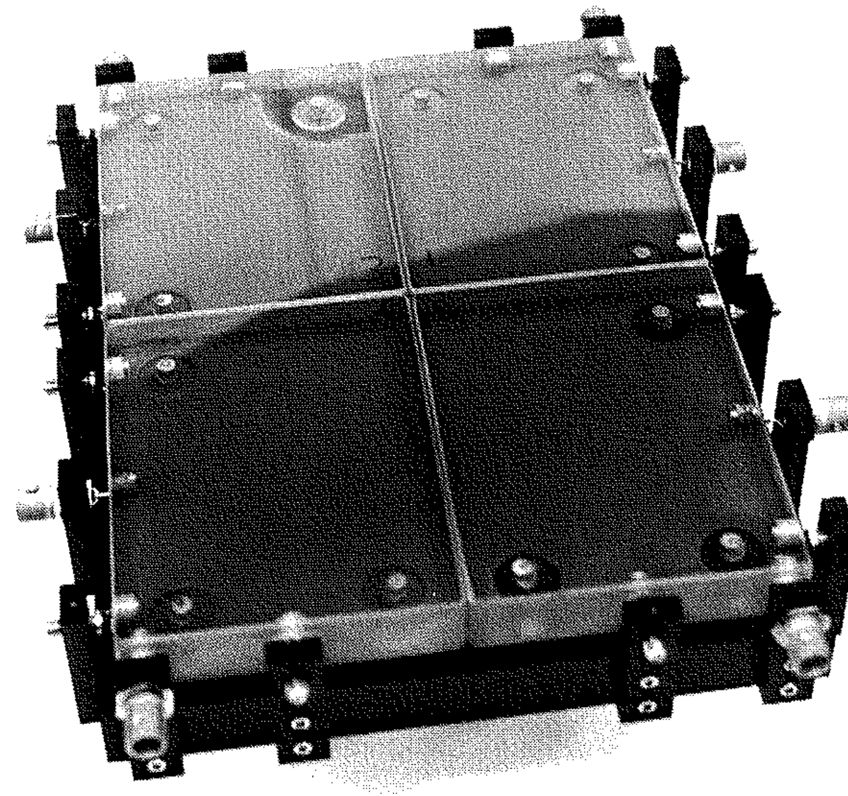
MOSAIC ASSEMBLY
7-8-87
MOS1
4"

