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Distribution Category UC-63

LASER-ZONE GROWTH IN A RIBBON-TO-RIBBON (RTR) PROCESS,
SILICON SHEET GROWTH DEVELOPMENT FOR THE LARGE AREA
SILICON SHEET TASK OF THE LOW COST SILICON SOLAR
ARRAY PROJECT

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Motorola Report No. 2256/1

Technical Quarterly Report No. 1

March 1976

JPL CONTRACT NO. 954376

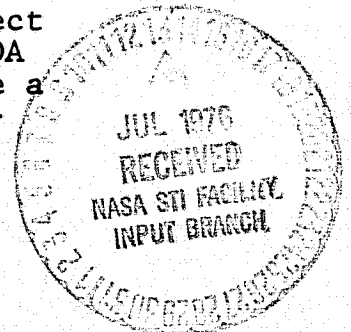
By

R. W. Gurtler, A. Baghdadi

PREPARED BY

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"The JPL Low-Cost Silicon Solar Array Project is funded by ERDA and forms part of the ERDA Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost solar arrays"



(NASA-CR-148316) LASER-ZONE GROWTH IN A RIBBON-TO-RIBBON (RTR) PROCESS, SILICON SHEET GROWTH DEVELOPMENT FOR THE LARGE AREA SILICON SHEET TASK OF THE LOW COST SILICON SOLAR ARRAY PROJECT Technical Quarterly

G3/44

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ABSTRACT

The objective of this research contract is to fully investigate the Ribbon-to-Ribbon (R-T-R) approach to silicon ribbon growth. Initial work has concentrated on modification and characterization of an existing R-T-R apparatus. In addition, equipment for auxiliary heating of the melt is being evaluated and acquired. Modification of the remote viewing system and mechanical staging are nearly complete. Characterization of the laser and other components is in progress and several auxiliary heating techniques are being investigated.

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SUMMARY

Modifications to the RTR growth facility are proceeding on schedule. The two main viewing camera systems have been installed and are operational. A third camera system for edge viewing, not necessary for initial growth experiments, has been designed and is being constructed. Various auxiliary heating techniques are under investigation for utilization in the RTR process; among these, the most promising are direct electrical heating, radiant sources and the "Energy Beam". Evaluation of the laser operating characteristics and performance of optical components has been initiated.

Some mechanical problems have arisen in the ribbon transport fixturing; the ribbon chucks do not move smoothly and consequently could cause sample breakage due to stressing of the ribbon, especially when operating in the independent mode where the feed and uptake chucks operate under separate motor control. Work is continuing to improve the performance of these transport stages.

PROGRESS

Camera System

The camera systems for viewing the ribbon from both sides of the ribbon simultaneously have been installed and are now operational. A third camera installation for edge viewing of the ribbon has been designed (engineering drawings are found in the Appendix) and is now being fabricated.

Since this third camera is not necessary for immediate use in the ribbon growth experimentation phase of the contract, the camera system may be considered operational.

Mechanical Transport System

Previous operation of the RTR apparatus (prior to the present contract) had indicated that our ribbon transport system needed modifications to improve the smoothness of operation and the tracking of the "feed" and "uptake" chucks which are on independent stepping motor drives (Responsyn HDM150, 2000 steps/rev.). Two precision leadscrews cause the translation of the ribbon chucks and .5" ground rods are used for alignment. Measurements showed separation distance variations (during translation) which were unacceptably large. Since ribbons as thin as 4 mils are to be investigated during the course of the contract, it was deemed desirable to maintain separation variations as small as possible. If the volume of the melt is

$$V = Wt\ell$$

where

W = ribbon width

ℓ = molten region length

t = molten region thickness

then a variation in chuck separation will reflect itself initially as a variation in l , δl . Maintaining the melt volume constant leads to the relation

$$\frac{\delta l}{l} + \frac{\delta W}{W} + \frac{\delta t}{t} = 0$$

Consequently, a variation in melt length will reflect itself in a variation in width and thickness. These variations depend on dynamics - a rapid change in length will probably be taken up initially as almost entirely a thickness change, because the required material transport needs to occur over only a short distance in the case of a thickness change, but a relatively much larger distance in the case of a width change. At worst, we may take

$$\frac{\delta t}{t} \approx \frac{-\delta l}{l}$$

If a molten region of 10 mils is assumed, a δl of 1 mil will give a 10% thickness variation at worst. A goal for the staging was set at a variation of + 1 mil.

The undesired variations in separation were, at least in part, a result of design of the chucks which held the ribbons; they were cantilevered out from the main ball bushings which maintained alignment, and the ratio of the cantilever length to ball bushing support length was relatively large, i.e., a magnification of small errors would occur. A modification has been incorporated into the staging which reduced this magnification. This seems to have improved matters, and indeed, initial tests indicated that variations of + 1 mil had been attained. Attempts to repeat this performance have been unsuccessful, however, and presently it is thought that some bearings are faulty. Efforts will continue to obtain the desired staging accuracies.

Independent staging is not a necessity for initial crystal growth studies since a single "C" shaped fixture which is entirely supported by a single chuck may be used to hold a ribbon. However, reliable independent control will be necessary when attempting seeding operations, and also in studies where thin ribbons are to be pulled from thicker ribbons.

Auxiliary Heating

Auxiliary heating techniques which can serve to relieve the power requirements of the laser, and as a means of reducing strain due to very steep thermal gradients, are being evaluated. It is desirable that the heating technique not interfere with the laser beam nor interfere with the observation of the ribbon. For these reasons, electrical, radiant, and "Energy Beam" heating are attractive.

Electrical Heating

Since silicon is a fairly good electrical conductor at high temperatures, direct electrical heating of the ribbon may be utilized if electrical contacts are provided. A theoretical treatment of an electrically heated ribbon in the presence of radiative and convective cooling, and contacts of a given thermal impedance, has been carried out in a one-dimensional treatment. Referring to Figure 1, the heat equation (steady-state) becomes

$$-WtK\frac{\partial^2 T}{\partial x^2} = P(x) - 2\bar{\epsilon}W\sigma(T^4 - T_A^4) - 2hW(T - T_A)^n$$

where $P(x)$ represents the power input per unit length due to electrical heating, the second term represents radiative cooling with an emissivity of $\bar{\epsilon}$ to an ambient at T_A and the third term represents convective cooling with a heat transfer coefficient h and a power law of n . $P(x)$ is given by

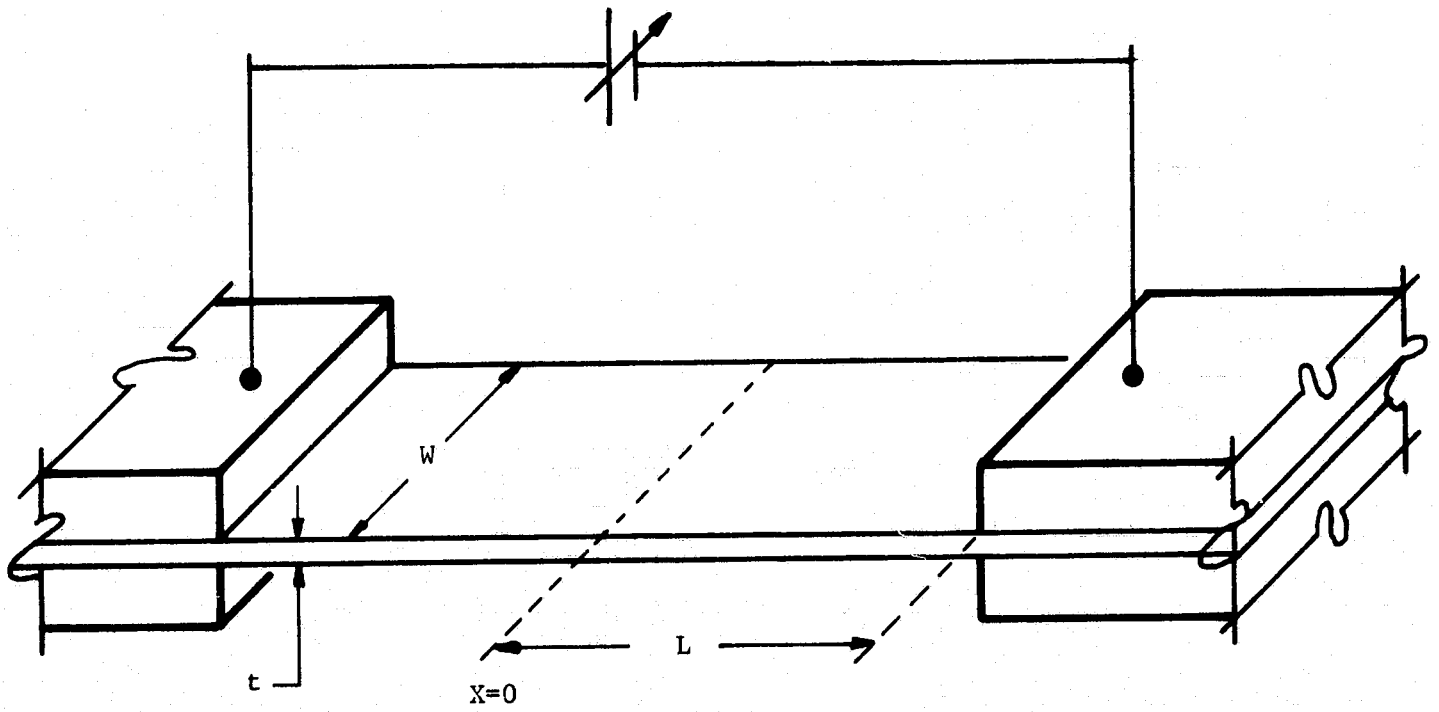


FIGURE 1

$$P(x) = I^2 R(x) = \frac{I^2}{Wt} \rho(x) .$$

I is the current and ρ is the local resistivity. ρ is highly temperature dependent unless the sample is heavily doped. Figure 2 gives a plot of $\rho(T)$ for various doped N type samples. $\rho(T)$ can be expressed as

$$\rho(T) = \sigma_{(T)}^{-1} = \left[q \left\{ (N_D + \eta_i(T)) \mu_e(T) + (N_A + \eta_i(T)) \mu_h(T) \right\} \right]^{-1}$$

where $\eta_i(T)$ is the intrinsic carrier concentration, N_D and N_A are donor and acceptor concentrations and μ_e and μ_h are electron and hole mobilities.

From Smith*

$$\eta_i(T) = 3.873 \cdot 10^{16} T^{3/2} e^{\frac{-7 \cdot 10^3}{T}}$$

$$\mu_e(T) = 4.0 \cdot 10^9 T^{-2.6}$$

$$\mu_h(T) = 2.5 \cdot 10^8 T^{-2.3}$$

The above differential equation was numerically integrated under the boundary conditions

$$\frac{\partial T}{\partial x} = 0 @ X=0$$

and

$$T(L) = T_A + \theta w t \frac{\partial T}{\partial x} \Big|_{x=L}$$

where θ is a contact thermal impedance. Using the following parameters, the solutions of Figure 3 were obtained.