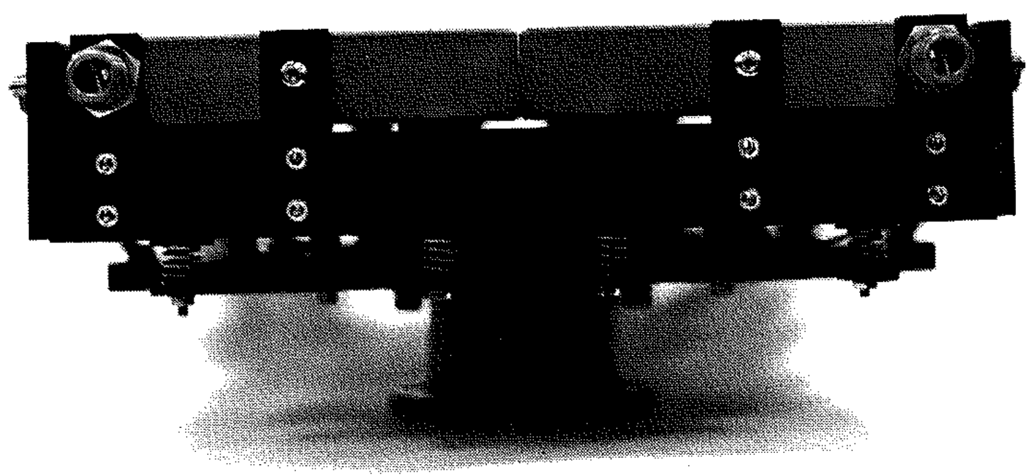

BACK SUPPORTS
2"
SIDE SUPPORTS
MOSAIC DETAILS
7-8-87
MOS2



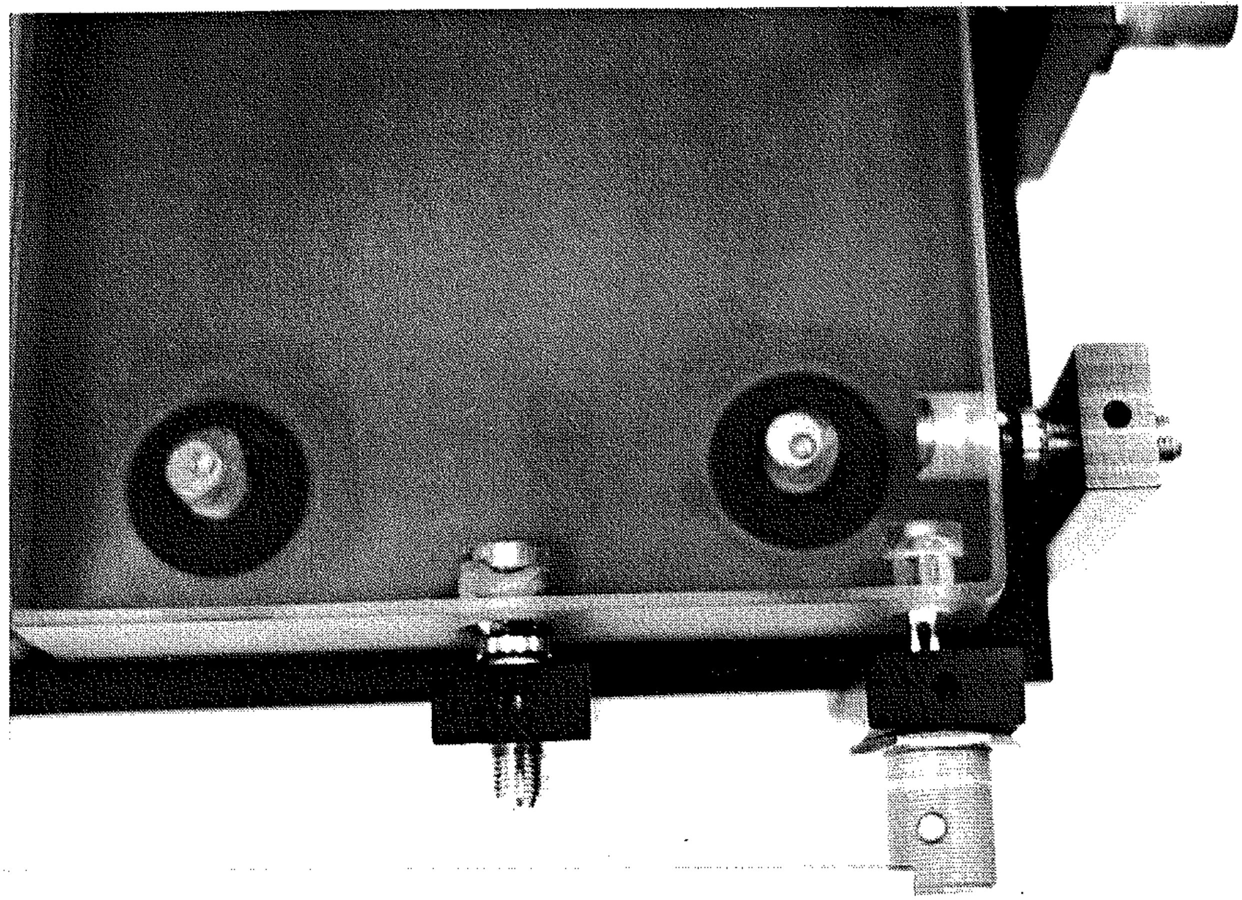


MOSAIC SIDE VIEWS

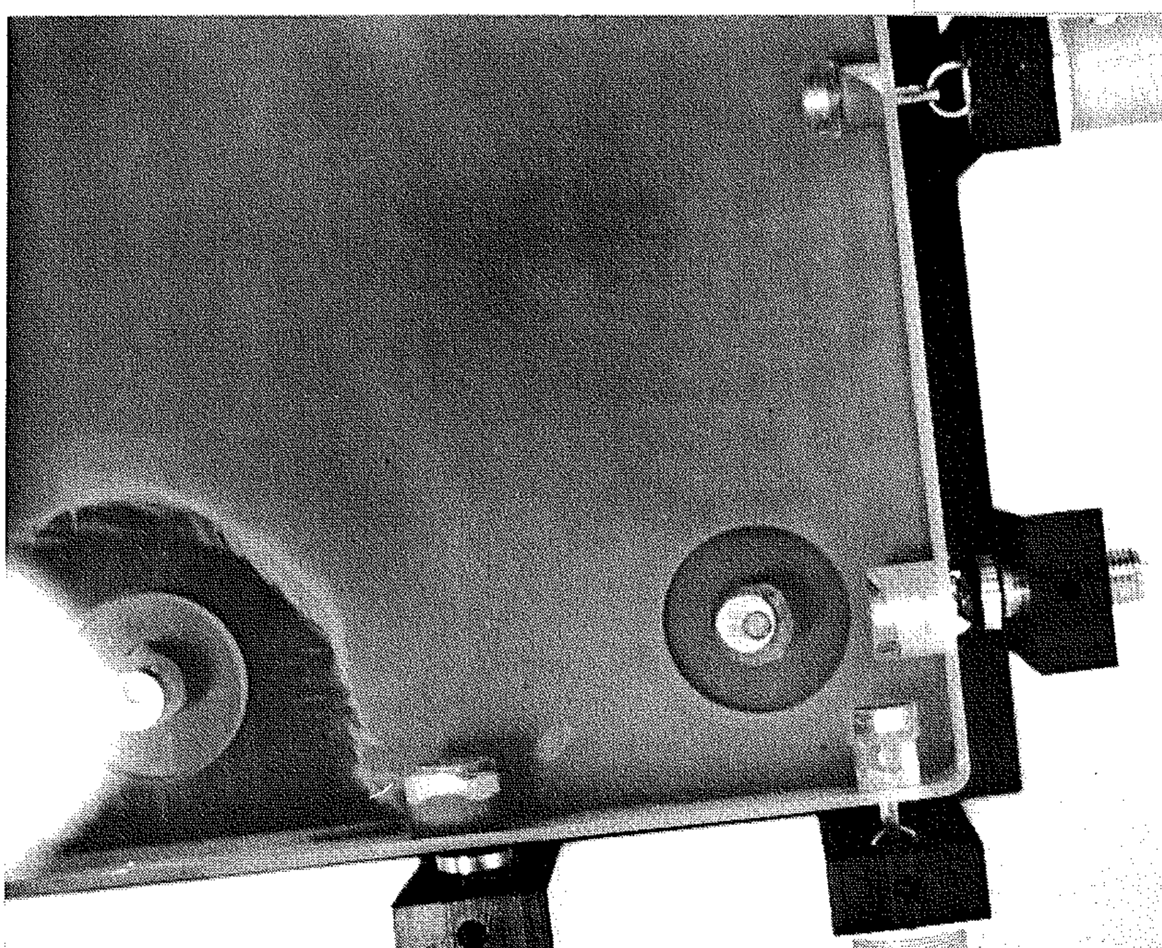


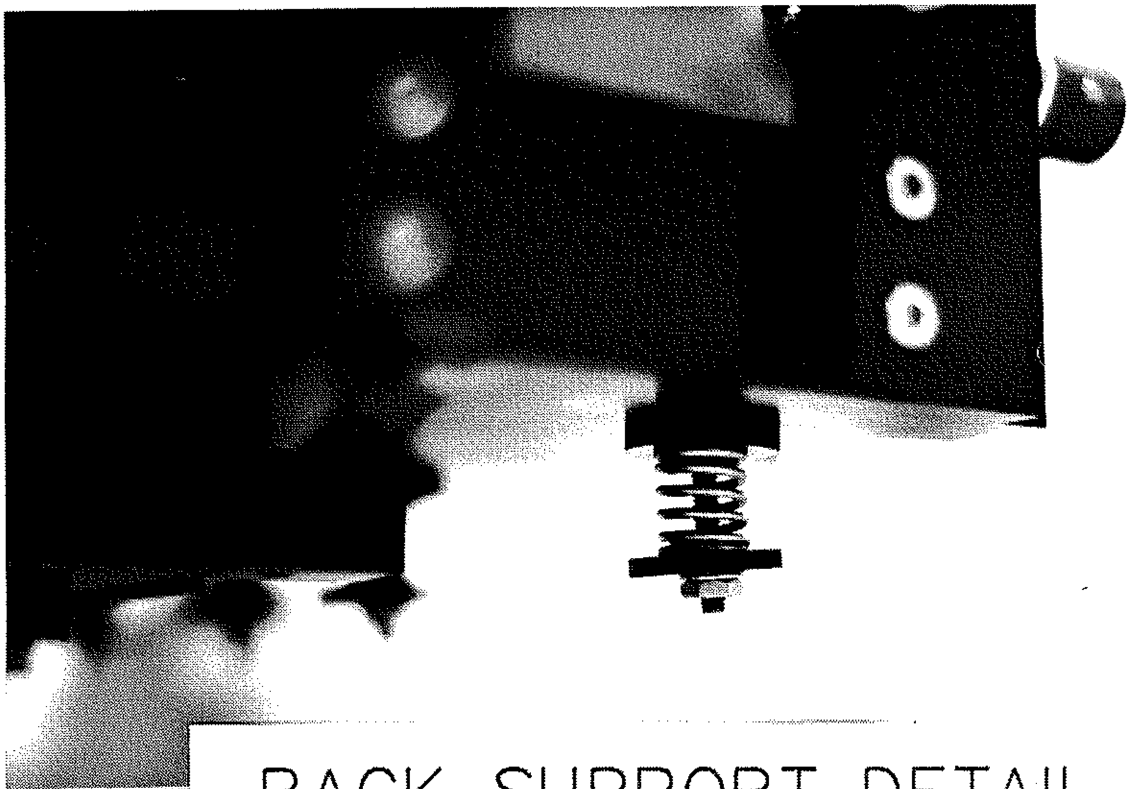


MOSAIC END VIEWS

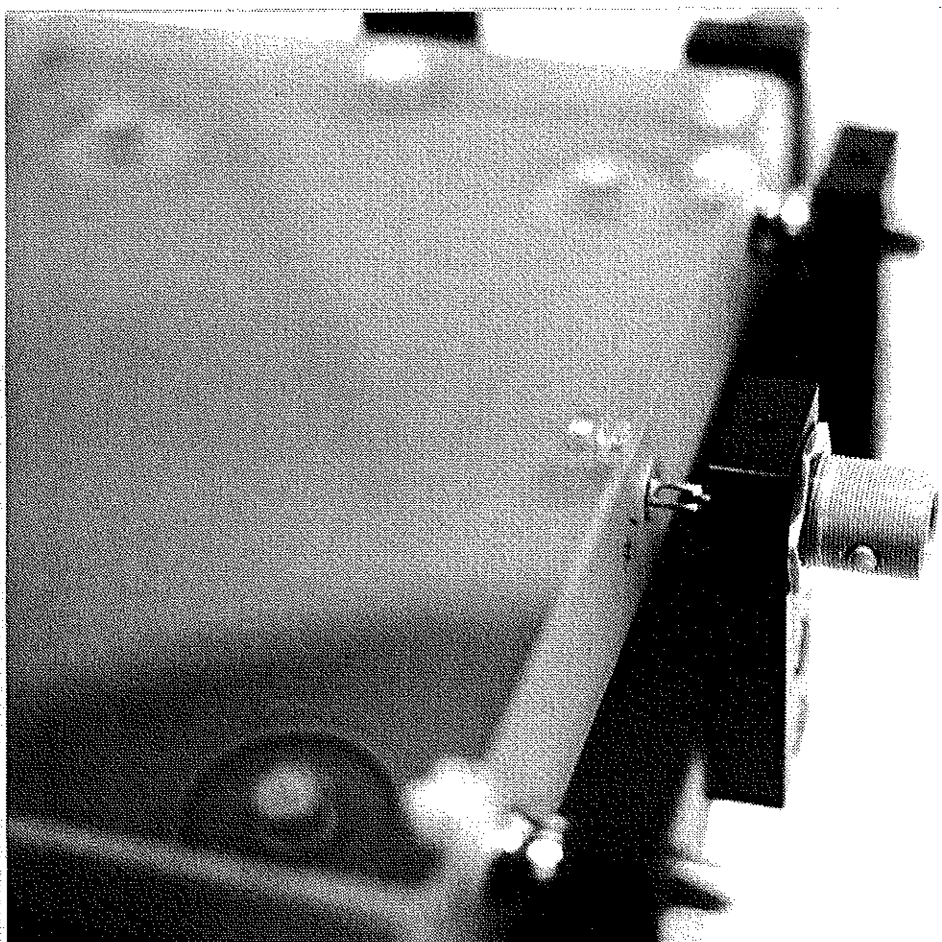


EDGE SUPPORT VIEWS





BACK SUPPORT DETAIL



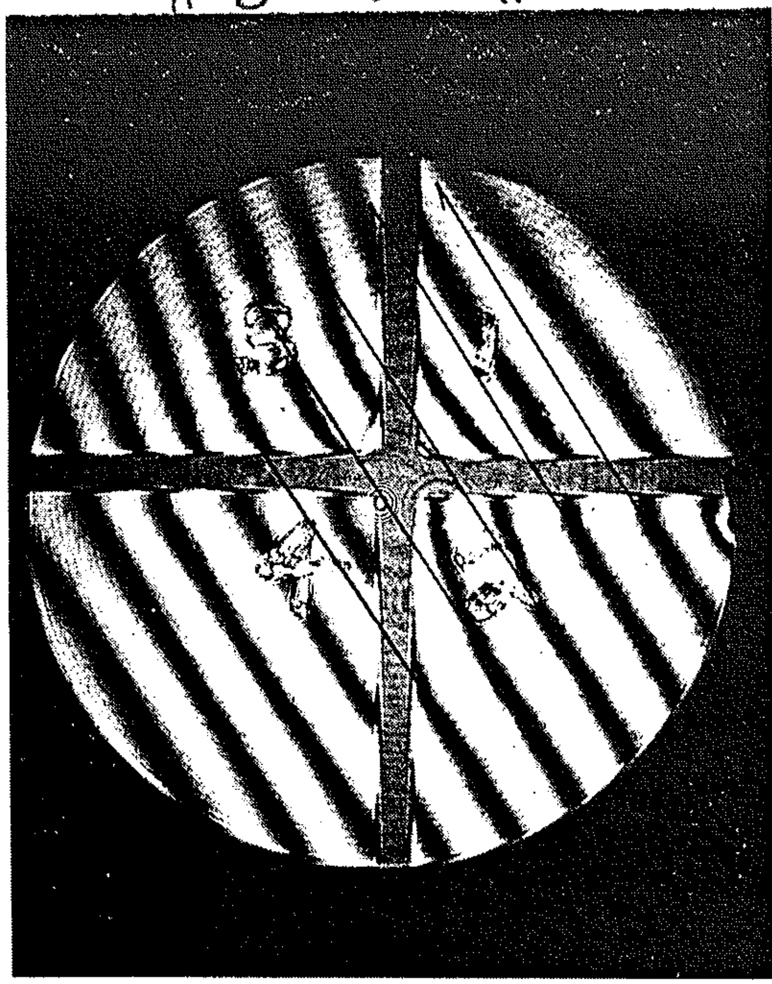
EDGE SUPPORT

2. THE INTERFEROGRAMS

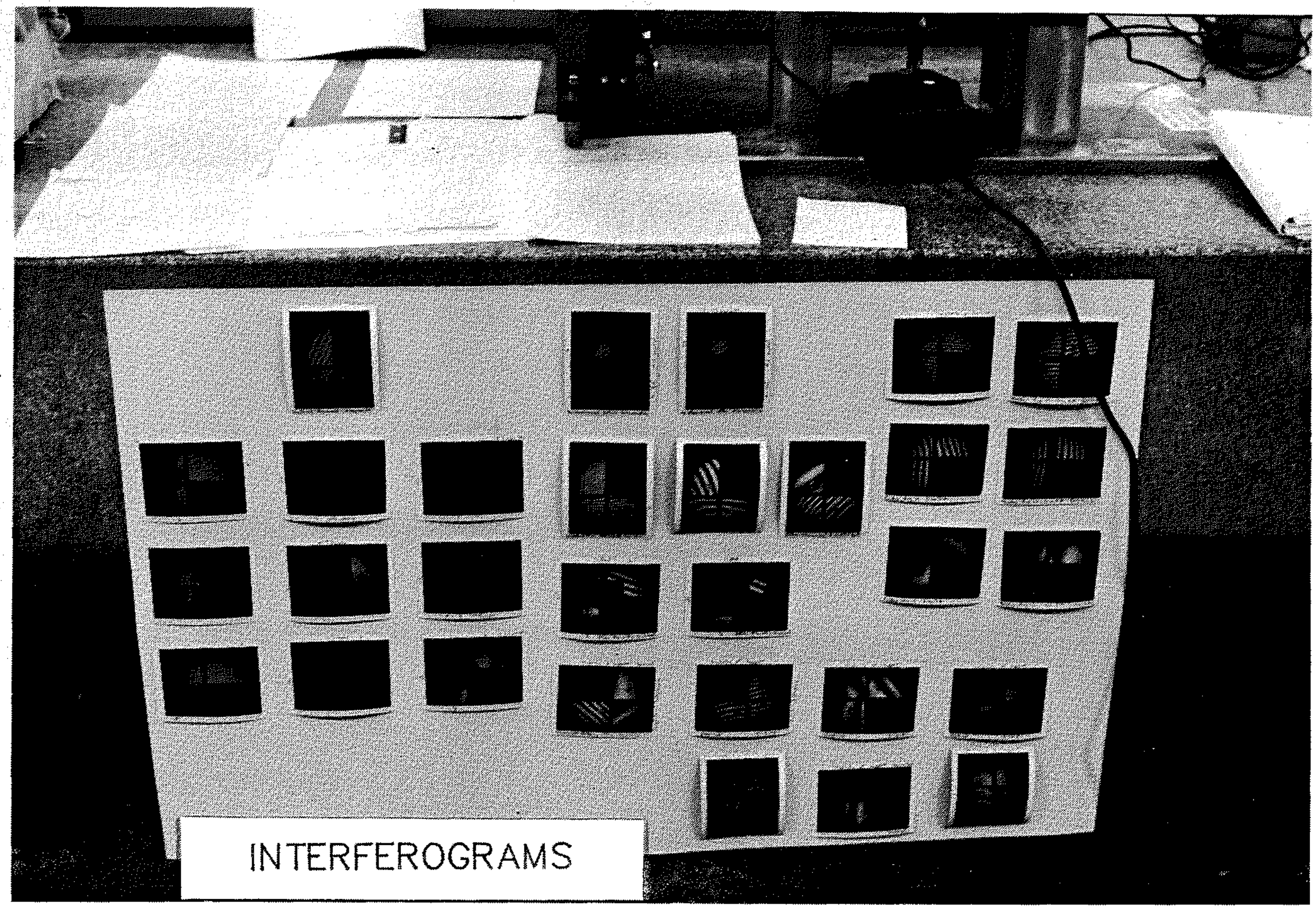
The photo shows the final interferogram. The limiting measurement is less than 1 arcsec. This represents about 1 fringe. It is possible to resolve less than 1 fringe and thus less than 1 arcsec. The interferograms were used to get the 4 gratings aligned. Then, interferograms were taken to test the subplate performance. When the mosaic was rotated about the primary axis (the grating rotation axis in the spectrograph), no deflection was seen. When the mosaic was rotated about the other axis, about 1/2 fringe was seen. We suspect this was due to flexure in the adapter we used to mount to the rotator head. It was a non-kinematic (over-constrained) piece of hardware.

The shop photo shows the chart of interferograms used during alignment.

#3 vs #2



FINAL INTERFEROGRAM


INTERFEROGRAMS

3. THERMAL CONSIDERATIONS

Partway through the fabrication of this support system, Jerry Nelson asked about temperature gradients in the subplate. We had not considered this and so we looked at the problem.

There are standard formulas for deflection in plates with given temperature gradients. The deflections we were interested in keeping below could be caused by 1/10° C across the 1.5 in. thickness of the subplate. This is of concern.

We next built a thermal model and asked the question "What kind of heat flow would exist if 1/10° existed across the subplate?" The answer is 100 W. There are no such heat sources in the spectrographs and so we concluded the subplate was isothermal.

There are other thermal effects. The aluminum subcell and the Zerodur gratings do not expand and contract at the same rate. The mosaic will be used at Mauna Kea in Hawaii where the temperature is likely to be 25° C different from the lab where the initial alignment will be done. If one considers the end support for one grating to be fixed and the other end free to slide across the subplate, then one can ask what that motion will be. For 25° it is 0.000 04 in. The grating support spacer might slide uphill if the subplate is not perfectly flat. This will misalign the grating. If the local "hill" is 1° (a large amount) then the misalignment will be 0.02 arcsec. This is tolerable.

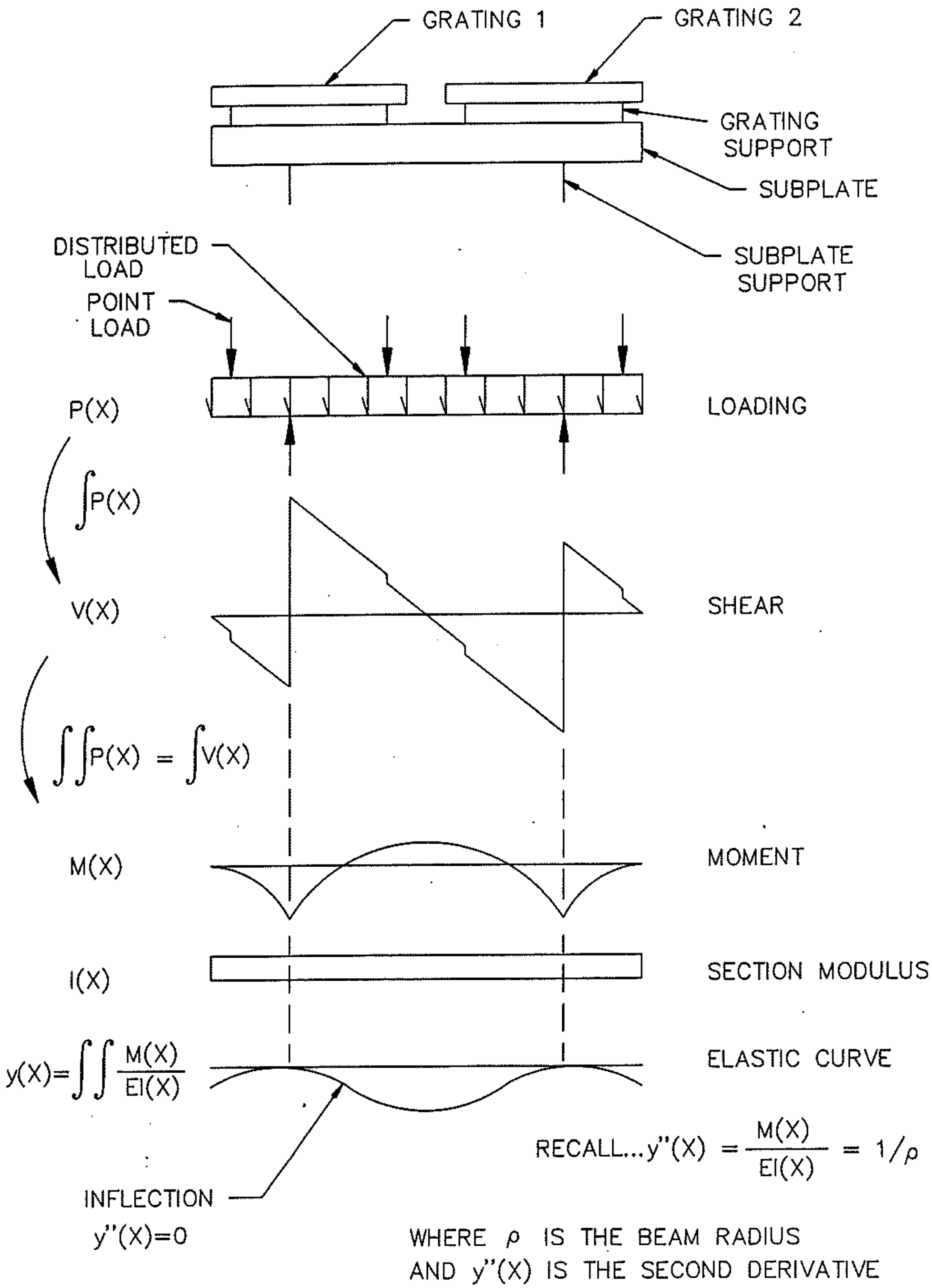
There will be friction between the support spacer (Zerodur) and the aluminum subplate during this thermal expansion. If the coefficient of friction is 1.0 and the clamping force is 2 g or 6 pounds, then the shearing force at the back of the grating is also 6 pounds. This generates a bending moment in the grating (35 mm thick) and the mid-span deflection is 1/30th wave. This is also tolerable. We are not sure what the coefficient of friction really is, but we intend to measure it. If the bending is unacceptable, then the mosaic might have to be dithered once at Mauna Kea to relax the shear stresses at the support feet.

4. FLEXURE OF THE SUBPLATE

A two-dimensional mathematical model was constructed to model the static deflection of the subplate with two gratings sitting above it. See the drawing. The equation of the deformed subplate was solved and the deflections at the grating support points were used to predict the mismatch in angular alignment of the two gratings. By iteration, the optimum locations of the subplate supports (R1 and R2) were found. This model says that zero deflection and therefore zero misalignment is possible. A sensitivity analysis was done: the weight of the glass gratings is unimportant, in fact, the angular misalignment is practically independent of grating weight; the location of the support points below the subplate is critical at the 1/8 in. level. The thickness of the subplate changes the sensitivity of the model to geometric changes. Thus, a 6 in. thick plate is tolerant to any kind of back support but a big weight penalty must be paid, while a 1/4 in. thick plate weighs less but has 0.001 in. kinds of tolerances. The selected thickness, 1.5 in., was somewhat arbitrary.

Many things were omitted from the model: the holes in the subplate were ignored, the side support hardware was ignored, and the attachment to the test fixture was never considered to be a problem. This last detail will have to be addressed in the Keck instruments because we observed bending moments caused by improper mounting. The 1 arcsec misalignments were 1000 times larger than any misalignments we expected to see.

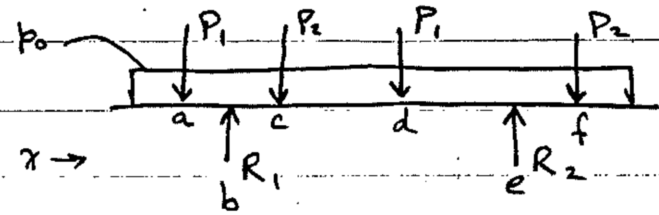
The formulas leading to the elastic curve are listed here. Also, the original basic program (running on a Commodore 64) is listed along with some sample output. All work since March 1988 used Borland Turbo Basic running on an IBM PC/AT - a much faster machine.



SUBPLATE FLEXURE

11-19-86 Jo
See Popov 2-18
Ch 11 also

The Loading Function is Discontinuous: Use Singularity Functions. e.g. $\langle x-a\rangle^1 \begin{cases} = 0 \text{ if } x<a \\ = x-a \text{ if } x>a \end{cases}$



$$\overset{+}{\curvearrowright} M(x) = -p_0\frac{x^2}{2} - P_1\langle x-a\rangle^1 + R_1\langle x-b\rangle^1 - P_2\langle x-c\rangle^1$$
$$- P_1\langle x-d\rangle^1 + R_2\langle x-e\rangle^1 - P_2\langle x-f\rangle^1$$

$$\int M(x) = -p_0\frac{x^3}{6} - \frac{P_1}{2}\langle x-a\rangle^2 + \frac{R_1}{2}\langle x-b\rangle^2 - \frac{P_2}{2}\langle x-c\rangle^2$$
$$- \frac{P_1}{2}\langle x-d\rangle^2 + \frac{R_2}{2}\langle x-e\rangle^2 - \frac{P_2}{2}\langle x-f\rangle^2 + C_1$$

$$\iint M(x) = -p_0\frac{x^4}{24} - \frac{P_1}{6}\langle x-a\rangle^3 + \text{-----} + C_1x + C_2 \quad \text{------- (1)}$$

Solve for C_1 and C_2 (at R_1 and R_2 $\iint M(x) = 0$):

$$C_1 = \frac{-1}{(e-b)}\left\{-p_0\frac{e^4}{24} - P_1\frac{(e-a)^3}{6} + R_1\frac{(e-b)^3}{6} - P_2\frac{(e-c)^3}{6} - \frac{P_1(e-d^3)}{6}\right.$$
$$\left. + \frac{p_0 b^4}{24} + \frac{P_1(b-a)^3}{6}\right\} \quad \text{---------------- (2)}$$

$$C_2 = \frac{p_0 b^4}{24} + P_1\frac{(b-a)^3}{6} - C_1 b \quad \text{---------------- (3)}$$

```
10 REM: MOSAICVI, OSBORNE, 12.15.86
20 REM: SUB PLATE FLEXURE
21 REM OPTIMIZE B&E FOR EQUAL FLEX AT A&C
22 REM I03 DISK
40 OPEN4,4
 i INPUT "COMMENT";A$
52 PRINT#4,A$
100 A=1.5: B=4.05: C=8: D=10
110 E=13.95:F=16.5
200 P1=7:P2=7
210 L=18:Y=10000000:W=14
220 H=1.50
221 REM DENSITY IN G/CC.
222 DE=2.70
225 P0=(DE*H*L*W*2.54^3)/(L*454)
230 I=W*H^3/12
235 R1=(2*P1+2*P2+P0*L)/2
237 R2=R1
239 GOSUB4000
240 PRINT"START POINT, DX":INPUTX0,DX
245 PRINT#4,"A;B;C;D;E;F;DE"
246 PRINT#4,A;B;C;D;E;F;DE
250 PRINT#4,"H;L;W;Y;P1;P2;P0;R1;R2"
252 PRINT#4,H;L;W;Y;P1;P2;P0;R1;R2
255 PRINT#4,"C1,C2";C1,C2
262 PRINT#4:PRINT#4,"INCHES ALONG; DEFLECTION, MICRO-INCHES, MICRONS"
265 REM
270 GOSUB1000
280 V=V/(Y*I)
295 IFX>LGOTO440
 70 V=V*1000000
 20 V=INT(100*V)/100
330 VM=INT(1000*V/40)/1000
350 PRINT#4,X,V,VM
360 X=X+DX
400 GOTO265
440 PRINT#4:CLOSE4
450 STOP
1000 XA=X-A:XB=X-B:XC=X-C:XD=X-D:XE=X-E:XF=X-F
1050 IFX<ATHENXA=0
1060 IFX<BTHENXB=0
1070 IFX<CTHENXC=0
1080 IFX<DTHENXD=0
1090 IFX<ETHENXE=0
1100 IFX<FTHENXF=0
1150 V=0
1160 V=V-P0*X^4/24
1170 V=V-P1*(XA)^3/6
1180 V=V+R1*(XB)^3/6
1190 V=V-P2*(XC)^3/6
1200 V=V-P1*(XD)^3/6
1210 V=V+R2*(XE)^3/6
1220 V=V-P2*(XF)^3/6
1230 V=V+C1*X
1240 V=V+C2
2000 RETURN
  00 REM INTEGRATION CONSTANTS C1 AND C2
4100 K1=-P0*E^4/24-P1*(E-A)^3/6+R1*(E-B)^3/6-P2*(E-C)^3/6-P1*(E-D)^3/6
4200 K2=P0*B^4/24+P1*(B-A)^3/6
4300 C1=-(K1+K2)/(E-B)
4400 C2=P0*B^4/24+P1*(B-A)^3/6-C1*B
4450 RETURN
8000 STOP
```

THIS RUN IS ALUMINUM. 12/15/86 WITH SAME DIMENSIONS AS OPTIMIZED GLASS
A;B;C;D;E;F;DE
1.5 4.05 8 10 13.95 16.5 2.7
H;L;W;Y;P1;P2;P0;R1;R2
1.5 18 14 10000000 7 7 2.04657826 32.4192044 32.4192044
,C2 51.8584822 -167.739602
[716 gratings (35 mm)

INCHES ALONG; DEFLECTION, MICRO-INCHES, MICRONS

INCHES ALONG	DEFLECTION, MICRO-INCHES	MICRONS
0	-4.27	-.107
.5	-3.61	-.091
1	-2.95	-.074
1.5	-2.3	-.058
2	-1.67	-.042
2.5	-1.09	-.028
3	-.59	-.015
3.5	-.22	-6E-03
4	-.01	-1E-03
4.5	-.01	-1E-03
5	-.19	-5E-03
5.5	-.48	-.012
6	-.85	-.022
6.5	-1.26	-.032
7	-1.65	-.042
7.5	-2	-.05
8	-2.28	-.057
8.5	-2.45	-.062
9	-2.51	-.063
9.5	-2.45	-.062
10	-2.28	-.057
10.5	-2	-.05
11	-1.65	-.042
11.5	-1.26	-.032
12	-.85	-.022
12.5	-.48	-.012
13	-.19	-5E-03
13.5	-.01	-1E-03
14	-.01	-1E-03
14.5	-.22	-6E-03
15	-.59	-.015
15.5	-1.09	-.028
16	-1.67	-.042
16.5	-2.3	-.058
17	-2.95	-.074
17.5	-3.61	-.091
18	-4.27	-.107

.02 μinch

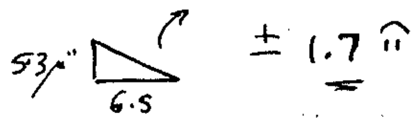
.02 μ"

11/26

```
A;B;C;D;E;F;DE
 .5  0  8  10  18  16.5  2.53
H;L;W;Y;P1;P2;P0;R1;R2;C1;C2
 1.55  18  14  15000000  7  7  1.98164362  31.8347926  31.8347926 -848.1644 -
375
```

INCHES ALONG;	DEFLECTION, MICRO-INCHES,	MICRONS
0	-.07	-2E-03
.5	-6.56	-.164
1	-13	-.325
1.5	-19.32	-.483
2	-25.47	-.637
2.5	-31.4	-.785
3	-37.08	-.927
3.5	-42.46	-1.062
4	-47.52	-1.188
4.5	-52.22	-1.306
5	-56.52	-1.413
5.5	-60.41	-1.511
6	-63.84	-1.596
6.5	-66.8	-1.67
7	-69.27	-1.732
7.5	-71.21	-1.781
8	-72.61	-1.816
8.5	-73.45	-1.837
9	-73.73	-1.844
9.5	-73.45	-1.837
10	-72.61	-1.816
10.5	-71.21	-1.781
11	-69.27	-1.732
11.5	-66.8	-1.67
12	-63.84	-1.596
12.5	-60.41	-1.511
13	-56.52	-1.413
13.5	-52.22	-1.306
14	-47.52	-1.188
14.5	-42.46	-1.062
15	-37.08	-.927
15.5	-31.4	-.785
16	-25.47	-.637
16.5	-19.32	-.483
17	-13	-.325
17.5	-6.56	-.164
18	-.07	-2E-03

Supports at end
1.55" thk



Thin subplate.

H;L;W;Y;P1;P2;P0;R1;R2;C1;C2
.55 18 14 15000000 5 5 .703163864 16.3284748 16.3284748 24.4534751 -7
.2926524

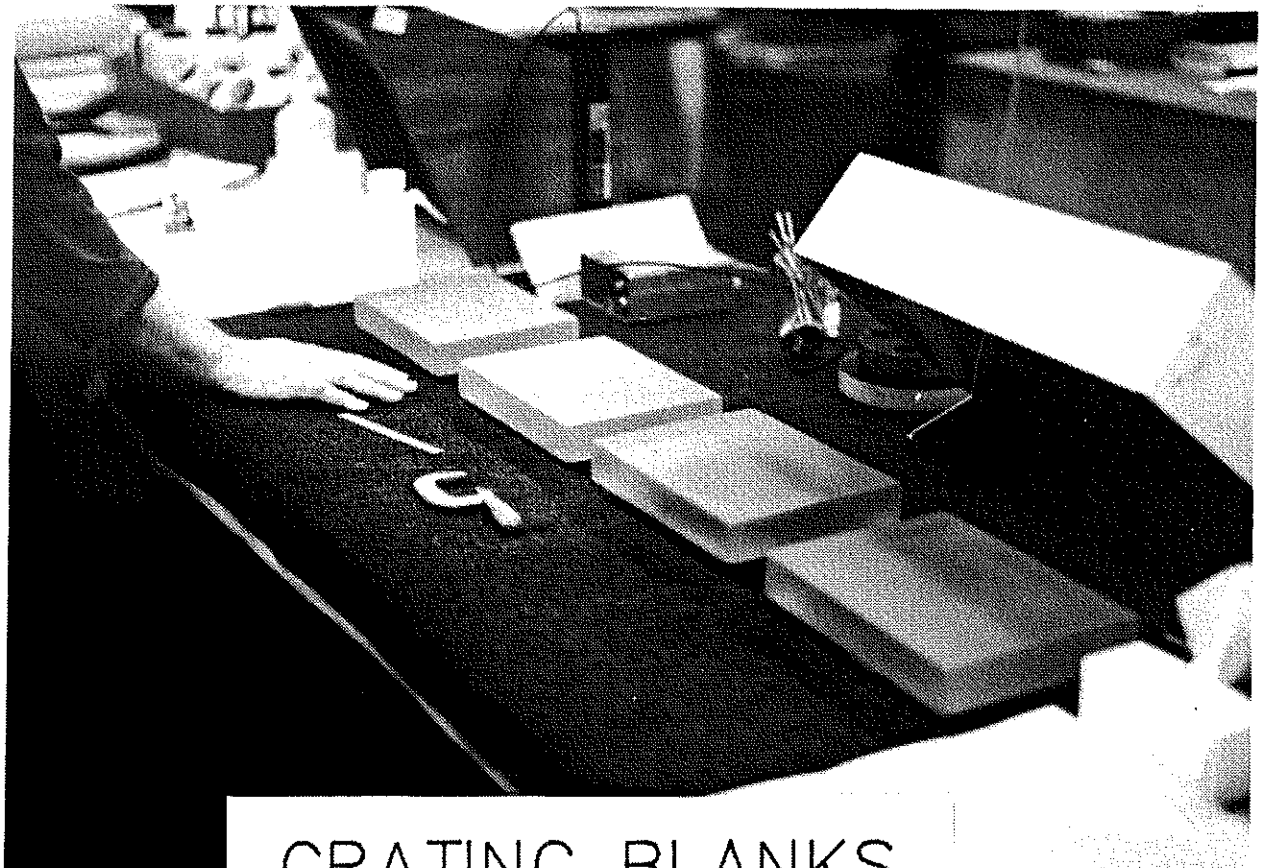
Δ = 1μ"

INCHES ALONG;	DEFLECTION, MICRO-INCHES,	MICRONS
.5	-26.55	-.664
1	-22.35	-.559
1.5	-18.16	-.454
2	-14	-.35
2.5	-9.95	-.249
3	-6.23	-.156
3.5	-3.14	-.079
4	-.96	-.024
4.5	0	0
5	-.49	-.013
5.5	-2.18	-.055
6	-4.73	-.119
6.5	-7.8	-.195
7	-11.1	-.278
7.5	-14.3	-.358
8	-17.15	-.429
8.5	-19.36	-.484
9	-20.72	-.518
9.5	-21.18	-.53
10	-20.72	-.518
10.5	-19.36	-.484
11	-17.15	-.429
11.5	-14.3	-.358
12	-11.1	-.278
12.5	-7.8	-.195
13	-4.73	-.119
13.5	-2.18	-.055
14	-.49	-.013
14.5	0	0
15	-.96	-.024
15.5	-3.14	-.079
16	-6.23	-.156
16.5	-9.95	-.249
17	-14	-.35
17.5	-18.16	-.454
18	-22.35	-.559

5. THE GRATING BLANKS AND REAL GRATINGS

The project tested four polished Zerodur blanks. Rulings were never applied to these blanks, although they could be. The angular adjustment in the plane of the blanks was only used to get them close. Real gratings would of course need to be aligned to get the grooves all parallel. This adjustment will require a spectrometer, but we feel that is simple to do. The handling of these blanks was not the same as if they had rulings. This will change. Installation will be done in one of our laminar flow clean benches and the mosaic will be stored face down.