$$K = .3 \frac{W}{cm^2 C}$$

$$\theta = 10 \text{ } ^\circ C/W$$

$$h = .5 \cdot 10^{-5} \frac{W}{cm^2 C^n}$$

$$T_A = 350 \text{ } ^\circ K$$

$$n = 5/4$$

$$2L = 10 \text{ cm}$$

$$N_D = 10^{15}$$

$$W = 2 \text{ cm}$$

$$t = .02 \text{ cm}$$

* "Semiconductors," R.A. Smith, Cambridge University Press, 1964, pp 355-359

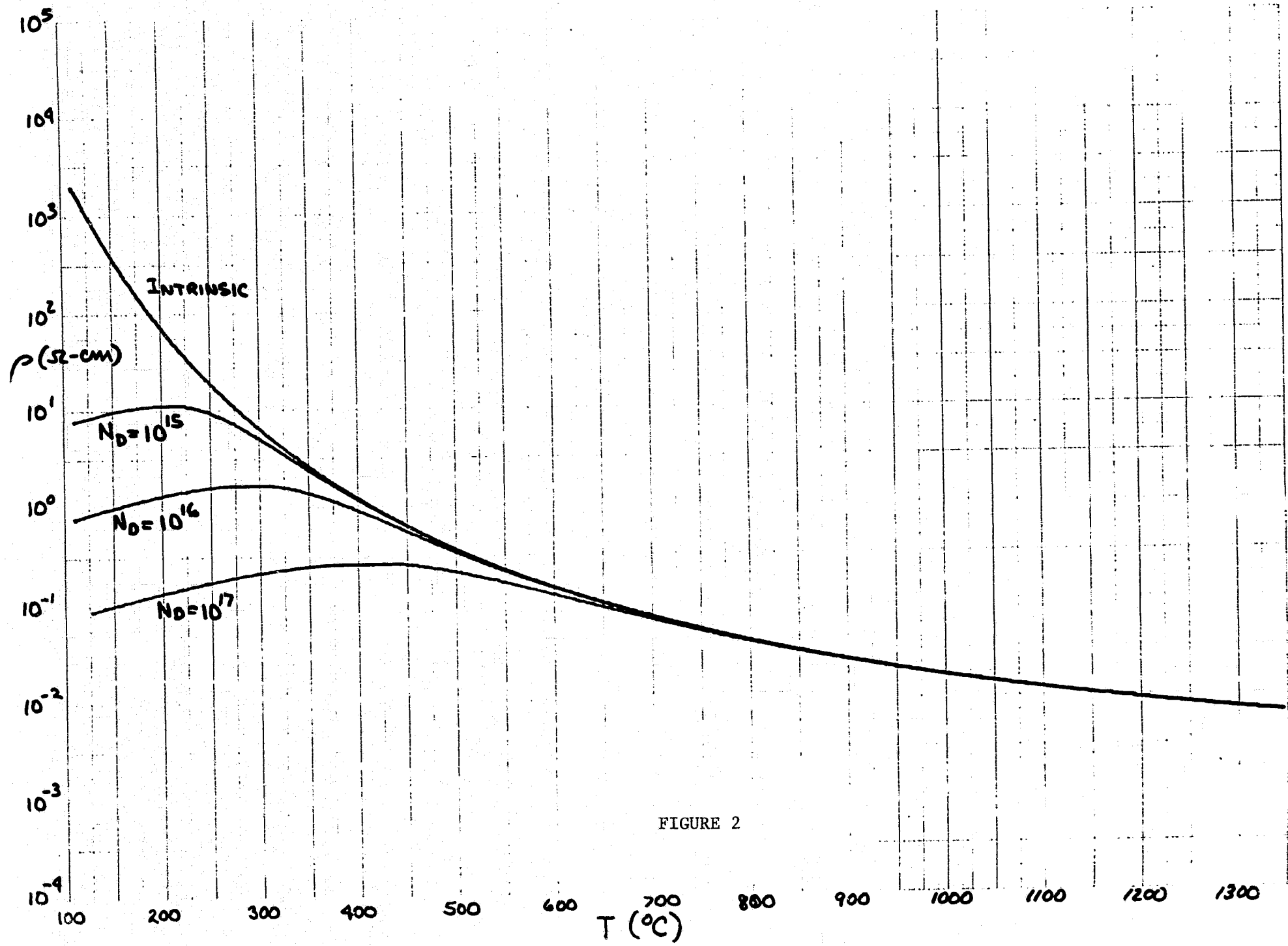


FIGURE 2

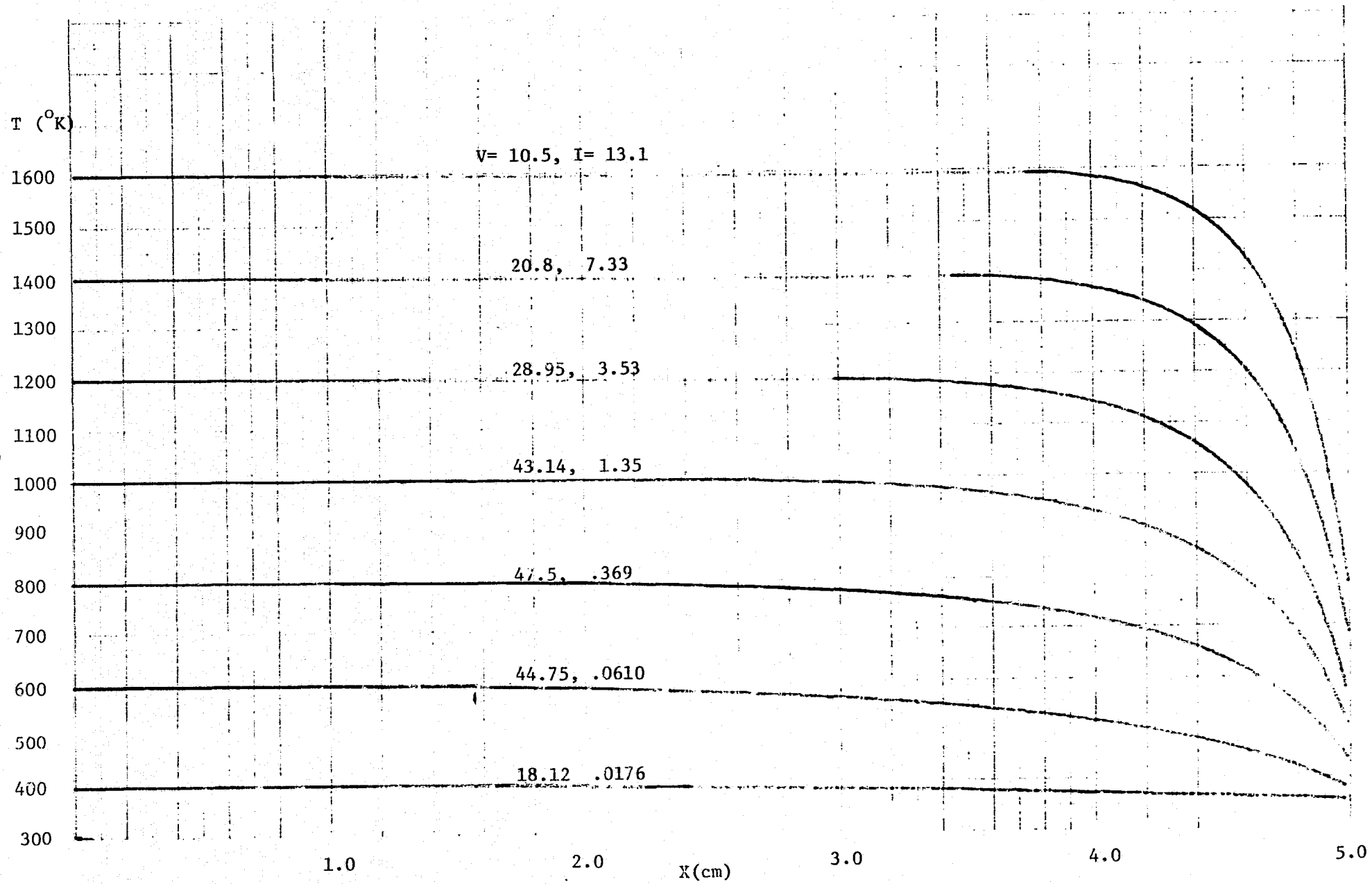


FIGURE 3

On each curve is noted the voltage and current required to obtain the curve in question. The voltage required for a given temperature is highly dependent on the thermal environment at the contacts since this is the region of high resistivity. On the other hand, the current is dependent only on the physical size of the ribbon and the radiative and convective losses. Note the very flat temperature profile over a substantial portion of the ribbon - conductive losses are unimportant over most of the ribbon.

A fixture has been constructed (diagram contained in Appendix) which allows electrical heating of a ribbon within the RTR apparatus. Boron nitride blocks provide the electrical isolation from the fixture and graphite blocks serve as the electrical contacts. Gold plated stainless steel contacts hold the graphite and ribbon under moderate tension and serve as the high conductivity connections to the graphite blocks.

The electrical heating fixture has been successfully tested. Detailed comparison with theory has not yet been performed, but general observations are in agreement with the presented model. In particular, very flat temperature profiles are obtained. Uniform heating to 1250°C has so far been attained, but some improvement in contacting uniformity is still desirable.

Electrical heating of ribbon promises to be a very useful research tool since one can very easily adjust the ribbon temperature and study the effects on laser input power requirements to melt. Also, by adjusting the ribbon temperature, the thermal gradient at the freezing point may be continuously varied. In addition, this will provide an effective way to measure optical and thermal properties of thin ribbon pieces.

Energy Beam

The Energy Beam is a trade name for an interesting Rf heating device manufactured by Energystics*. Figure 4 represents our conception of the Energy Beam operation. A gas stream is passed through a conducting tube which is in contact with an RF oscillator output coil (it actually serves to cool the coil also). A second, cylindrically concentric gas stream passes over this tube and serves to collimate the inner jet, i.e. buffer it from the atmosphere and maintain laminar flow; initially it is also electrically isolated from the inner stream. RF energy ionizes the gas within the inner jet which then, because of its macroscopic motion in the gas stream, effectively provides a conducting path (plasma) along the inner jet stream. The inner plasma jet thus serves as a conductive extension of the output coil and if an object is allowed to intercept this stream, dielectric and conductive heating will occur at the sample, little energy being expended in the plasma jet. The return path of the circulating RF current is through leakage to the atmosphere. Alternatively one can electrically ground the sample.

The device has very good overall efficiency ($\approx 60\%$) and can locally heat a spot of the order of $3/16''$ at $4''-5''$ working distances. A trip was made to the Energystics facility to evaluate the Energy Beam as a means of auxiliary heating. A linear array of Energy Beams is evidently feasible and they are attempting to demonstrate relatively uniform heating in this mode. If this can be demonstrated, a 2KW unit will be obtained.

* Energystics Inc., Toledo, Ohio

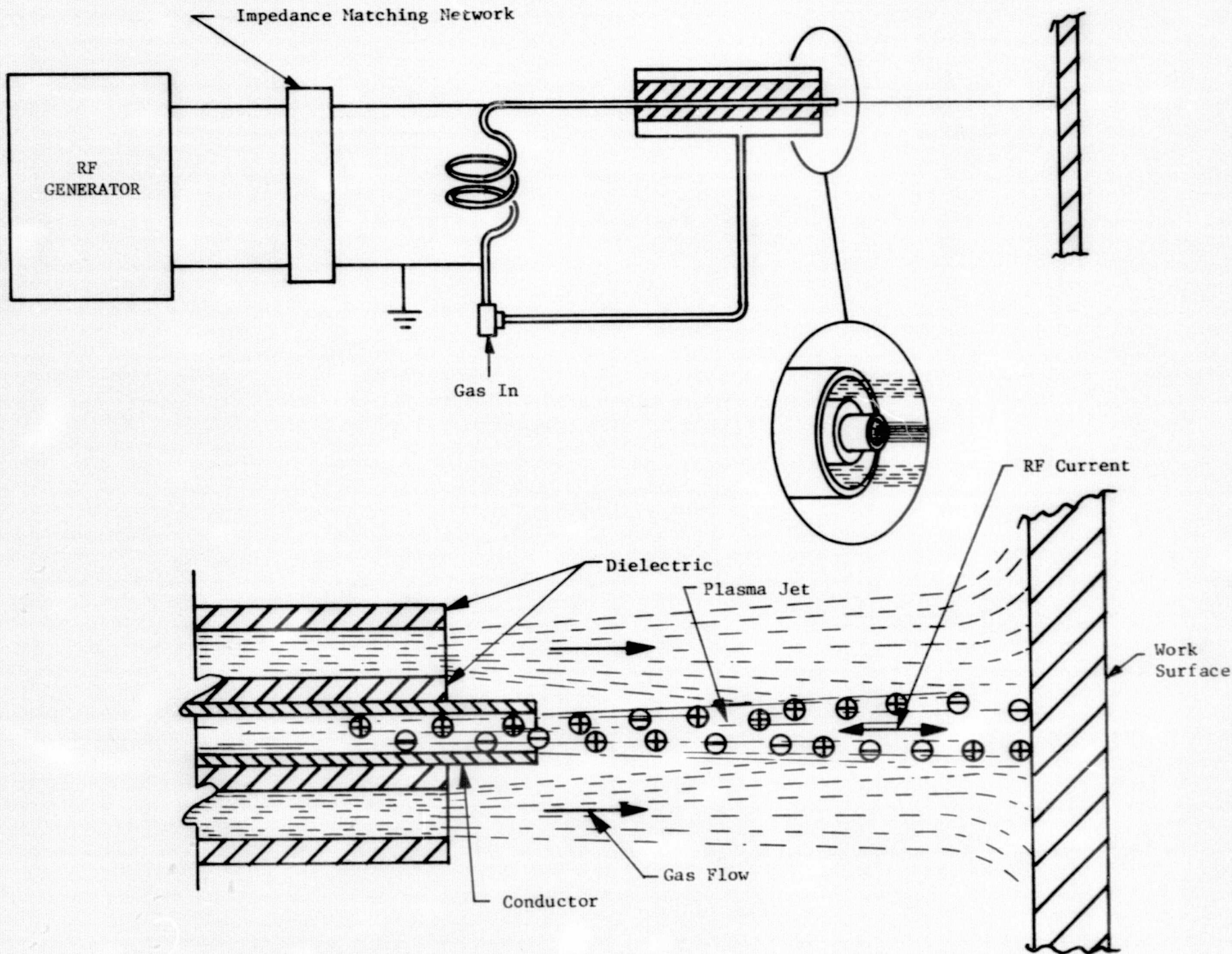


FIGURE 4

Radiant Heating

One vendor (Fusion Systems) has shown considerable interest in supplying radiant heat sources for our requirements. We have sent them some ribbon samples for experimentation and if they are successful in reaching temperatures near the melting point, at reasonable angles and working distances, then a system will probably be obtained. The lamps are arc lamps and they have expressed some willingness to adjust gas compositions in order to better match the spectral output to the absorption of silicon.