A 6 in. $\times$ 8 in. blank weighs 6.7 pounds each and fits easily with a large conditioning flat on a small flat-master. A photo of the four blanks is included, along with a photo of the flat carrier used during "flat-making." The 12 in. $\times$ 16 in. blanks for HIRES weigh 58 pounds each and will be made on a larger machine.



GRATING BLANKS

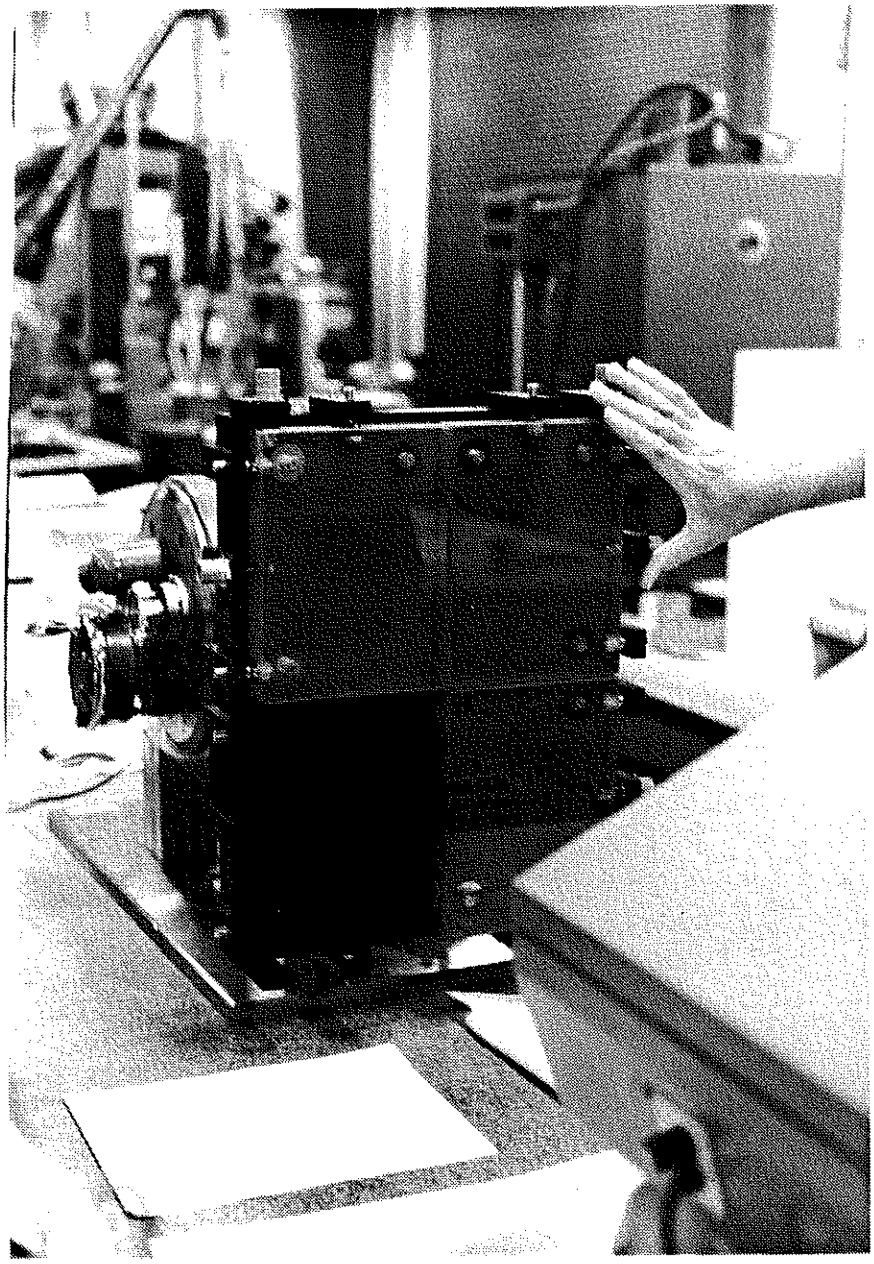
6. ALIGNMENT AND TESTING

A difference of 1 arcsec between grating blanks produces motion at the detector. This motion will depend on the camera focal length alone. The distance from grating to detector is not involved. The detector is important because the pixel size determines what is tolerable. For the core version of HIRES, a Tektronix 2048 $\times$ 2048 has been chosen and a 30 in. camera will be the only camera in the near future. We have considered also an Ultra High Resolution (UHR) camera where the collimator mirror is used as the camera mirror and the gratings are used in a "double-pass" mode.

The 1 arcsec difference is calculated for a 90° rotation of the mosaic (gravity on and gravity off). The gratings in MODRES would certainly see this and perhaps twice this since the spectrograph would rotate as the field rotates. The HIRES, however, is fixed on the Nasmyth platform and the gratings rotate slightly. The Echelle mosaic (1 $\times$ 3) moves $\pm$2.8° and the axis is horizontal. The Cross Disperser (2 $\times$ 1) moves $\pm$30° and the axis is only 16° from vertical. The Echelle "sees" a 0.0011 g change and the Cross Disperser "sees" a 0.23 g change in loading. If the deflection tolerance turned out to be very difficult to maintain over 90° then the mosaics could be aligned at their operating angles and shipped to Hawaii. We hope this will not be the case.

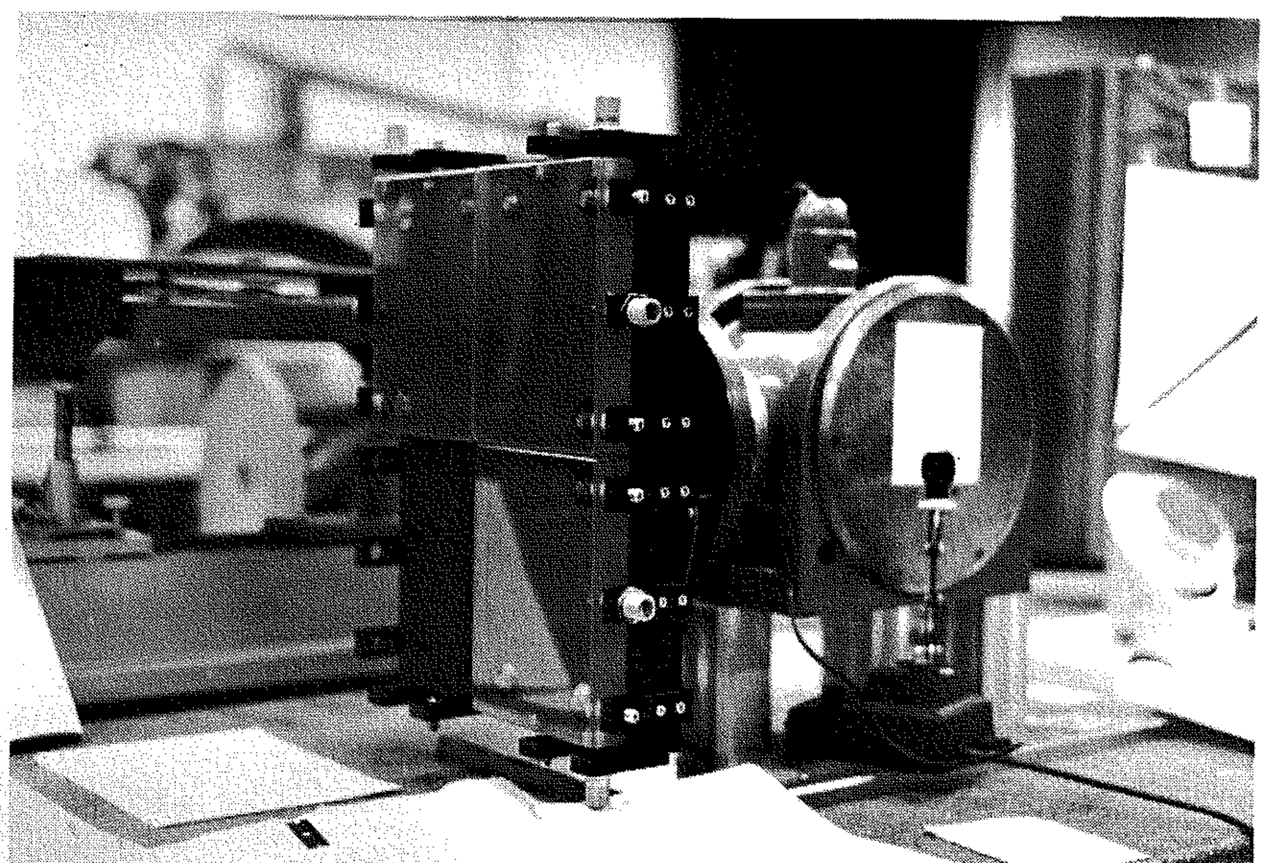
The alignment must also be insensitive to temperature. The testing of HIRES will be done in a refrigerated enclosure and so we will be looking at this. No tests of temperature changes have been done.

Photos in this section show the mosaic mounted on the two-axis rotary head in the Optical Shop. All testing was done on the large granite test bed.



TEST SETUP

INTERFEROMETER



7. WHAT OTHER OPTIONS DO WE HAVE?

A complete active control system is possible but too expensive for a grating mosaic. A system like the Keck primary mirror could be built.

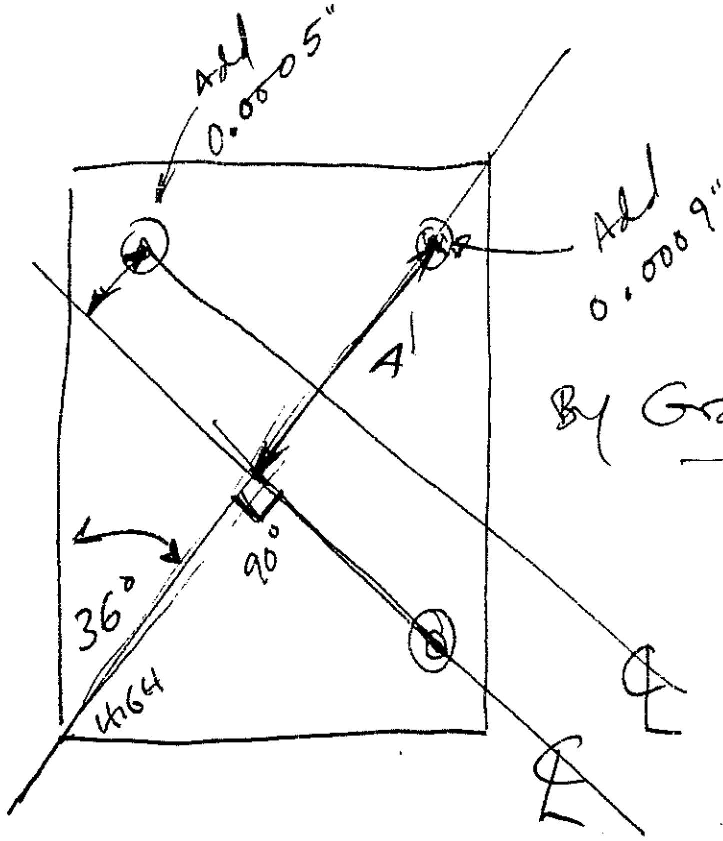
Mosaics in the past have been built with daily or monthly adjustments required (Richardson and Oke). We considered a passive system with manual adjustments. This would be our fallback position if the current plan fails. There are several ways to make an adjustable mosaic. All of them require blocking the gratings and bringing the spectra into alignment one at a time. For the Echelle (1 $\times$ 3) at the Keck HIRES spectrograph, this means tuning two gratings. The Cross Disperser (2 $\times$ 1) would only require tuning one grating per Cross Disperser pair. The 2 $\times$ 2 mosaic for MODRES no longer exists but would require adjusting three gratings. The simplest and cheapest system would be hand turned screws on the back of the mosaic. This means that a human does the adjusting while watching the output monitor of a spectrum. A more expensive, but easier system would have piezoelectric crystals at the support points and knobs to adjust the voltage at each support. These piezos cost about $1000 per support point. They are also not stiff and would need readjusting as a grating is rotated (with a changing gravity vector).

8. MISCELLANEOUS NOTES

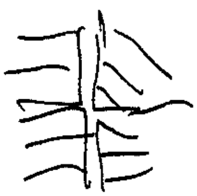
This is a collection of the authors' notes so that they remain in a safe place. There is no order implied. Some of the derivations of the shimming procedure are contained here. Some of the early data outputs are here.

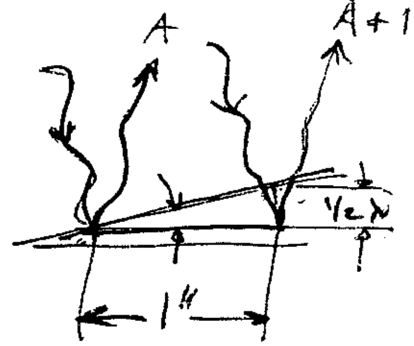
Grating #4:

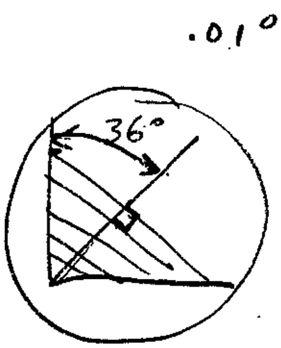
MOSAIC Adjustments
4 (2x2) in place
8-24-87
JO/DH

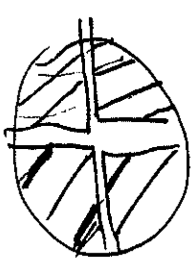


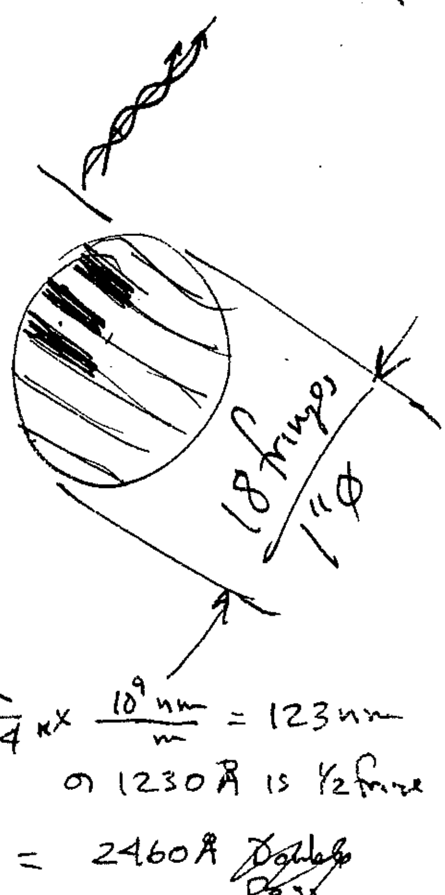
By Graphical Solution







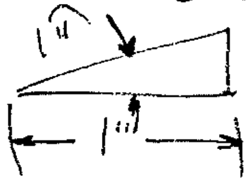


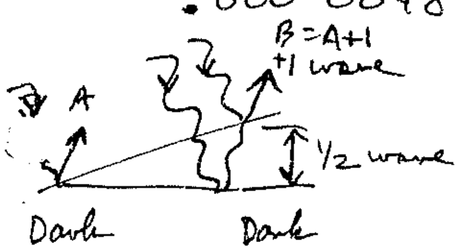


We assume
1/2 fringe / 1"
is 1 arc sec
of wedge....
sic

$.000\,0048'' \times \frac{1\,m}{39.4} \times \frac{10^9\,nm}{m} = 123\,nm$

or 1230Å is 1/2 fringe

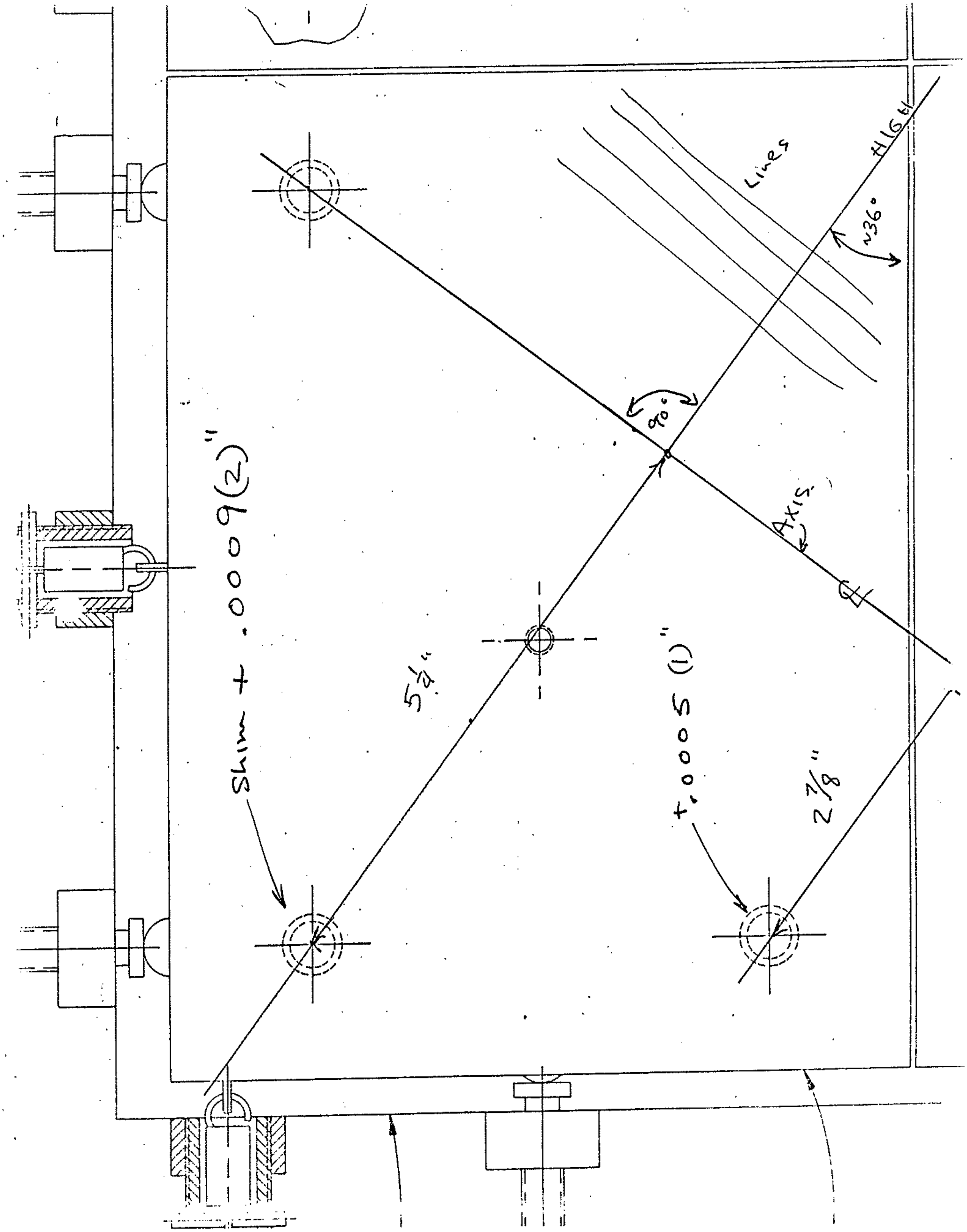




λ = 2460Å ~~Double Pass~~

?

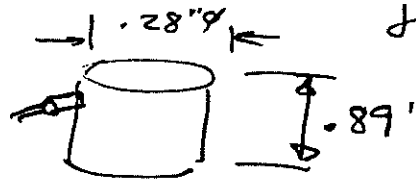
or Double Pass is 4920Å ~ 5000Å OK


Shim + .0009(2)"
5 1/4"
90°
Axis
Lines
HIGH
~36°
+.0005 (1)"
2 7/8"

"MOSAIC"

12-2-86
Jo.

PIEZO -
Burleigh
0-150 vdc
PZO-015



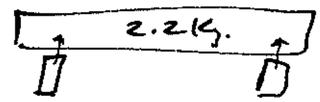
15 μm for 150 vdc
1 μm for 10 vdc

This looks good for trimming.

5% linearity.
25 Kg (50 lbs.)

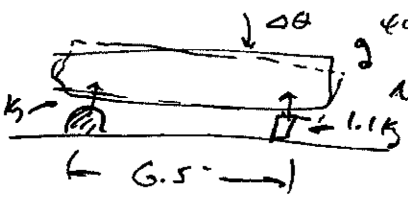
k = 1 μm/Kg

!! 40μ"/2.2 lb.



35mm
6x8
Glass

OK



NOT OK

$\Delta\theta = \tan^{-1}\left(\frac{40\mu''}{6.5}\right) = 1.3''$

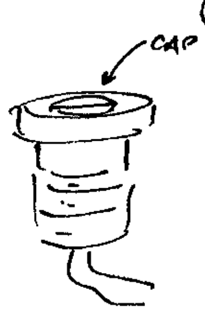
10X over limits

pusher.

#PZT: PZ30 - 30μm. 0-1000v
piezoelectric translator

"Resolution to <.001μm
depending on power supply."

Sens: .005μm/volt
maxload = 10 lbs
k = ?
8uf capacitance
~1" long x .65"ø
Sealectro #51-045-0000 connector



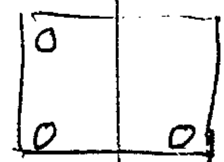
V=IR
1000v: .25A R
R = 4000 Ω
at 10v (.05μm) → $I = \frac{V}{R} = \frac{10v}{4000\Omega} = 2.5$ mamps

Some thoughts on grating Mounting!
V. Nov 21/86. Bev.

J.C.
11-26-86

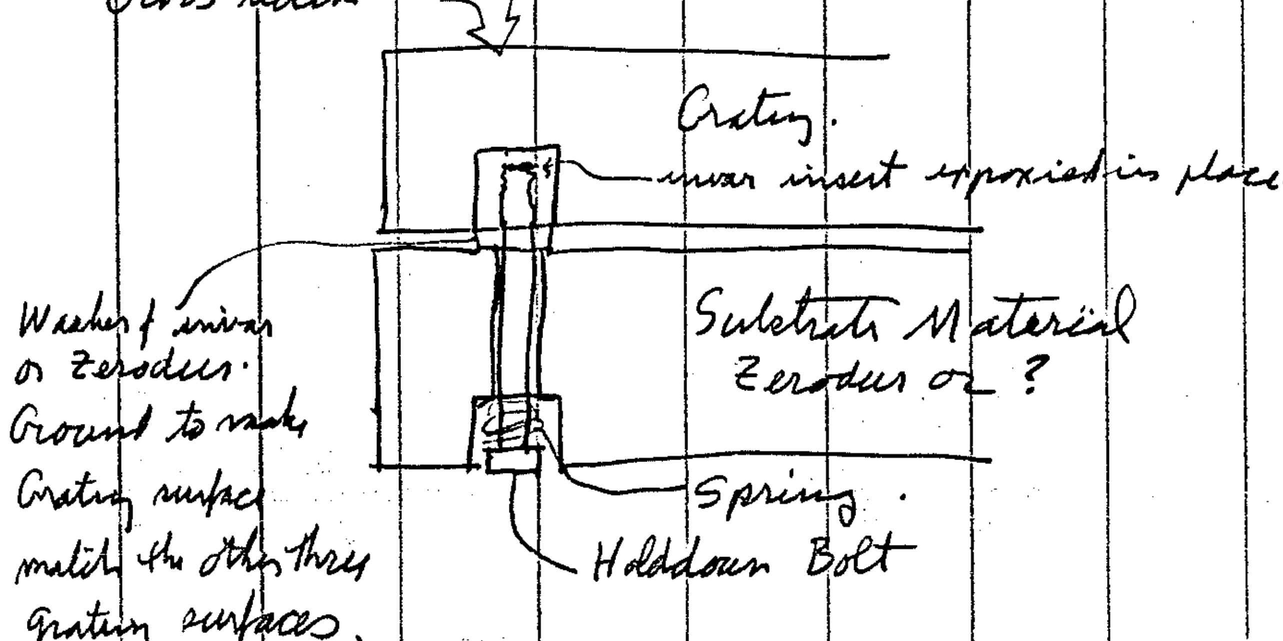
Grating attachment to Substrate Material.

✓ (1). Support at three places, ie →



✓ (2). Put invar inserts into the rear of grating for attachment.

✓ (3). Grating hold down
Cross section



what problems?

(4) The above design should eliminate problems we had with the 200-inch Coudé Mosaic a few years ago -

✓ (5). I show the holddown bolt spring loaded this minimizes torques on the grating.
✓ It means that the gratings must be defined → on their edges for rotation and translation.
YES.

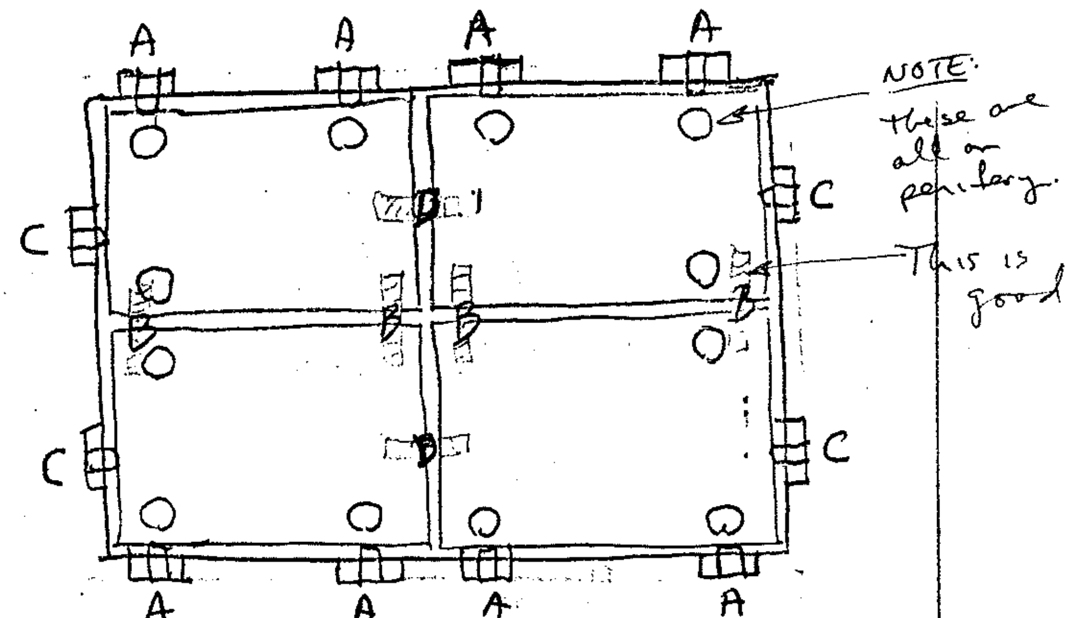
If the bolt were solid (no springs) they could be tight enough so that the gratings would not need further support. ... would have to be

I agree →

set up initially in a jig. The solid hold down would exert some torque on the Grating itself. An engineer should think about this question.

many have →

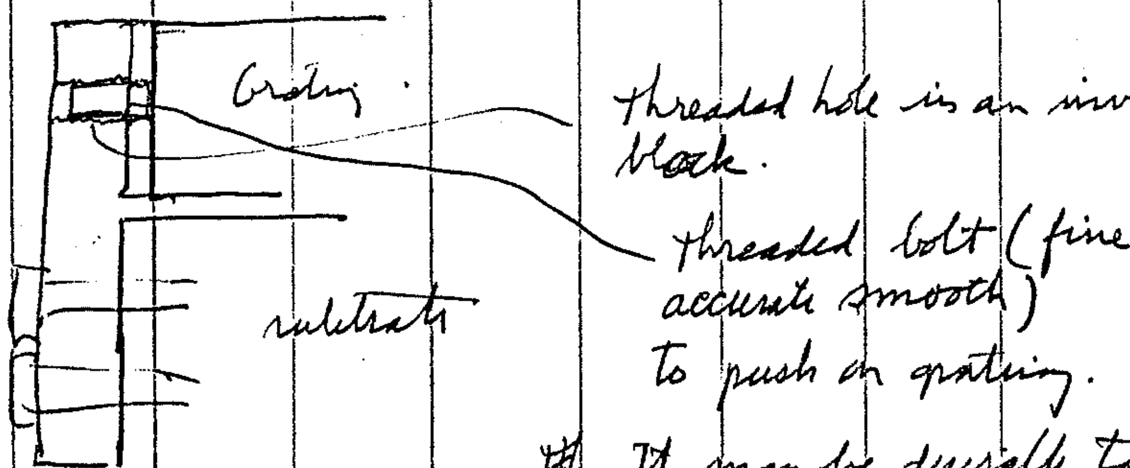
Alignment of four Grating (assume surface alignment done with washers (ie page 1).
This applies if the gratings are not held rigidly with holddowns (item 5, page 1).
Configuration is as shown.



this assumes the substrate is invar so that blocks can be bolted to it. to make a cell for the 4 gratings. (Epoxy to zerodur? or bolt to zerodur)

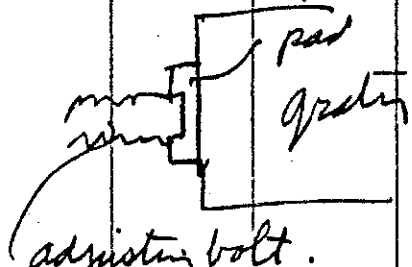
4.