RF Heating

Investigation is continuing into the use of RF heating (KHZ to MHZ) for pre-heating and post-heating of silicon ribbon. Eight vendors have been contacted, and our initial inquiries are now being followed up with appropriate vendor discussions. The most probable approach for implementing RF heating for these applications is via the use of a shaped susceptor which is encapsulated in a quartz envelope; the RF coils are placed externally around the susceptor with a coil-to-coil spacing which varies to allow the desired temperature profiling along the length of the susceptor. The application to auxiliary heating by this method is questionable because of the difficulty of allowing for the entrance of the laser beam. If this proves to be too much of a problem, RF heating may still find use in stress relief at a location somewhat removed from the actual growth area.

Laser Characterization

The laser employed for the RTR growth apparatus is a Photon Sources, model 300, CO₂ laser with a conservatively rated 375W CW output. In operation, various gas mixtures need to be adjusted to optimize the

operation of the laser. The gas mixtures (He, CO₂ and N₂) affect the output mode as well as total output power. Several experiments have been performed to evaluate the laser characteristics as well as a few of the optical components.

Utilized for these evaluations were a galvanometer mirror scanner (General Scanning G-300 PDT), a 1% ZnSe beam splitter (to reduce power to the detector) a moderate bandwidth (20Hz - 100kHz) pyroelectric detector (Laser Precision KT-2010S 1mm detector and KTH-201(7) preamplifier), a pyroelectric radiometer (Laser Precision RK 3440) and a high speed optical chopper (Laser Precision CTX-534).

Beam Profile

The apparatus used to measure the beam profile is shown schematically in Figure 5. The beam splitter used for this measurement transmits 1% of the incoming beam. Figure 6 is a transmission spectrum of the beam splitter showing 1% transmission at the CO₂ laser wavelength, 10.6 microns.

An example beam profile in both the X and Y directions is shown in Figure 7. The two dimensions were obtained by directly measuring the profile as indicated in Figure 5 for the X direction and then incrementing the detector in the Y direction to obtain the Y variation. Although the beam profile is not an ideal Gaussian, it serves our purposes well: it is sharply peaked, and has no "ringing" or "doughnut" modes. The 1/e² points are about 9mm apart in both the Y and X directions.

Beam Stability

The apparatus used to measure the beam stability is shown in Figure 8. A single-sweep oscilloscope trace of the measured output is shown in Figure 9.