(1) Points A. are for aligning the gratings ~~xxx~~ horizontally and adjusting vertical position.



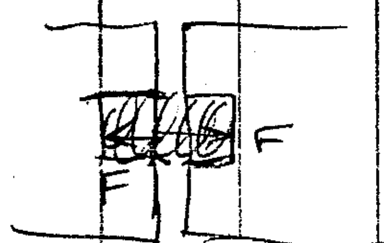
~~Th~~ It may be desirable to have a solid pad

ie



B are springs between the gratings. Probably captured in holes drilled in the gratings.

ie.



They must support the grating against gravity.

e.g. $F > 10$ lbs.

This allows pairs of gratings to be tilted and displaced.

✓ The separation between gratings can be small, ie 1 mm for example. - This is [illegible]able.

✓ C are basically the same as A, no fine adjustments are needed. Two springs (D) would also be located

✓ between the gratings, serving the same function as E

the above scheme is similar to that used on the 200-in Coudé.

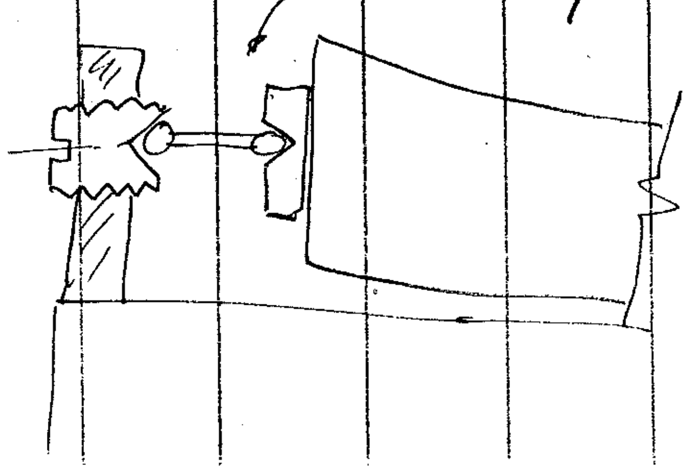
<u>Problem</u>

adjustments A as sketched do not allow the gratings to move vertically in any easy way.

✓ This may not matter since the three pads per grating will already have been ground.

- One could easily modify the threaded adjusting bolts so they allow some motion as they push.

e.g. TMT-T.D.

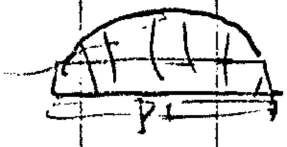


Substrate

The choice appears to be Zerodur or Invar.

Invar Advantages:
- Easy to machine and bolt things to.
- The ~~cell~~ substrate can be made to be the cell itself, ie no additional size needed
- There is probably room to ~~to~~ shape the invar so the thickness is effectively better.

invar



Invar disadvantages
- Heavy material.
- Weight to strength ??
- Does it rust?

Zerodur advantages
- Can match the grating material accurately
- Weight to Strength ??

Zerodur Disadvantages –
- Substrate would have to be attached to a cell. this takes more weight and space.
- Harder to machine?

Aluminum (Mechanite) ——
- Easy to machine.
- Cost less.
- No rust
- weight to strength good
- Thermal expansion

- Present Design.

I am enclosing a few blueprints which show the restrictions on the grating assembly dimensions. These were made some time ago.

- More thickness than 3 inches may be possible but it would require carving off corners. This is O.K. since it will occur where stiffness is not important.

1/30 λ for μ=1

11/26/86
J.O.

What about these thermal effects?

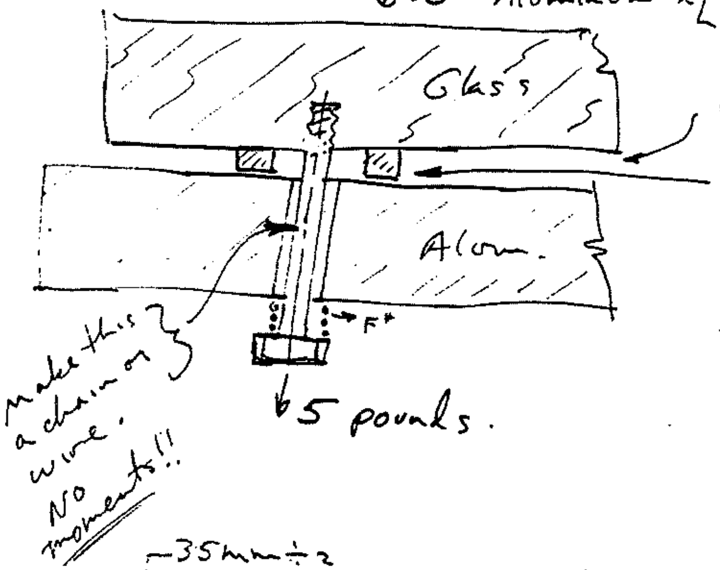
Subplate:
Invar, Zerodur or Alum

$\Delta T = 1°C$

Δ flat surface = ? x/λ

6.5" Aluminum $\times \left[12\times10^{-6}\frac{in}{in\,°F}\times\frac{9}{5}\right] = .00014"/°C$

$21\times10^{-6}\frac{in}{in\,°C} \rightarrow 20°C \rightarrow .003"$



washer, typical.

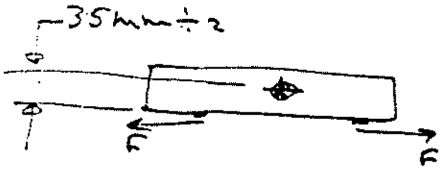
$F_{Lat} = \mu N$ $N = 5$ pounds

~~[struck out]~~

μ glass/alum = ?

Say 1.0 !! ✕

Then F_{Lat} = 5 lb.

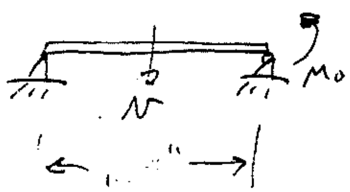


$I = \frac{1}{12}bh^3 = \frac{1}{12}6\frac{1}{2}(38mm)^3$

$I = 1.42\ in^4$

Similar to $M = 3.4$ in-lb.

Case A':



$N_{max} = N\left(\frac{L}{\sqrt{3}}\right) = \frac{-M_o L^2}{9\sqrt{3}\,EI}$

$N_{max} = 43\times10^{-8}$ in (.43 μinches)

or 4×10^{-7} in $\times \frac{1\times10^6\ microns}{40\ in} = .01\ \mu m$

$N_{max} = 100\ Å$

Say $\mu_f = 1$ or 10 !! then 100 Å or 1000 Å

Marks glass on nickel μ = .78

$\frac{100\ Å}{6000\ Å}$ = 1/60 th or double pass: 1/30 th λ

Pat
Just Replace
page 40 to
look like this
(Keep the line-outs)

9. TOLERANCES

The speci[illegible] combination of worst case resolution rec[illegible] focal length camera. Pixel resolution of 1/50th was dreamed of in the beginning of this project. Using the Tektronix 2048 by 2048 CCD as detector with 27 micron pixels and the UHR camera mode in double pass, with 164 in. focal length, a specification was created: 0.007 arc-sec. This is the flexure tolerance for grating rotations of 180°.

The specification has changed to 1 arc-sec over 180°. The motion at the detector during any exposure will be less than 1/10th pixel. (No exposure will change the subplate loading by more than 0.02 g.)

Machining tolerances on the glass are standard quarter wave flatness and front-to-back parallelism of 1 arc-min or so. The pockets in the glass are diamond tooled and not polished.

Machining tolerances on the metal parts are standard shop practice. The tighest tolerance is 0.005 in. and is easily achieved.

The material properties for the subplate represents the biggest uncertainty: questions of long term stability cannot be answered without long term measurements. We are 12 months into a long term stability measurement now. ~~The changes are unmeasurable. If a sudden dimensional change occurs in time, then the gratings may need realigning. We doubt that this will happen.~~ We now suspect that aluminum is not the best material to use for the subplate. By July 1988 the subplate had distorted so that all gratings appear to have shifted. The largest shift is 3 arc-sec. We don't know if this change was sudden or gradual with time. Future measurements will be made. Notes are included here. Pyrex is being investigated as an alternate material for the subplate.

Please replace page 40 with these 6 new pages.

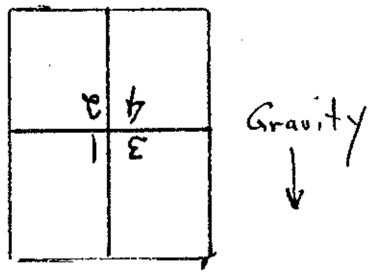
Three Orientations used to Collect Test Data for Mosaic Study Update

7-20-88
D.F.H.

Position #1

Nulling Segment #2 as Reference Plane, Tilt of:

Segment #1 ~ 2.5 fringes
Segment #3 ~ 1.5 fringes
Segment #4 ~ < 1 fringe
all over a 2" Diameter Aperture.



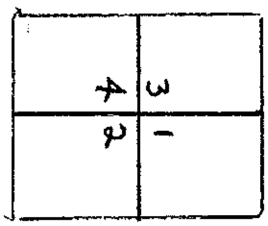
With 1 fringe over a 2" Ø = 1.28 seconds Tilt,

Segment #1 ~ 3.2 seconds
Segment #3 ~ 1.92 seconds
Segment #4 ~ < 1 second

Position #2

Nulling Segment #2 as Reference Plane, Tilt over 2" Aperture:

Segment #1 ~ 2 fringes
Segment #3 ~ 1.5 fringes
Segment #4 ~ < 1 fringe



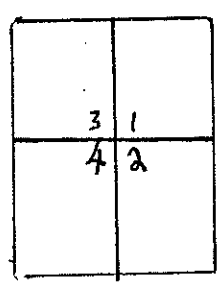
Tilt in Seconds

Segment #1 ~ 2.56 Seconds
Segment #3 ~ 1.92 seconds
Segment #4 ~ < 1 second

Position

Nulling Segment #2 as Reference Plane, Tilt over 2" Aperture:

Segment #1 ~ 2 fringes
Segment #3 ~ 2.5 fringes
Segment #4 ~ < 1 fringe



Tilt in Seconds

Segment #1 ~ 2.56 Seconds
Segment #3 ~ 3.2 Seconds
Segment #4 ~ < 1 second

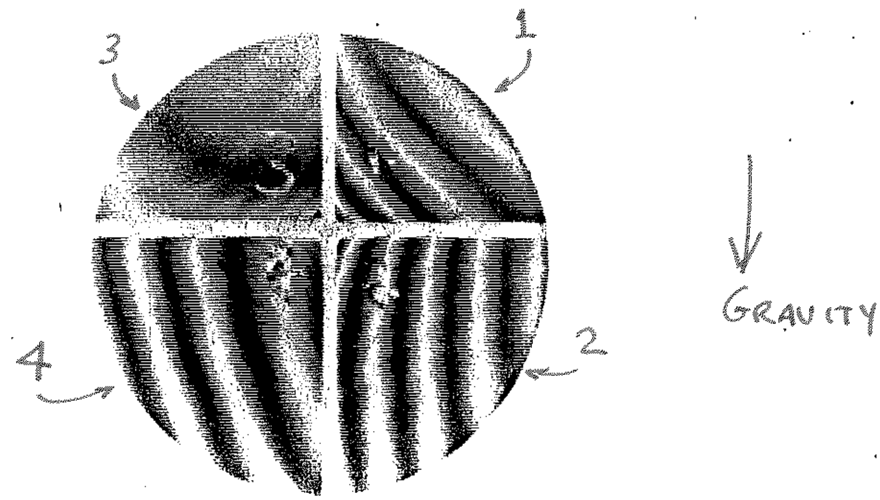
Mosaic Study Update

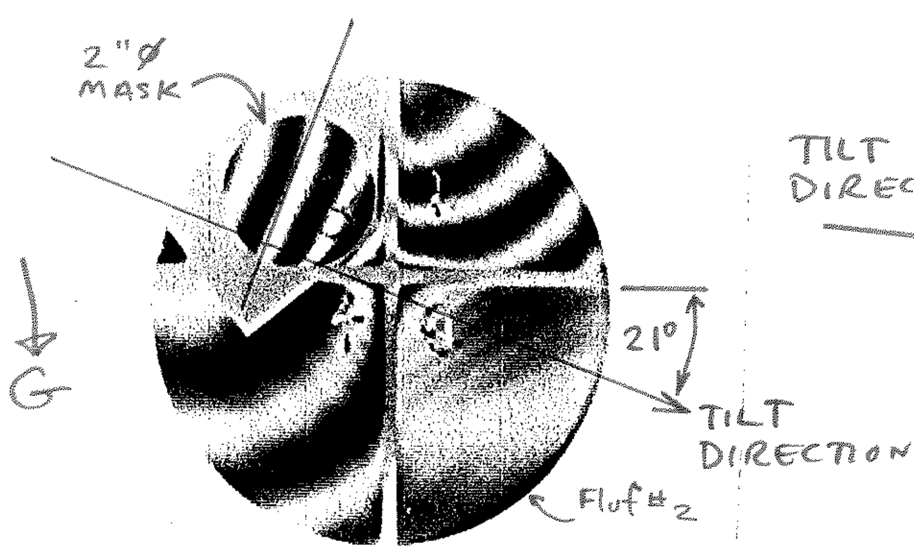
7-20-88
D.F.H.