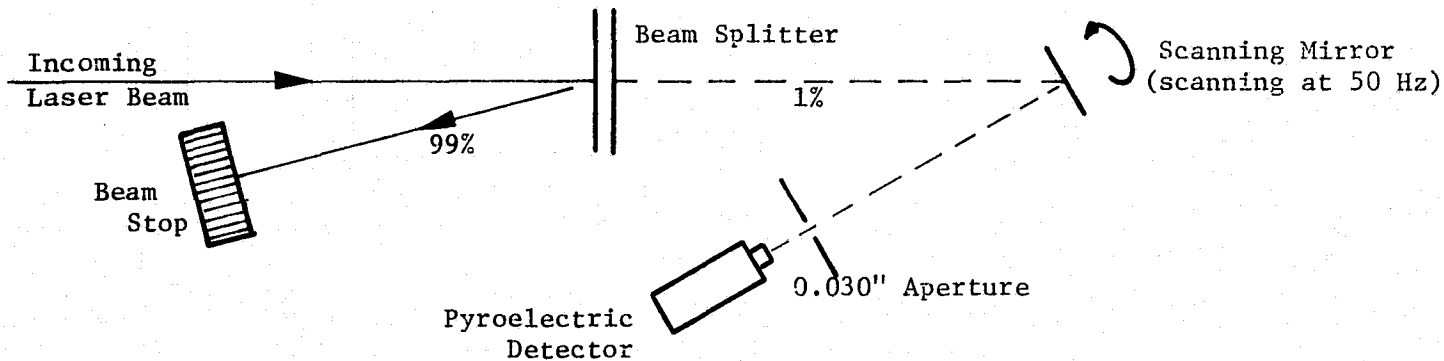


FIGURE 5

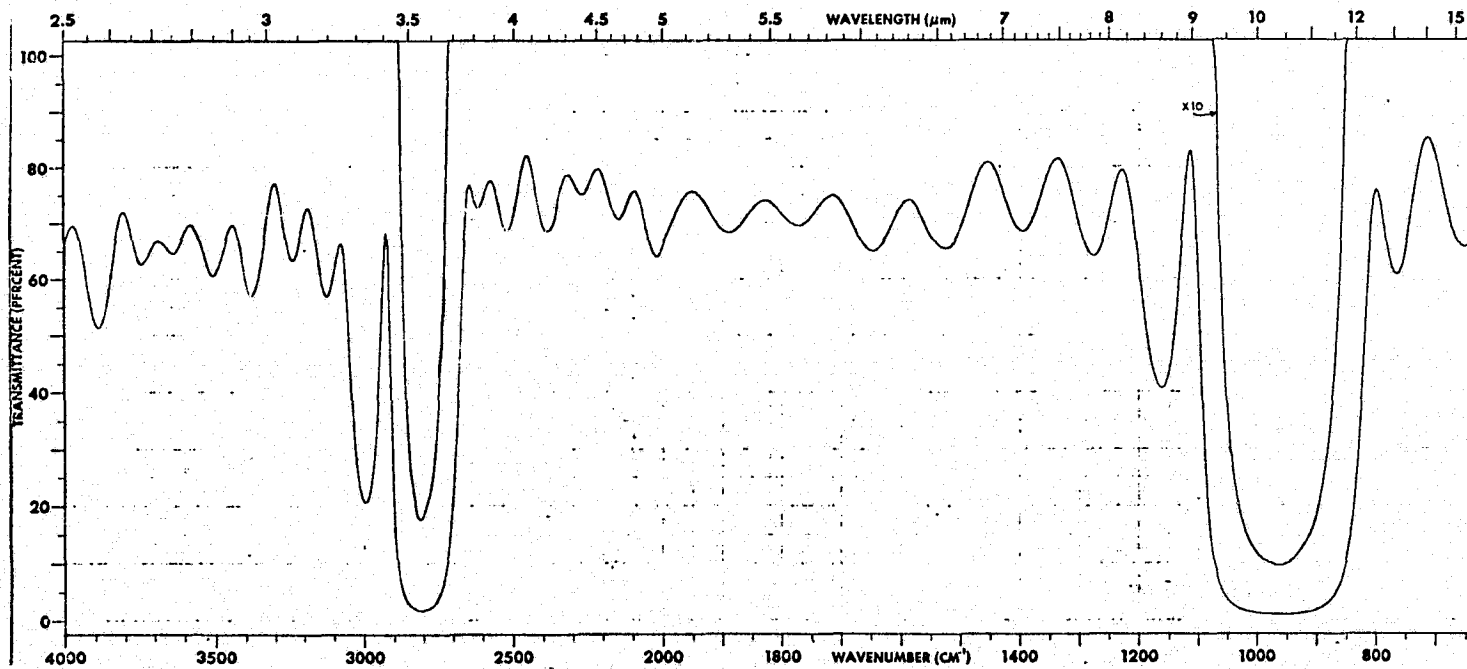


FIGURE 6

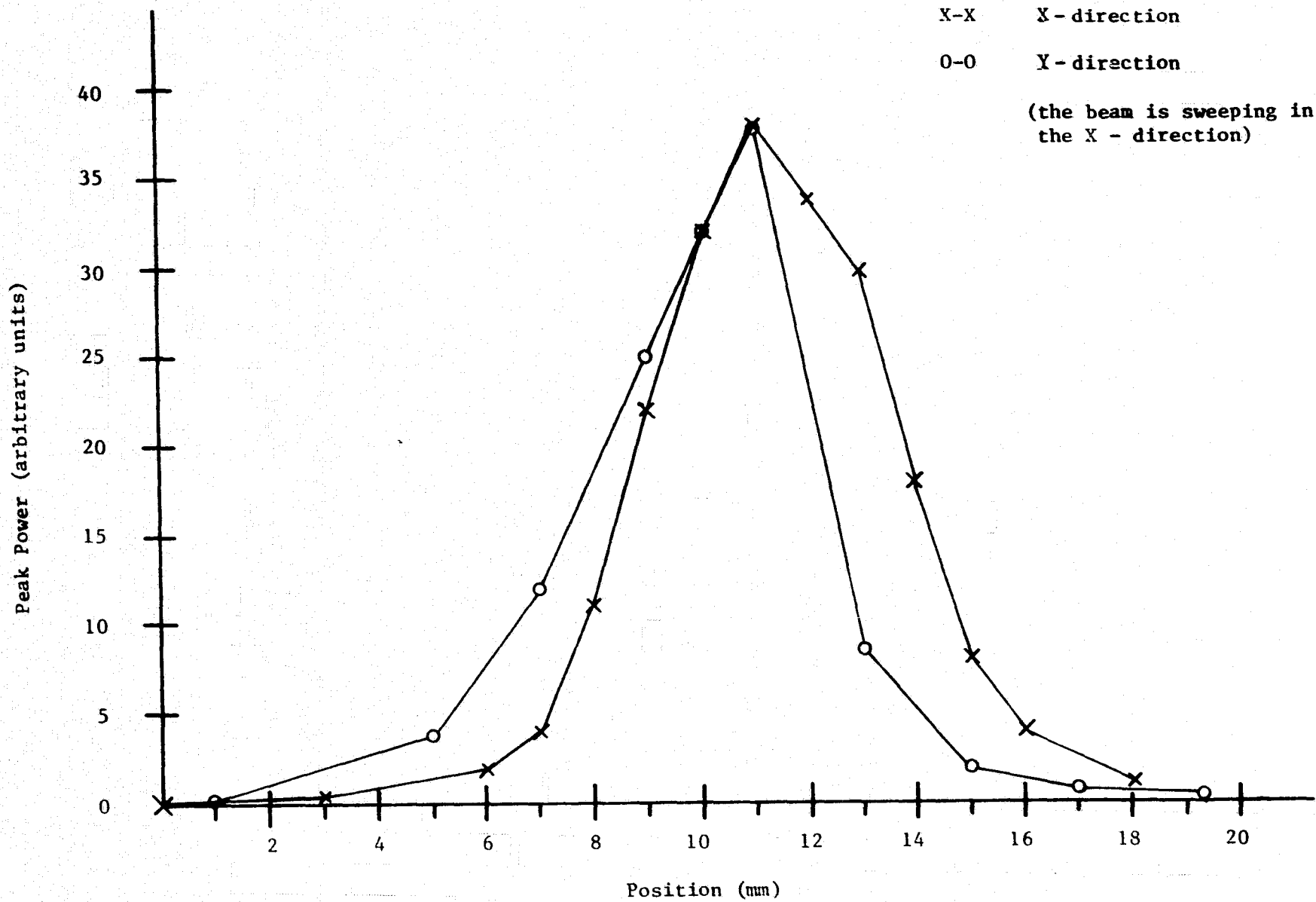


FIGURE 7

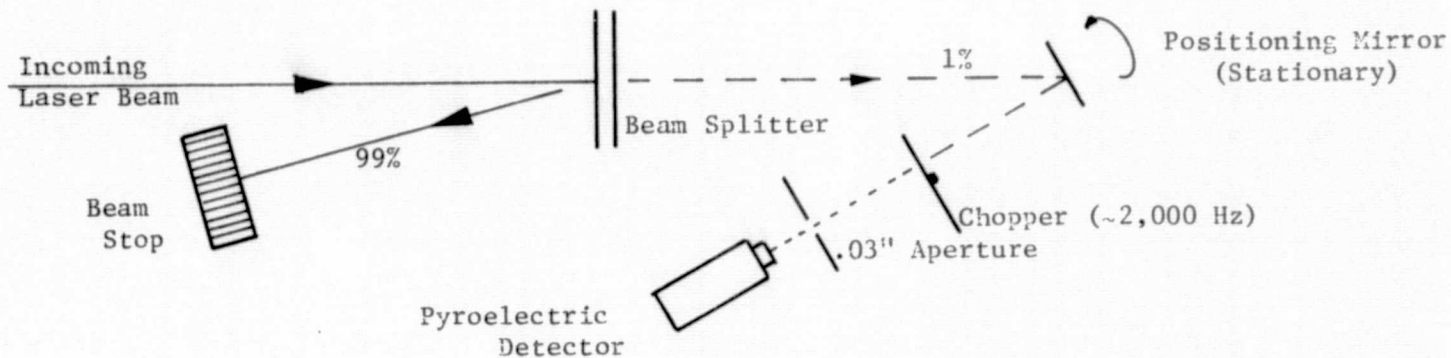


FIGURE 8

Power: 200 Watts
 Current Setting: 138
 He Flow: 12.0
 CO₂ Flow: 4.5
 N₂ Flow: 2.5
 Vertical Scale:* Relative Power
 Horizontal Scale: 50 ms/cm

*Power Indication is Difference
 Between Upper and Lower Heavy
 Traces

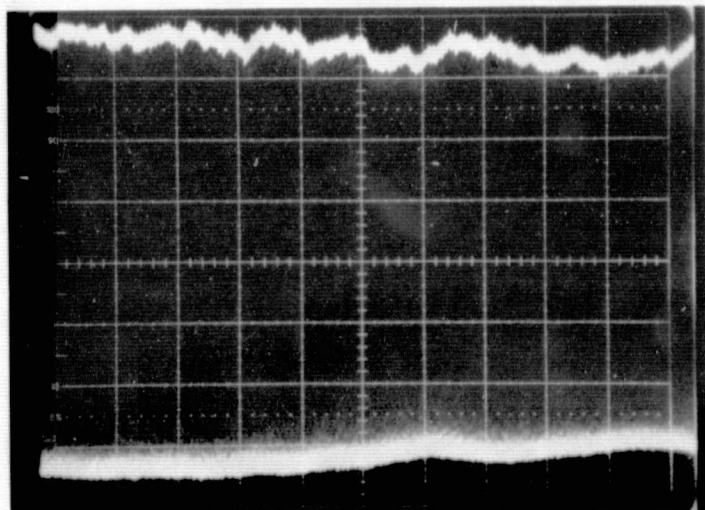


FIGURE 9

Note that the total sweep time is 0.5 seconds. The power output of the laser thus has random fluctuations on the order of 5% - 10%. The fluctuations are also random in their time intervals, ranging from 5 msec to hours.

"Far-field" Power

A significant portion of the radiation produced by the CO₂ laser does not go into the coherent, collimated laser beam. Due to aperture diffractions and imperfections in the laser cavity, some of the radiation is uncollimated, and thus does not reach the silicon ribbon. The power meter we have been using for these experiments was mounted by Photon Sources inside the laser apparatus, at the end of the laser cavity opposite to the output mirror. It therefore measures the "near-field" power, including some energy that is not delivered in the "far-field". We measured the far-field power using the apparatus shown in Figure 10. The results of this measurement are straightforward: once steady-state operation is reached, the far-field power meter reads about 6% lower than the Photon Sources near-field meter. Since the ZnSe lens absorbs 1% of the power it transmits, we conclude that about 5% of the laser power may be lost in a strongly diverging beam, although the calibration accuracies of the power meters are no better than 5% themselves. Under certain conditions, during initial warm-up, large discrepancies (~30%) between the two measurements can occur; this however, should not be a problem during operation.

Operating Parameters

Four parameters are used to control the output power of the laser: plasma current, Helium flow, CO₂ flow and N₂ flow. The same output power can be achieved using many different values of the operating parameters. The apparatus used for these measurements was shown in Figure 5. Figure 11a

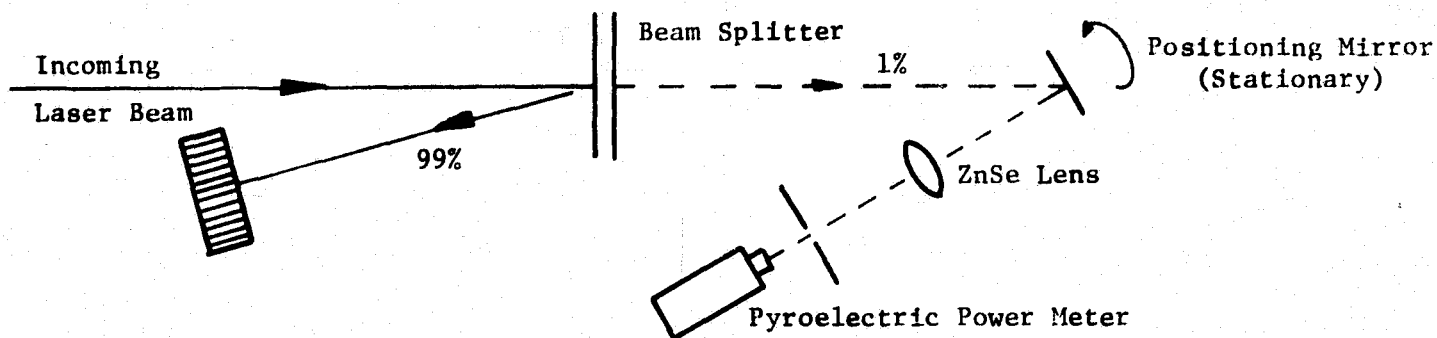
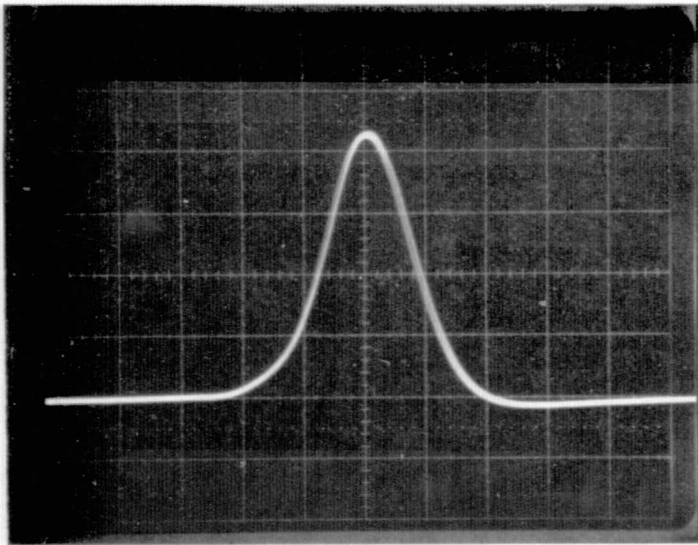
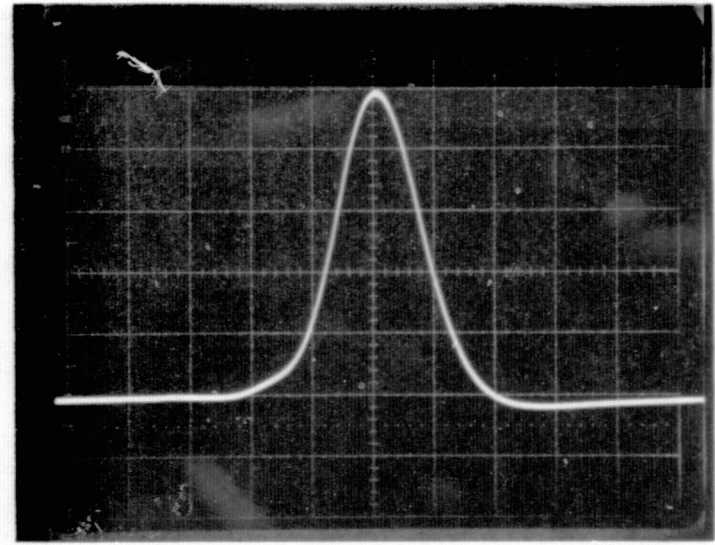


FIGURE 10



(a)

Power: 300 Watts
 Laser Current: 490
 Vertical Scale: Relative Power
 Horizontal Scale: $\approx 4\text{mm/Div}$
 He Flow: 8.0*
 CO₂ Flow: 4.5
 N₂ Flow: 2.2



(b)

Power: 300 Watts
 Laser Current: 364
 Vertical Scale: Relative Power
 Horizontal Scale: $\approx 4\text{mm/Div}$
 He Flow: 12.0
 CO₂ Flow: 4.5
 N₂ Flow: 2.5

* Flow rates are dial settings only

FIGURE 11

shows the beam profile obtained at 300 watts using the operating parameters suggested by Photon Sources, Inc. Figure 11b shows the optimal beam profile so far obtained. By using higher He and N₂ flow rates, with a lower plasma current, a narrower, more efficient beam profile was obtained. Similar results were obtained at all power levels.

Problems

As mentioned previously, some problems have arisen in the mechanical staging. These problems will receive more attention in an attempt to resolve them, but it should be realized that little impact is expected on the program initially, because of the ability to utilize a single stage for most of our investigations. In addition, the instabilities in laser output power need to be reduced to a minimum, and measures will be taken to accomplish this.

Plans

During the next quarter we will have proceeded from the sheet growth facility modification task (Task I) into the actual sheet growth (Task II) and ribbon characterization stages (Tasks III & IV).

Yet to be accomplished under Task I are the full characterization of the laser and other optical components, evaluation and implementation of some auxiliary heating techniques, and fabrication of a growth velocity "Programmer". Some optical and thermal analysis of various electrically heated ribbon samples will be performed to obtain some useful physical data relevant to the ribbon samples used in RTR growth. The thermal measurement instrumentation will be tested and calibrated, and the environmental control of the enclosure will be evaluated.

ENGINEERING DRAWINGS

Drawings of the side-looking camera system and an electrical heating fixture are found in the Appendix.