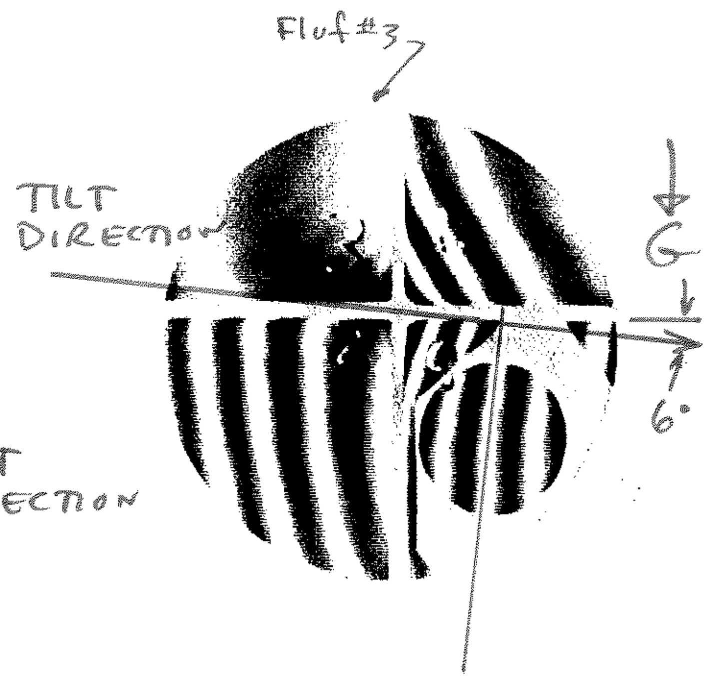
Previous Alignment Test Results in November of 1987 showed greatest misalignment of segments to the reference plane of Segment #2 was that of Segment #3 at about .5 fringe which translates to .64 second of angular tilt.

Updated Alignment Tests show that Segment #4 has remained truest to plane to Segment #2 with a tilt of somewhat less than 1 second. Segment #1 has shifted out of alignment to Segment #2 by 2.5 seconds to 3.2 seconds, while Segment #3 is between 1.9 seconds and 3.2 seconds. The range of misalignment is due to test data variations at different degrees of orientation of the assembly. This variation could conceivably be reduced by stiffening the support mount or tweeking in the tension supports.

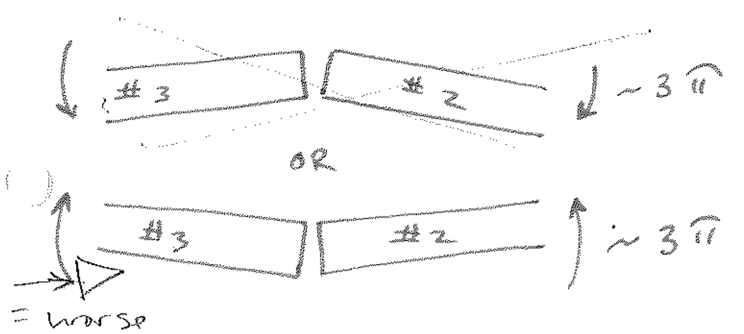
This re-evaluation of alignment was a "quick test" with no effort made to locate cause of error, or establishing means of correction. A more indepth test is suggested to confirm error.







~3 Fringes in 2"Ø



.36 SCALE

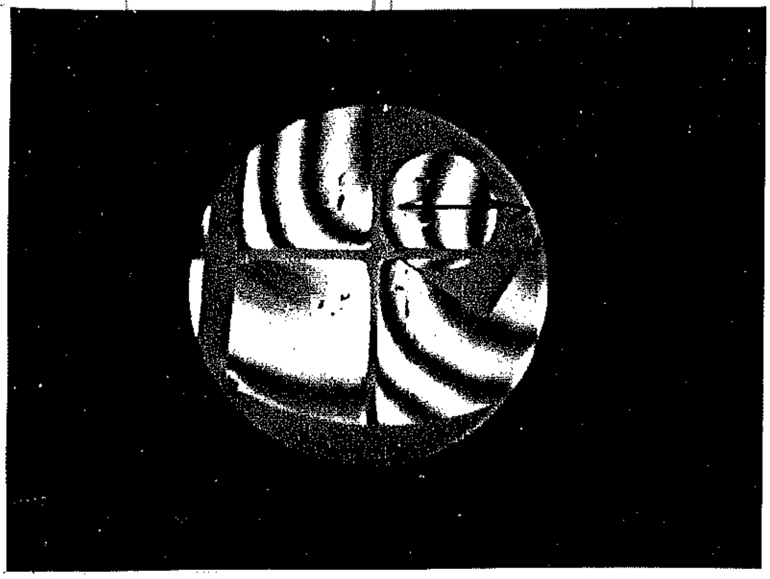
6"

7-28-88

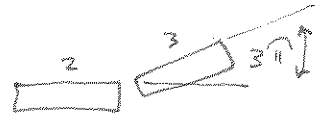
"MOSAIC"

JO
DH

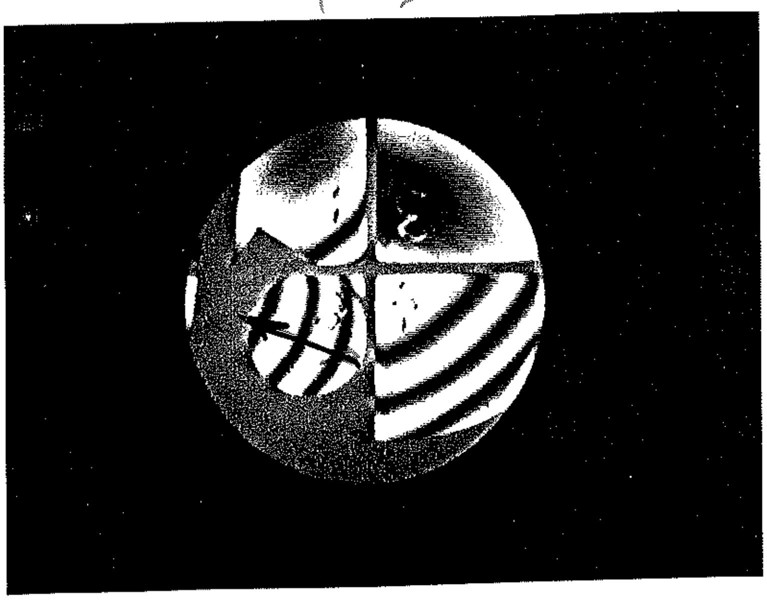
1 3

2  4

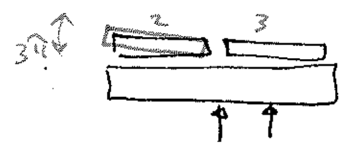
8-15-88
Null 2
3 is 3⥣ as shown (uphill arrow)



1 3

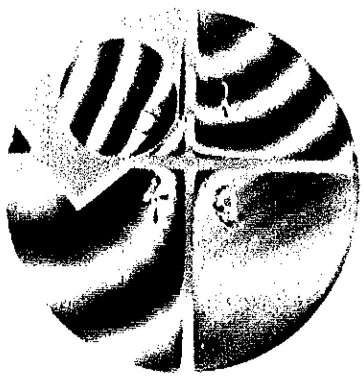
2  4

Null 3
2 is 3⥣ as shown (uphill)

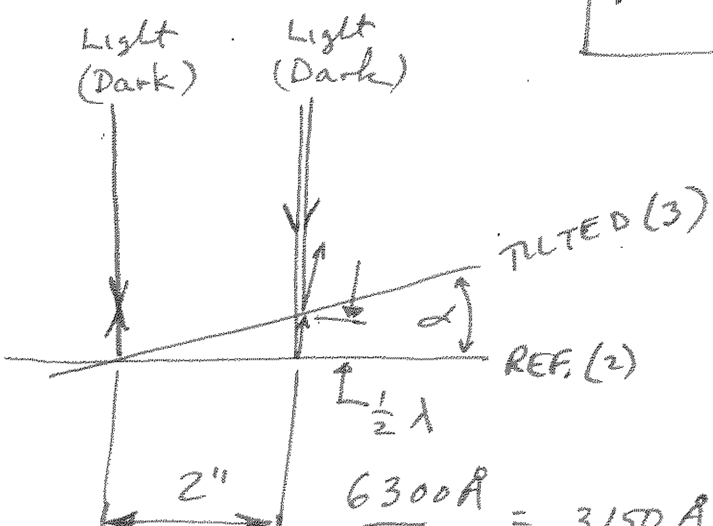


NON-IDEAL SUPPORT (LIKE 8-12-88)

Ref. Only



FOR 2" ∅:
1 FRINGE = 1.28″



$$\frac{6300\text{Å}}{2} = 3150\text{ Å}$$

$$\tan\alpha = \left\{ \frac{3150\text{Å} \times \left(\frac{315\text{ nm} \times 1\text{ m}}{1 \times 10^9\text{ nm}} \times \frac{39.4''}{1\text{ m}} \right)}{2''} \right\}$$

$\alpha = 0.00036°$
$= 1.28″$

3 Fringes = 3 × 1.28″ = 3.8″

9. SPECIFICATIONS AND TOLERANCES

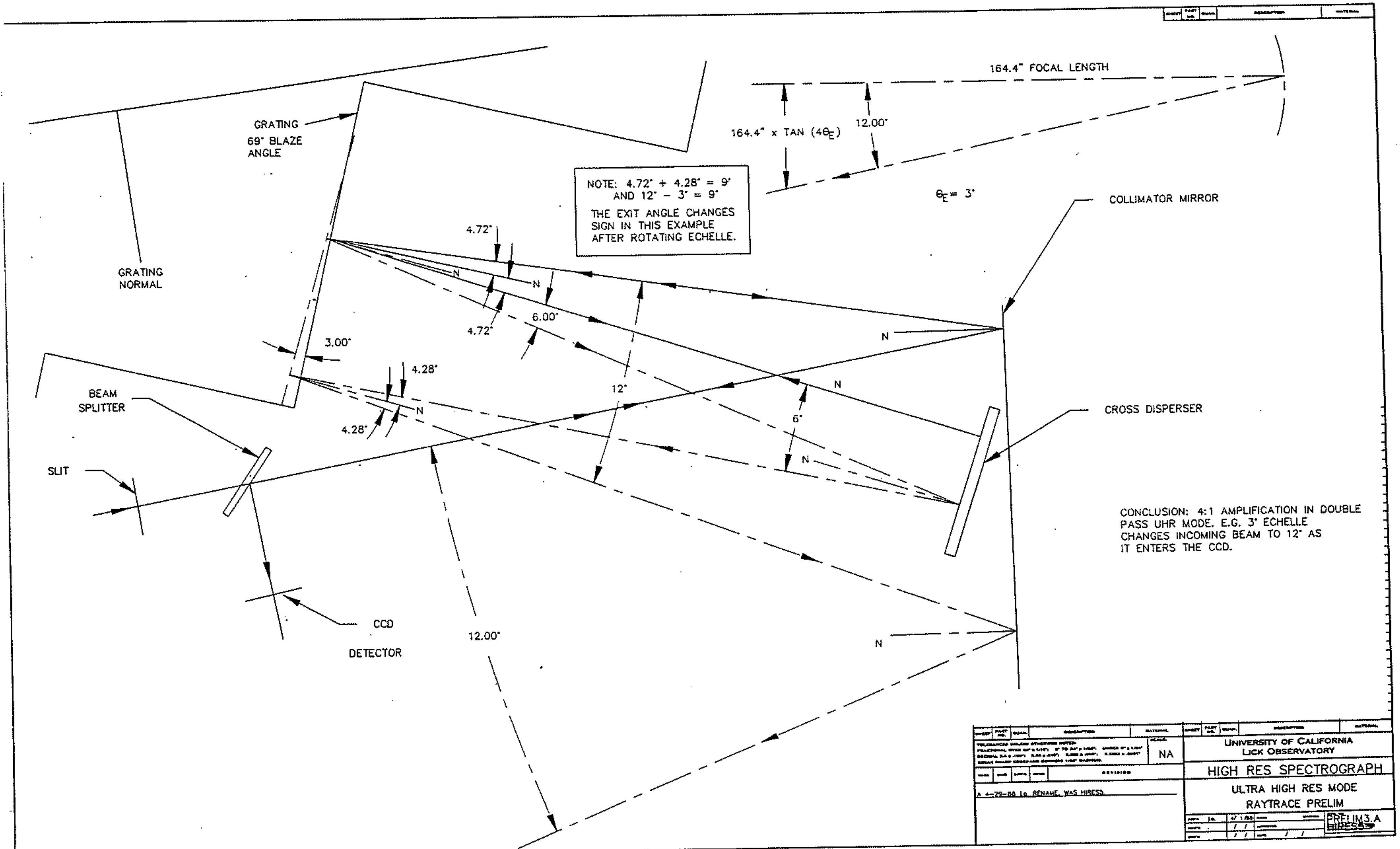
The specifications began as a combination of worst case resolution requirement and longest focal length camera. Pixel resolution of 1/50th was dreamed of in the beginning. Using the Tektronix CCD as detector with 27 μ pixels and the UHR camera mode in double pass, with 164 in. focal length, a specification was created: 0.007 arcsec. This is for grating rotations of 180°.

The specification has changed to 1 arcsec over 180°. The motion at the detector during any exposure will be less than 1/10th pixel. (No exposure will change the subplate loading by more than 0.02 g.)

Machining tolerances on the glass are standard quarter wave flatness and front-to-back parallelism of 1 arcmin or so. The pockets in the glass are diamond tooled and not polished.

Machining tolerances on the metal are also standard shop practices. The tightest tolerance is 0.005 in. and is easily achieved.

The material properties for the subplate represents the biggest uncertainty: questions of long term stability cannot be answered without long term measurements. We are 12 months into a long term stability measurement now. The changes are unmeasurable. If a sudden dimensional change occurs in time, then the gratings may need realigning. We doubt that this will happen.