NEW TECHNOLOGY

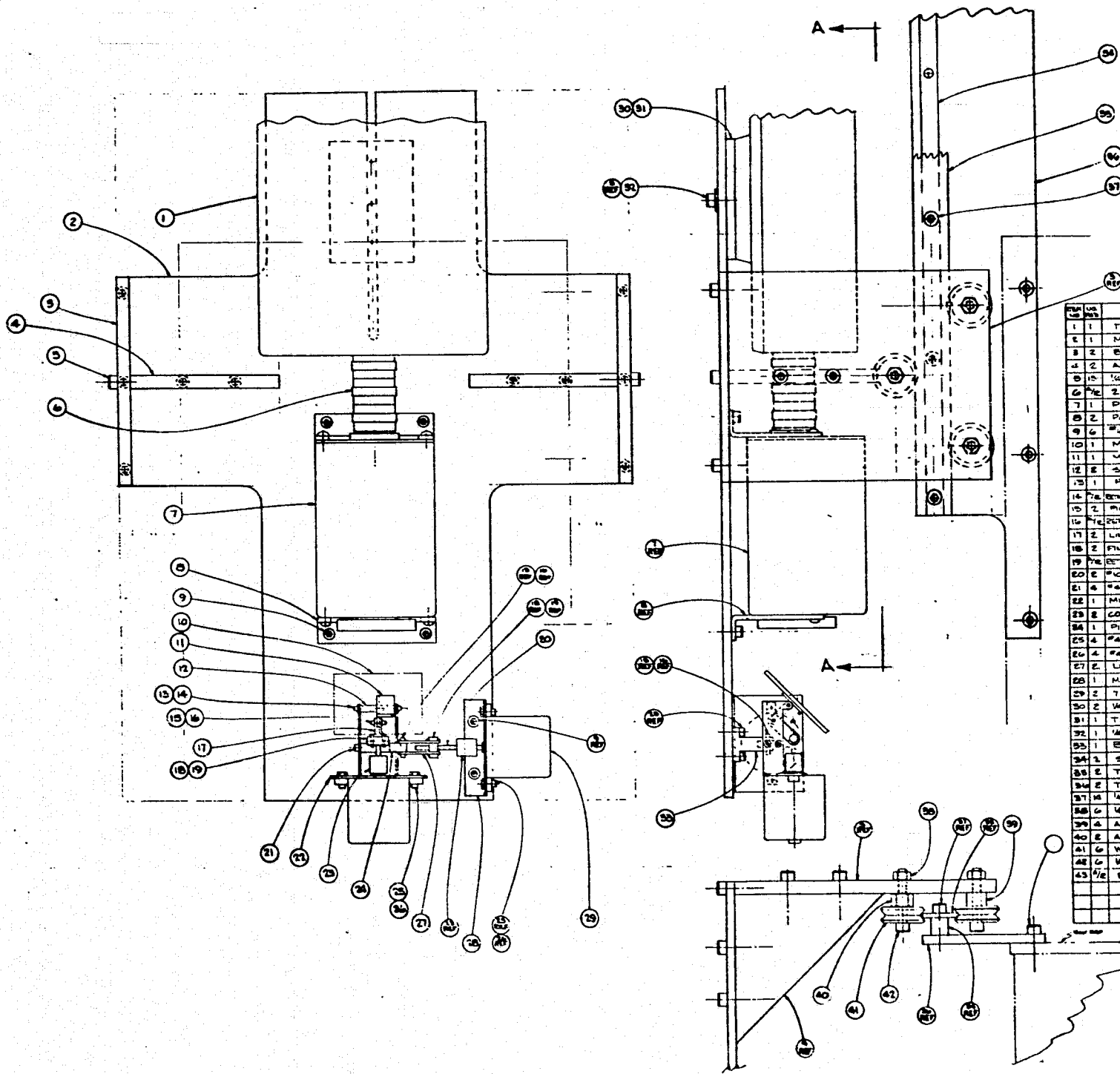
There have been no reportable "New Technology" items uncovered during this reporting period.

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CONCLUSIONS AND RECOMMENDATIONS

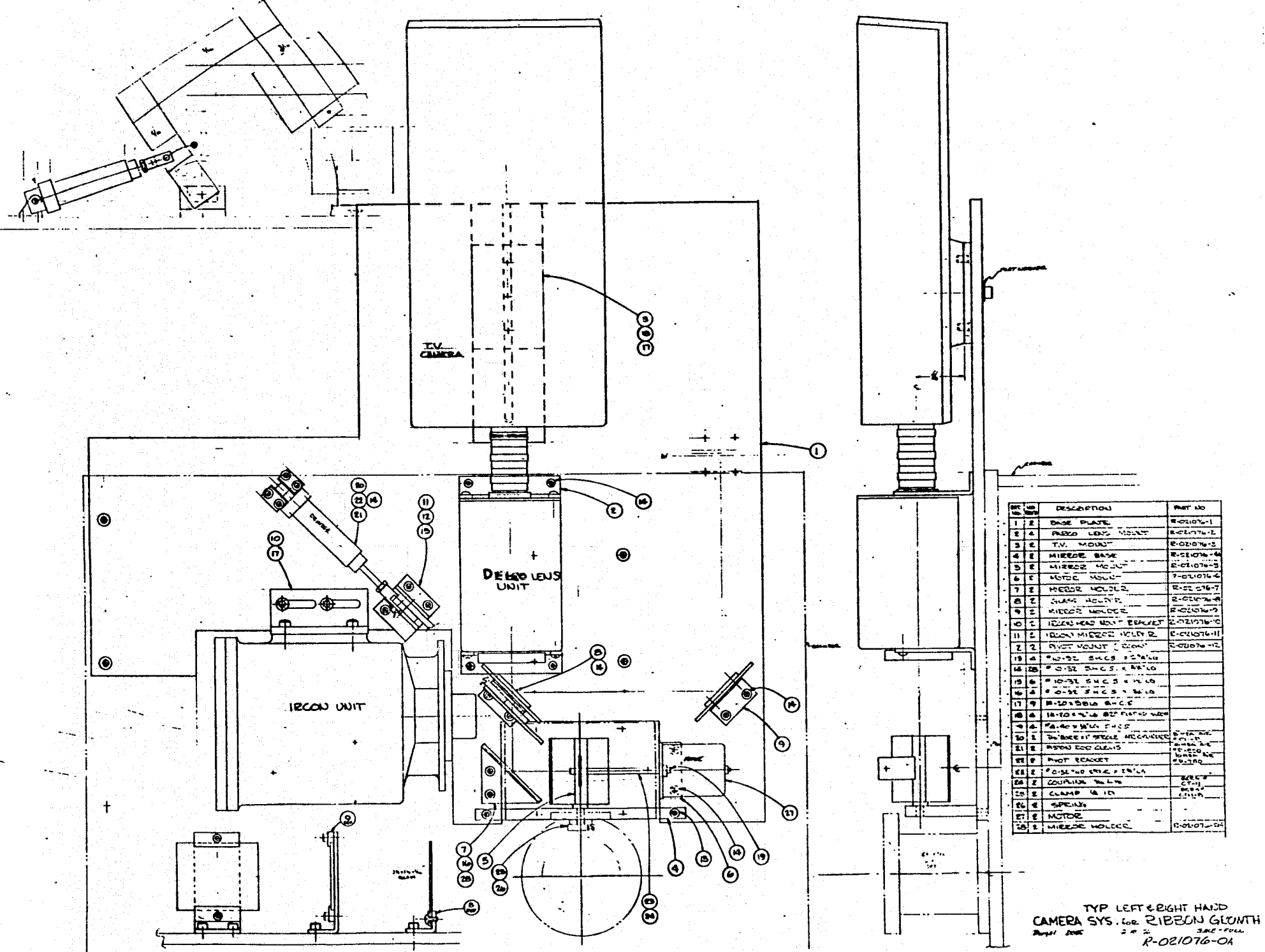
Progress is proceeding essentially on schedule and problems which have surfaced are not expected to have any impact on our ability to meet the objectives of the contract. No recommendations are, therefore, offered at this time.

APPENDIX
ENGINEERING DRAWINGS



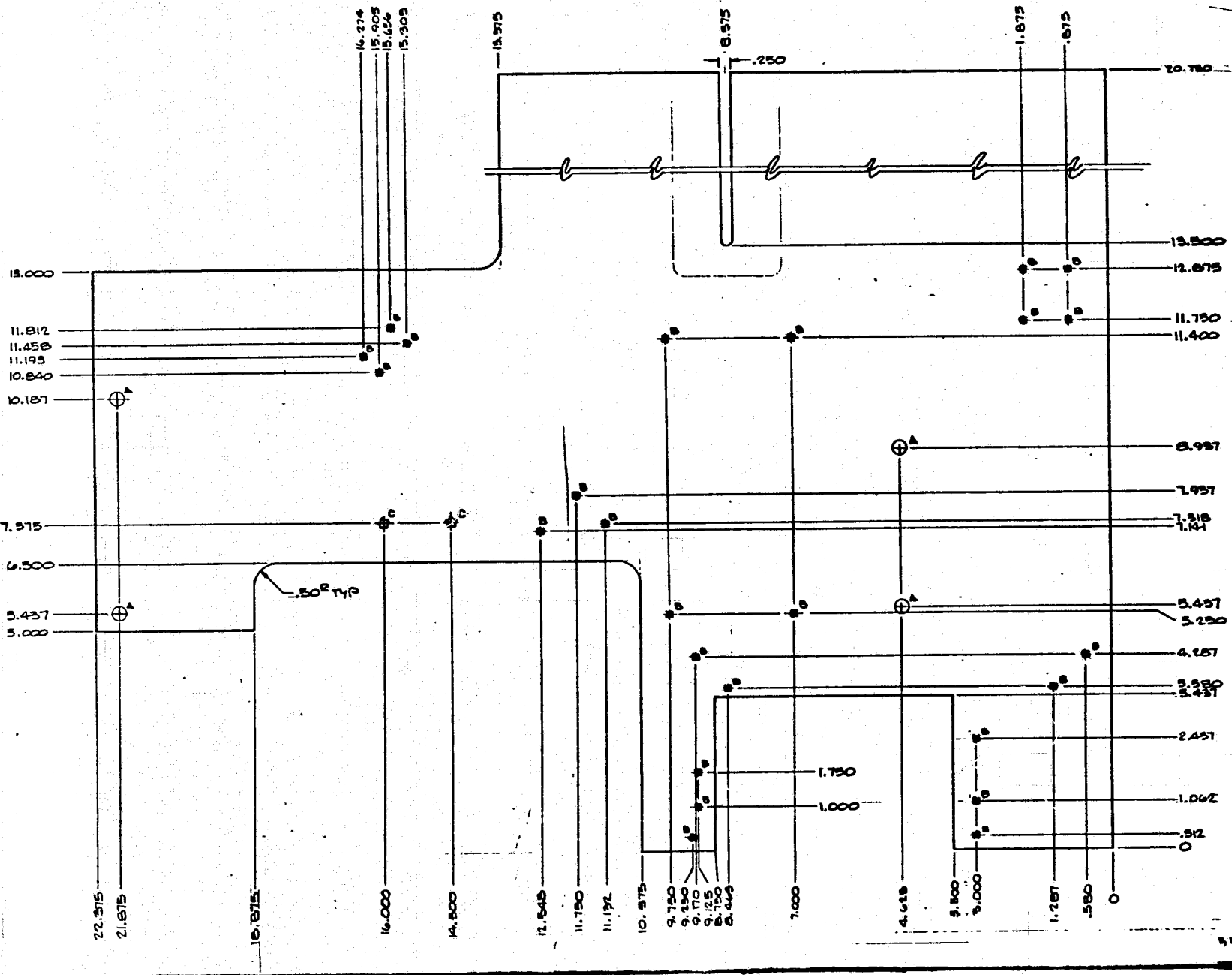
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3	ALGUE SUPPORT	E-000036-4
4	1/4-20 X 1/8 SHCS	
5	2X LENS EXTENDER	TV-02
6	PARCO LENS JOINT	TV-02
7	PARCO LENS MOUNT	E-023076-2
8	20-24 X 1/8 SHCS	
9	MIRRORE	
10	MIRRORE MOUNT	E-023076-1
11	SPACE	E-023076-2
12	PIV 3/8 DIA X 1/8 LG (ST)	FAB
13	20-24 X 1/8 SHCS	
14	20-24 X 1/8 SHCS	
15	PIV 1/8 DIA X 1/8 LG (ST)	FAB
16	20-24 X 1/8 SHCS	
17	LINKAGE	E-023076-7
18	PIV 3/8 DIA X 1/8 LG (ST)	FAB
19	20-24 X 1/8 SHCS	
20	20-24 X 1/8 SHCS	
21	1/4-20 X 1/8 SHCS	
22	MIRRORE MOUNT BRACKET PIVOT	E-023076-22
23	COUPLER 1/8 DIA X 1/8 LG	FAB
24	PIVOT SUPPORT CENTER	E-023076-24
25	1/4-20 X 1/8 SHCS	
26	1/4-20 X 1/8 SHCS	
27	LINKAGE	E-023076-1
28	MOTOR BRACKET	E-023076-28
29	7 RPM MOTOR	FAB
30	1/4-20 X 1/8 SHCS	
31	TV. MOUNT	E-023076-3
32	1/4-20 X 1/8 SHCS	
33	BASE PIVOT BLOCK	
34	SPACE 1/4 X 1/2 X 1/2	E-023076-34
35	TRACK 1/8 X 1/2 X 1/2	E-023076-35
36	TRACK SUPPORT 1/4 X 1/2	E-023076-36
37	1/4-20 X 1/8 SHCS	
38	1/4-20 X 1/8 SHCS	
39	ADAPTER	FAB
40	ADAPTER OFF-SET	FAB
41	WHEEL GUIDE	FAB
42	1/4-20 X 1/8 SHCS	
43	EXTENSION SPRING	

FRONT CAMERA SYS
 8-22-76
 R-023076-0



QTY	NO	DESCRIPTION	PART NO
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2	4	PRISM LENS MOUNT	R-021076-2
3	2	TV MOUNT	R-021076-3
4	2	MIRROR BASE	R-021076-4A
5	2	MIRROR MOUNT	R-021076-5
6	2	MOTOR MOUNT	T-021076-6
7	2	MIRROR HOLDER	R-021076-7
8	2	SHAKE MOUNT	R-021076-8
9	2	MIRROR HOLDER	R-021076-9
10	2	RECON HEAD MOUNT BRACKET	R-021076-10
11	2	RECON MIRROR HOLDER	R-021076-11
2	2	PHOT MOUNT PLATE	R-021076-12
13	4	1/2-32 SACS 1/2" DIA	
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41	2	1/2-32 SACS 1/4" DIA	
42	2	1/2-32 SACS 1/4" DIA	
43	2	1/2-32 SACS 1/4" DIA	
44	2	1/2-32 SACS 1/4" DIA	
45	2	1/2-32 SACS 1/4" DIA	
46	2	1/2-32 SACS 1/4" DIA	
47	2	1/2-32 SACS 1/4" DIA	
48	2	1/2-32 SACS 1/4" DIA	
49	2	1/2-32 SACS 1/4" DIA	
50	2	1/2-32 SACS 1/4" DIA	
51	2	1/2-32 SACS 1/4" DIA	
52	2	1/2-32 SACS 1/4" DIA	
53	2	1/2-32 SACS 1/4" DIA	
54	2	1/2-32 SACS 1/4" DIA	
55	2	1/2-32 SACS 1/4" DIA	
56	2	1/2-32 SACS 1/4" DIA	
57	2	1/2-32 SACS 1/4" DIA	
58	2	1/2-32 SACS 1/4" DIA	
59	2	1/2-32 SACS 1/4" DIA	
60	2	1/2-32 SACS 1/4" DIA	
61	2	1/2-32 SACS 1/4" DIA	
62	2	1/2-32 SACS 1/4" DIA	
63	2	1/2-32 SACS 1/4" DIA	
64	2	1/2-32 SACS 1/4" DIA	
65	2	1/2-32 SACS 1/4" DIA	
66	2	1/2-32 SACS 1/4" DIA	
67	2	1/2-32 SACS 1/4" DIA	
68	2	1/2-32 SACS 1/4" DIA	
69	2	1/2-32 SACS 1/4" DIA	
70	2	1/2-32 SACS 1/4" DIA	
71	2	1/2-32 SACS 1/4" DIA	
72	2	1/2-32 SACS 1/4" DIA	
73	2	1/2-32 SACS 1/4" DIA	
74	2	1/2-32 SACS 1/4" DIA	
75	2	1/2-32 SACS 1/4" DIA	
76	2	1/2-32 SACS 1/4" DIA	
77	2	1/2-32 SACS 1/4" DIA	
78	2	1/2-32 SACS 1/4" DIA	
79	2	1/2-32 SACS 1/4" DIA	
80	2	1/2-32 SACS 1/4" DIA	
81	2	1/2-32 SACS 1/4" DIA	
82	2	1/2-32 SACS 1/4" DIA	
83	2	1/2-32 SACS 1/4" DIA	
84	2	1/2-32 SACS 1/4" DIA	
85	2	1/2-32 SACS 1/4" DIA	
86	2	1/2-32 SACS 1/4" DIA	
87	2	1/2-32 SACS 1/4" DIA	
88	2	1/2-32 SACS 1/4" DIA	
89	2	1/2-32 SACS 1/4" DIA	
90	2	1/2-32 SACS 1/4" DIA	
91	2	1/2-32 SACS 1/4" DIA	
92	2	1/2-32 SACS 1/4" DIA	
93	2	1/2-32 SACS 1/4" DIA	
94	2	1/2-32 SACS 1/4" DIA	
95	2	1/2-32 SACS 1/4" DIA	
96	2	1/2-32 SACS 1/4" DIA	
97	2	1/2-32 SACS 1/4" DIA	
98	2	1/2-32 SACS 1/4" DIA	
99	2	1/2-32 SACS 1/4" DIA	
100	2	1/2-32 SACS 1/4" DIA	

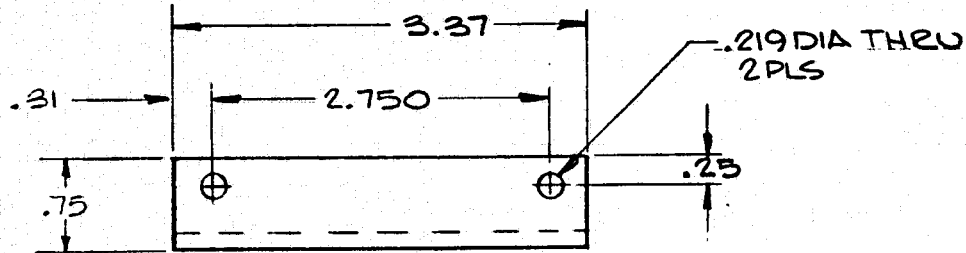
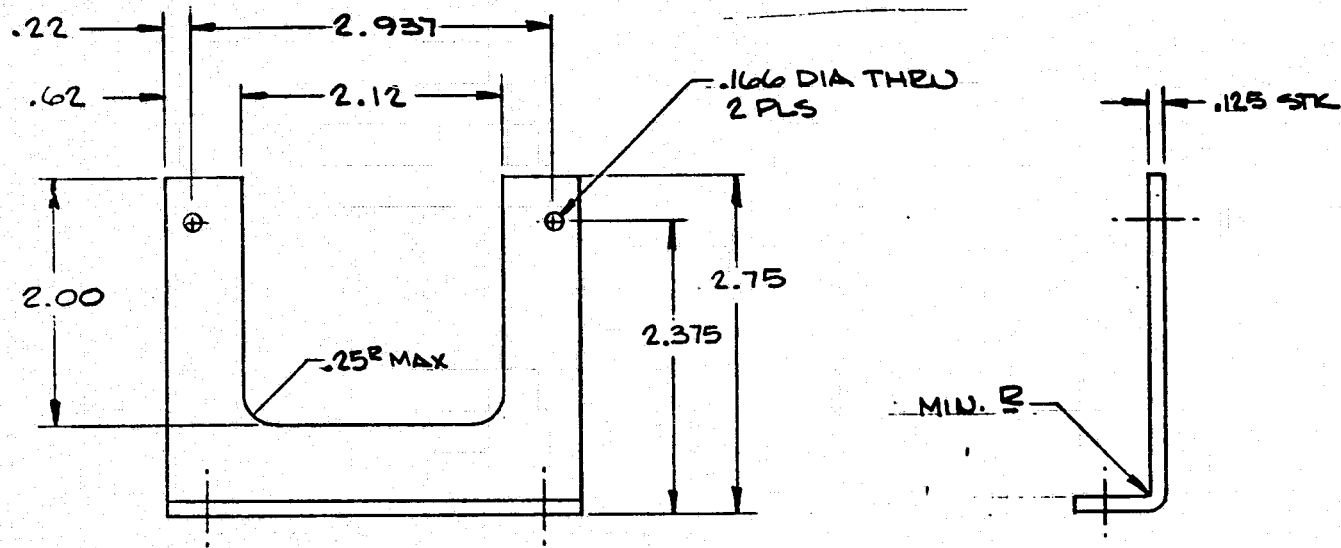
TYP LEFT & RIGHT HAND
 CAMERA SYS. FOR RIBBON GROWTH
 R-021076-0A