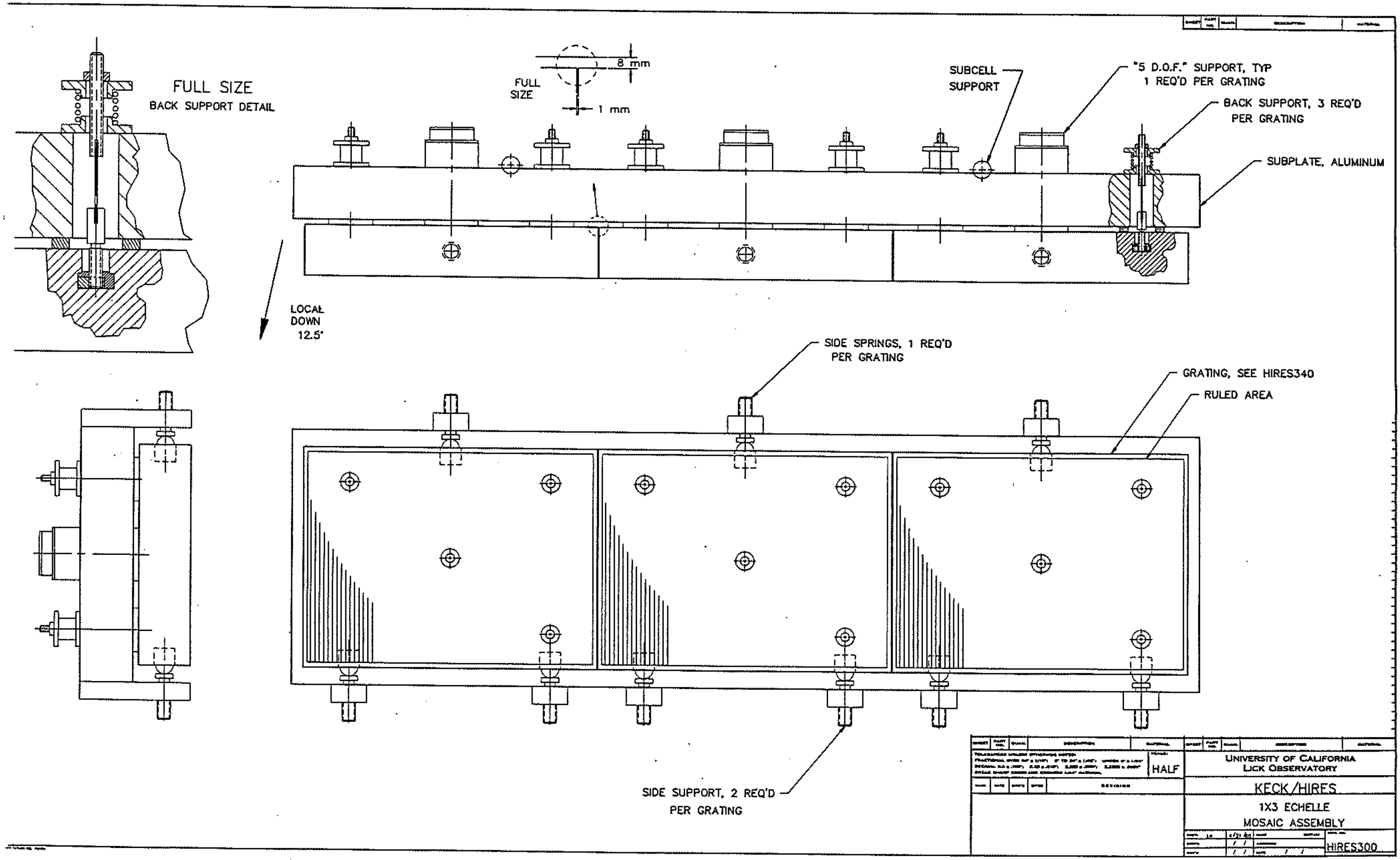


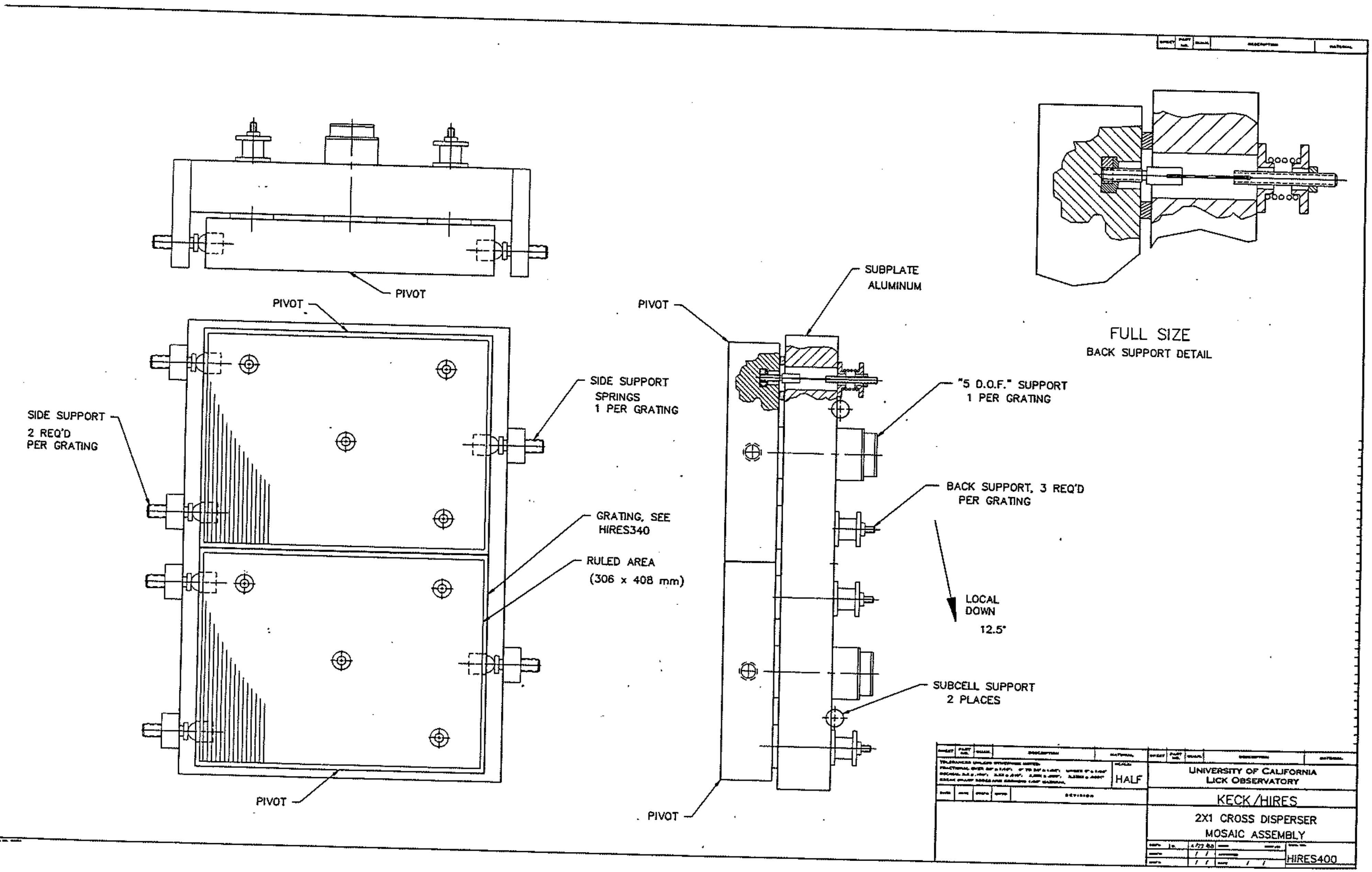
164.4" FOCAL LENGTH
164.4" x TAN (4θE)
12.00°
θE = 3°
COLLIMATOR MIRROR
GRATING
69° BLAZE
ANGLE
NOTE: 4.72° + 4.28° = 9°
AND 12° - 3° = 9°
THE EXIT ANGLE CHANGES
SIGN IN THIS EXAMPLE
AFTER ROTATING ECHELLE.
GRATING
NORMAL
4.72°
N
6.00°
3.00°
4.28°
12°
6°
BEAM
SPLITTER
SLIT
CROSS DISPERSER
CONCLUSION: 4:1 AMPLIFICATION IN DOUBLE
PASS UHR MODE. E.G. 3° ECHELLE
CHANGES INCOMING BEAM TO 12° AS
IT ENTERS THE CCD.
CCD
DETECTOR
12.00°
NA
UNIVERSITY OF CALIFORNIA
LICK OBSERVATORY
HIGH RES SPECTROGRAPH
ULTRA HIGH RES MODE
RAYTRACE PRELIM
PRELIM3.A
A 4-29-88 Lo RENAME, WAS HIRESS.

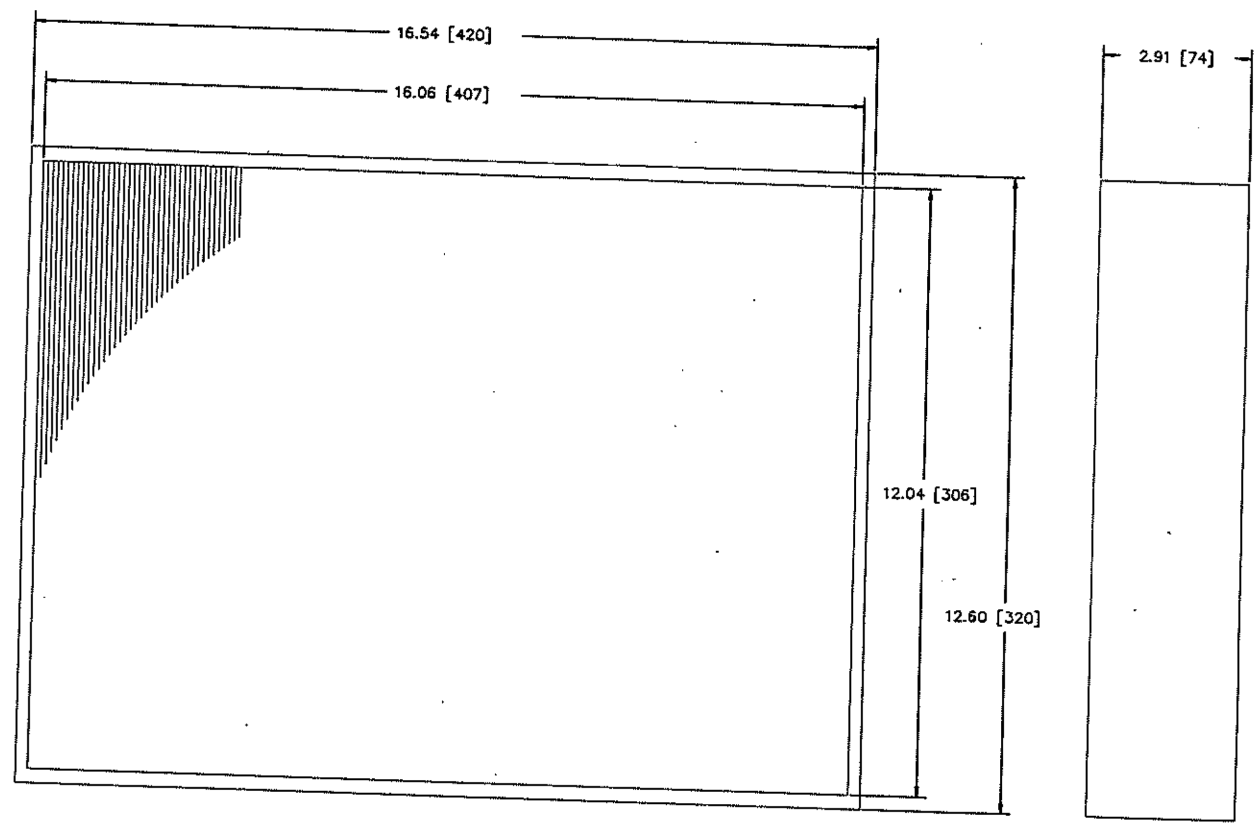
10. WORK IN PROGRESS

Subplate design is in progress for the Keck HIRES spectrograph. The Echelle mosaic and the Cross Disperser mosaic are being designed. Preliminary designs are presented here. These gratings are 12.6 in. × 16.54 in. × 2.91 in. as shown in a drawing. The computer optimization is being done on an IBM PC/AT using Borland Turbo Basic. Also, a finite element analysis program (FEAP) is being developed with NISA II software to more fully model the mosaic subplate system and to gain experience using a FEAP.

Future testing will benefit from the Zygo Mark II interferometer which we have recently purchased. It has several accessories: video output, connection to an IBM PC/AT for digitizing, and software for interferogram interpreting.


FULL SIZE
BACK SUPPORT DETAIL
8 mm
FULL SIZE
1 mm
SUBCELL SUPPORT
"5 D.O.F." SUPPORT, TYP
1 REQ'D PER GRATING
BACK SUPPORT, 3 REQ'D
PER GRATING
SUBPLATE, ALUMINUM
LOCAL DOWN 12.5°
SIDE SPRINGS, 1 REQ'D
PER GRATING
GRATING, SEE HIRES340
RULED AREA
SIDE SUPPORT, 2 REQ'D
PER GRATING
HALF
UNIVERSITY OF CALIFORNIA
LICK OBSERVATORY
KECK/HIRES
1X3 ECHELLE
MOSAIC ASSEMBLY
HIRES300


PIVOT
PIVOT
SIDE SUPPORT
2 REQ'D
PER GRATING
SIDE SUPPORT
SPRINGS
1 PER GRATING
GRATING, SEE
HIRES340
RULED AREA
(306 x 408 mm)
PIVOT
PIVOT
SUBPLATE
ALUMINUM
PIVOT
"5 D.O.F." SUPPORT
1 PER GRATING
BACK SUPPORT, 3 REQ'D
PER GRATING
LOCAL
DOWN
12.5°
SUBCELL SUPPORT
2 PLACES
FULL SIZE
BACK SUPPORT DETAIL
HALF
UNIVERSITY OF CALIFORNIA
LICK OBSERVATORY
KECK/HIRES
2X1 CROSS DISPERSER
MOSAIC ASSEMBLY
HIRES400



⊖ GLASS BLANK

ZERODUR

REF: MILTON ROY GRATING CO.
TABLE 5
CROSS DISPERSERS:
1. "RED/BLUE" IS 300 LINES/mm
2. "LONGSLIT 1" IS 600 LINES/mm

FULL

UNIVERSITY OF CALIFORNIA
LICK OBSERVATORY

KECK/HIRES

MOSAIC GRATING BLANKS
DETAILS

HIRES340

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