HOLE	SIZE	TOTAL QTY
A	3/16 DIA	4
B	#10-32	25
C	1/4-20	2

MAT'L AL, 300 #606172
 7/8 ONE PCE
 TOL: .XXX ± .015

MOUNTING PLATE
 2-10-76 SCALE: 1:1
 R-021076-1

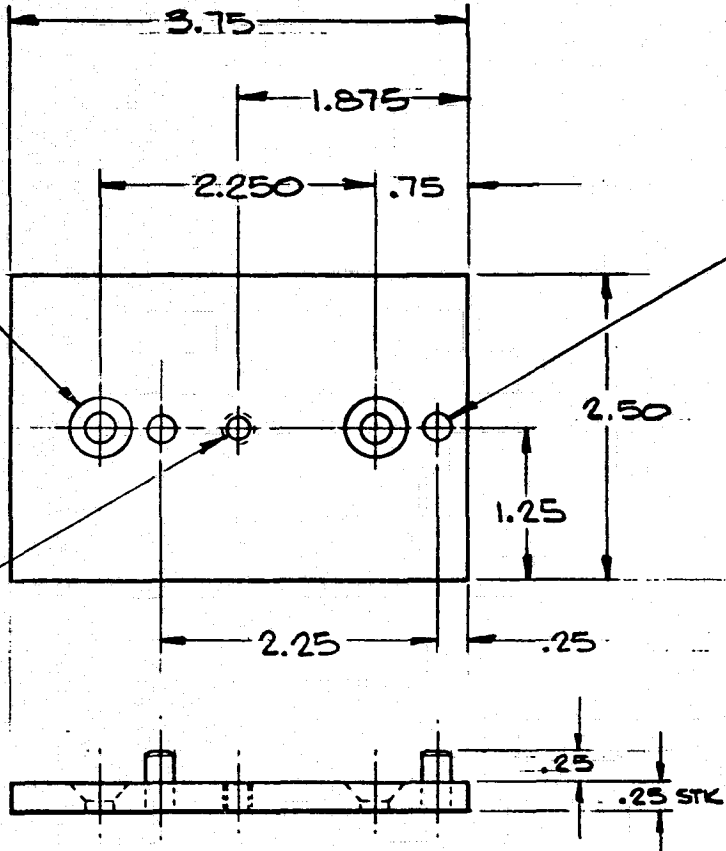


MAT'L AL 6061-T6
 TOL:
 .XX = ±.02
 .XXX = ±.005

PELCO LENS BRACKET
 By D. Doss 2-10-76 SCALE 1=1
 R-021076-2

.281 DIA THRU
C/SINK 82°
2 PLS

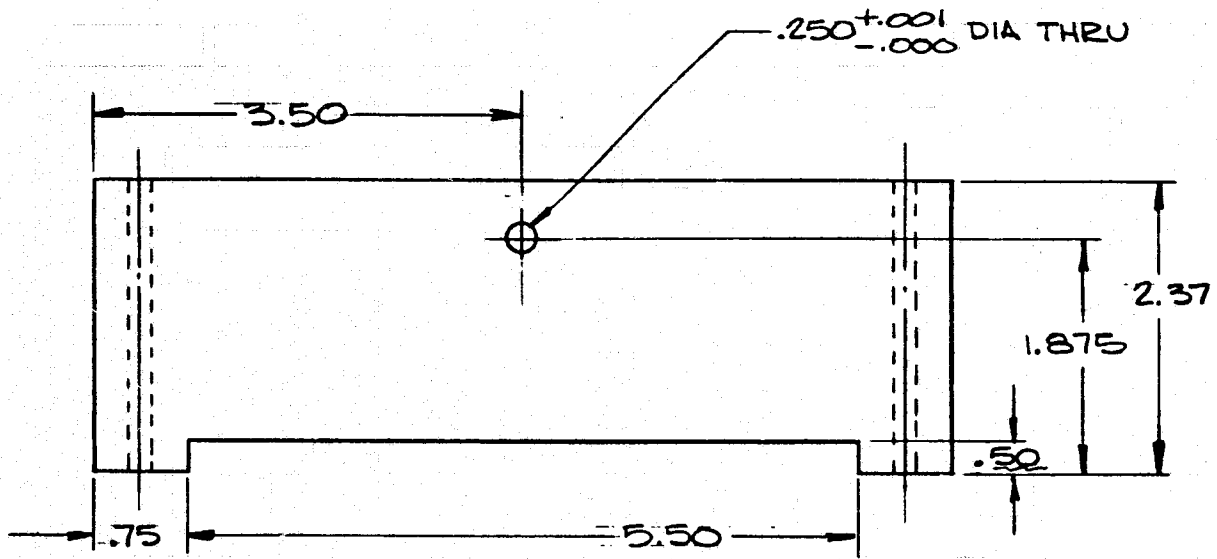
1/4-20 THD
THRU



1/4" DIA DOWEL
RF. IN PLACE
2 PLS

MAT'L: AL 6061-T6
TOL:
.XX = ± .02
.XXX = ± .005

T.V. MOUNT BRACKET
By D. Dore 2-11-76 SCALE: FULL
P. 021076-3

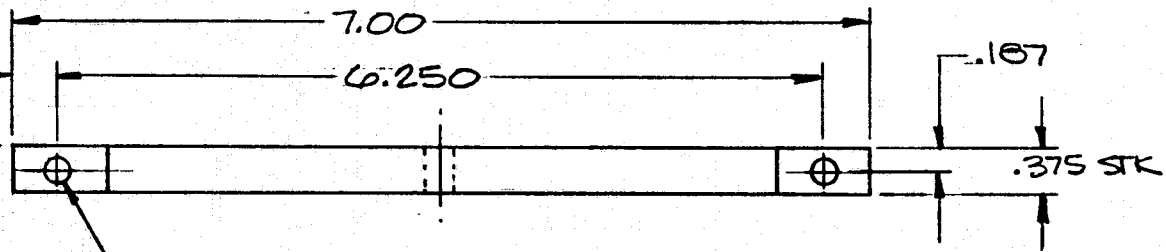


MAT'L: 6061-T6

TOL:

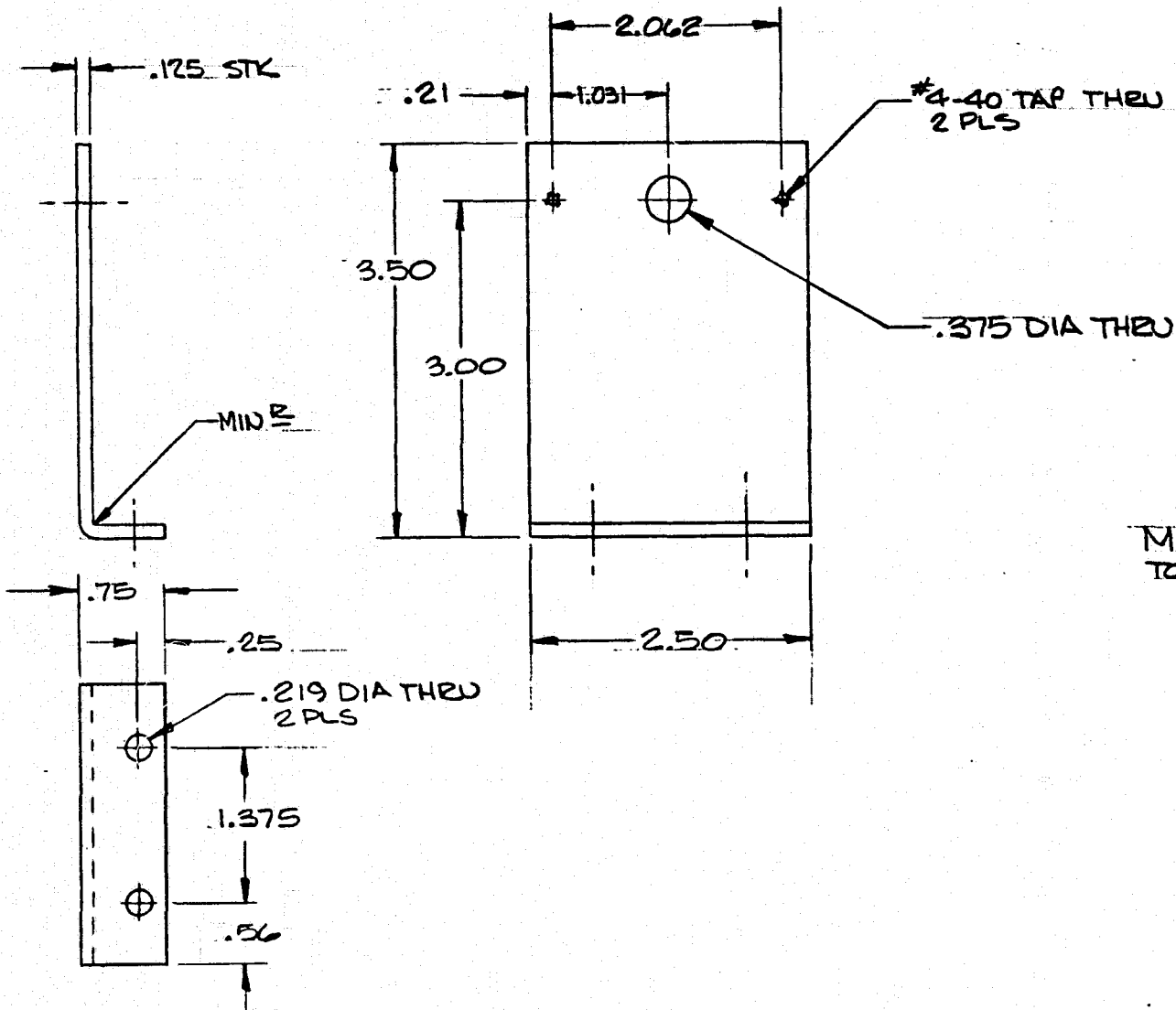
...XX = ±.02

...XXX = ±.005



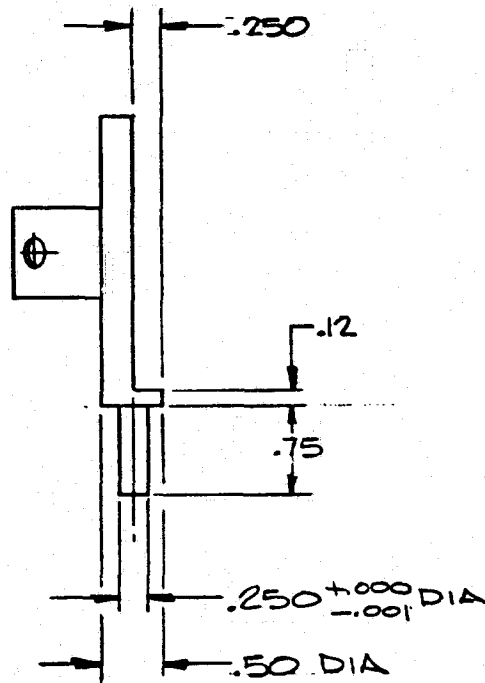
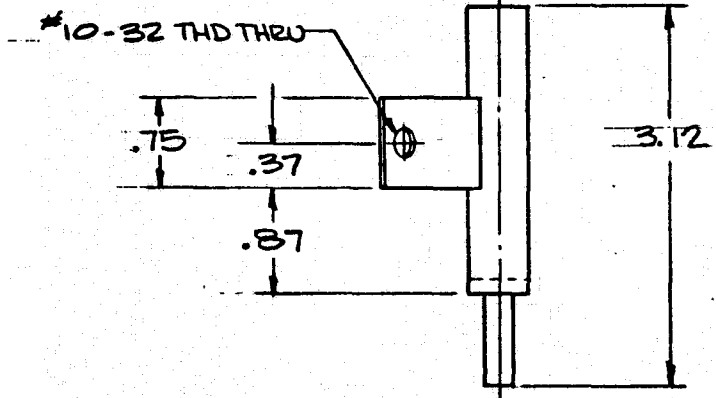
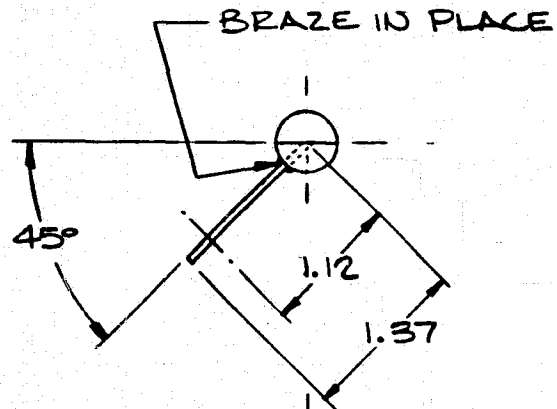
.219 DIA THRU
2 PLS

MIRROR BASE
By R Dm 2-11-76 SCALE: FULL
R-021076-4A



MATL: 6061-T6
 TOL:
 .XX = $\pm .02$
 .XXX = $\pm .005$

MOTOR BRACKET
 B. D. DOR 2-11-76 SCALE: FULL
 R-021076-6

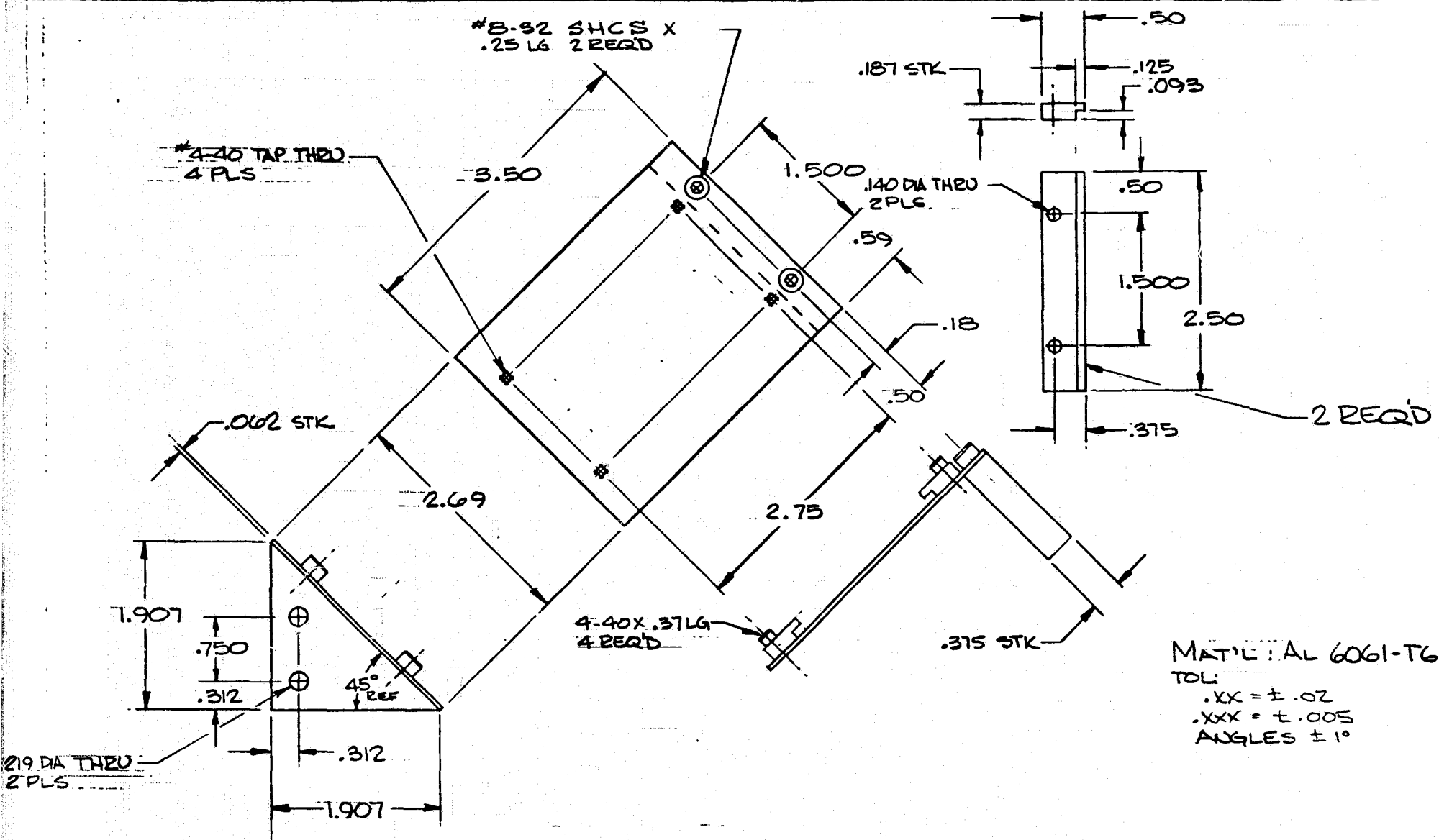


MAT'L: COLD ROLL S+L

TOL:

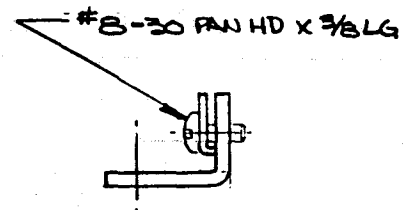
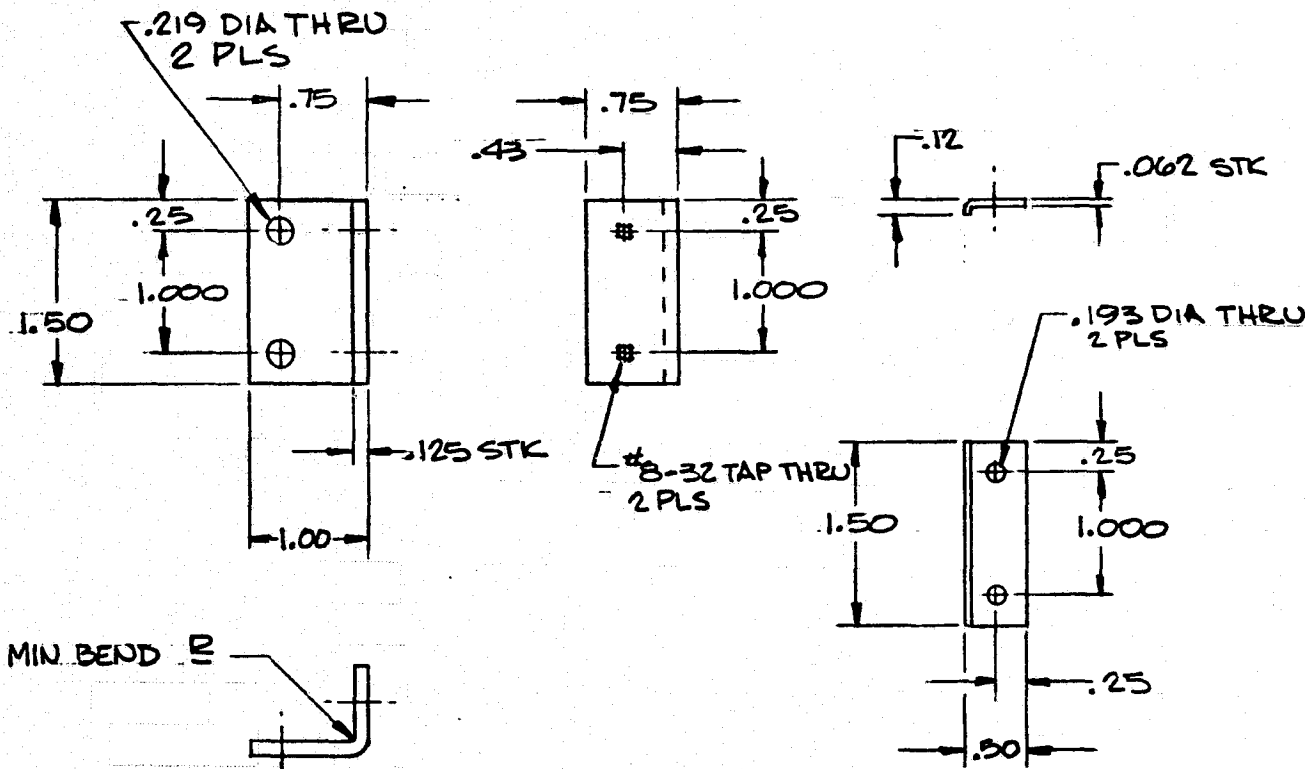
- .XX = $\pm .02$
- .XXX = $\pm .005$
- ANGLES $\pm 5^\circ$

MIRROR MOUNT
 By D. Doss 2-11-76 SCALE = FULL
 R-021076-5



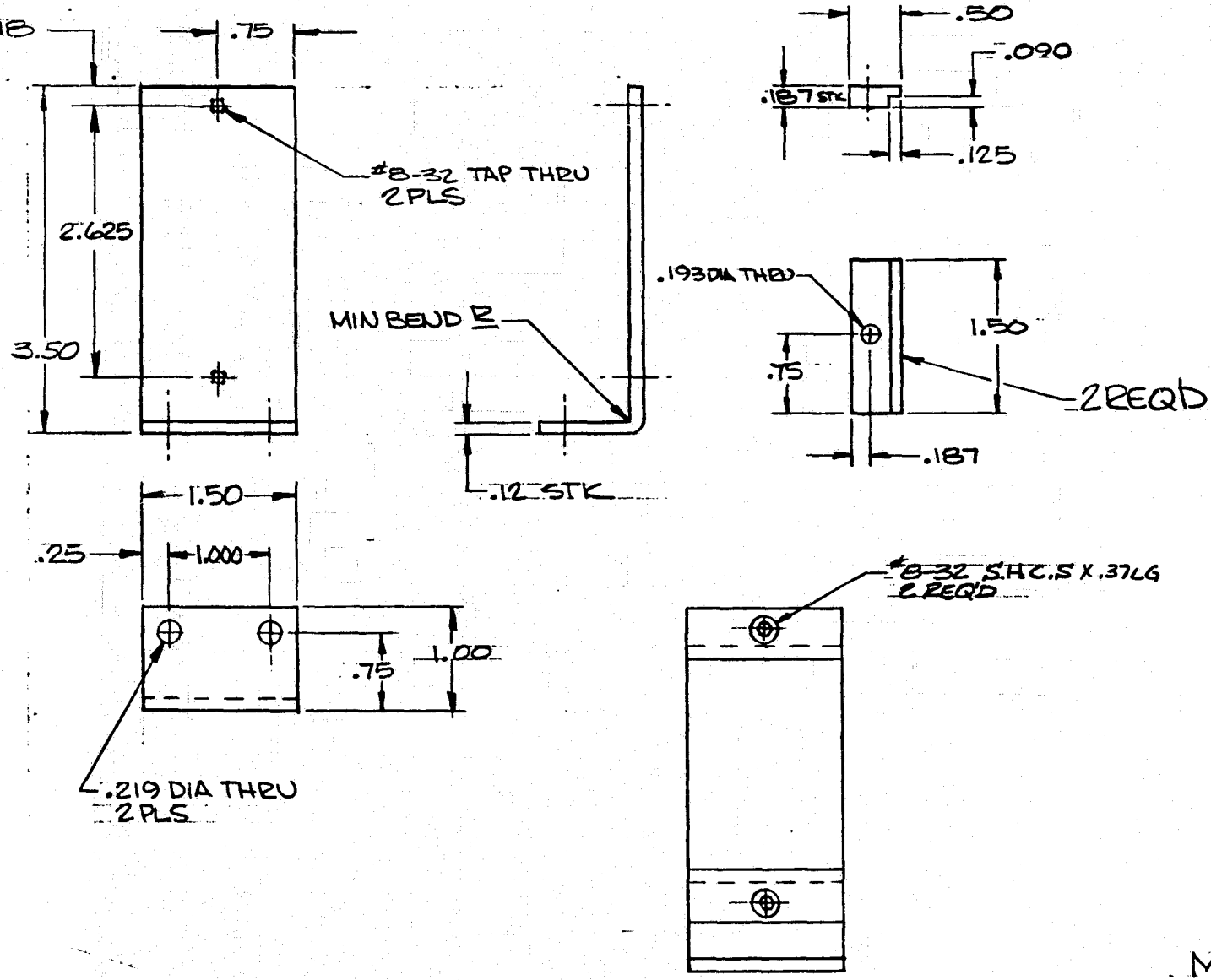
MATERIAL AL 6061-T6
 TOL
 .XX = ± .02
 .XXX = ± .005
 ANGLES ± 1°

MIRROR HOLDER
 By R.Doss 2-12-76 SCALE = FULL
 R-021076-7



MAT'L: AL 6061-T6
 T&L:
 .XX = ± .02
 .XXX = ± .005
 ANGLES ± 1/2°

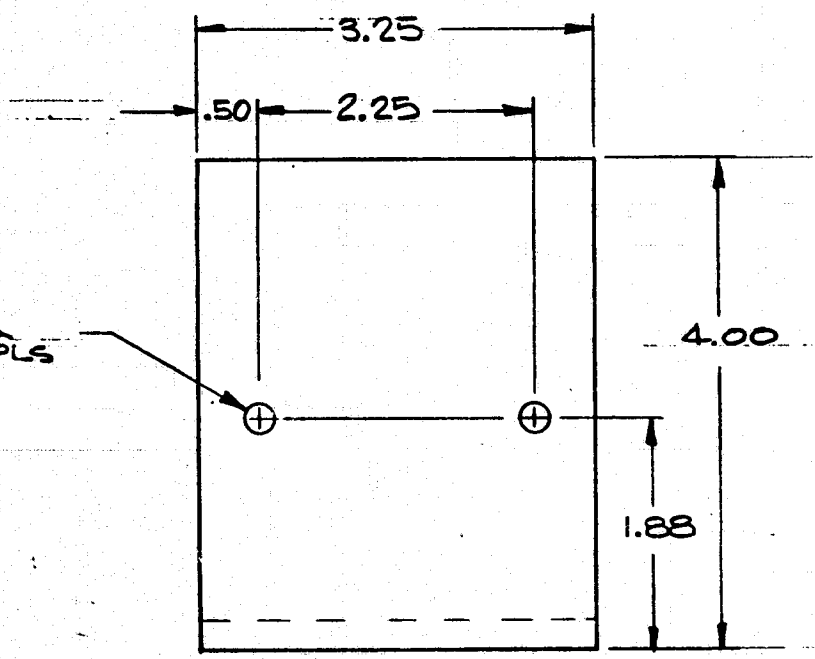
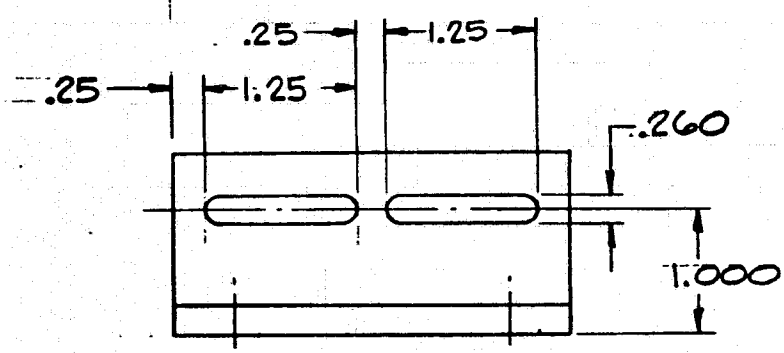
GLASS HOLDER
 By D. Doss 2-12-76 SCALE=FULL
 R-021076-8



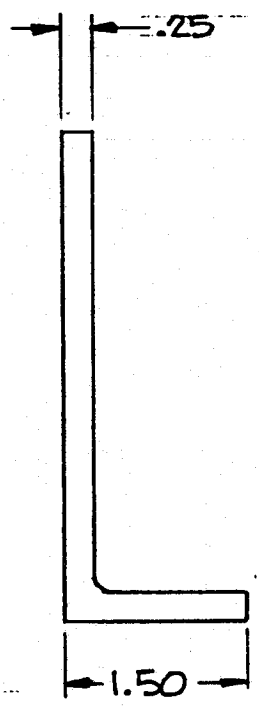
MAT'L: AL 6061-T6

TOL:
 .XX = ± .02
 .XXX = ± .005
 ANGLES ± 1°

MIRROR HOLDER (FOR SCALE)
 By D. Doss 2-12-76 SCALE = FULL
 R-021076-9

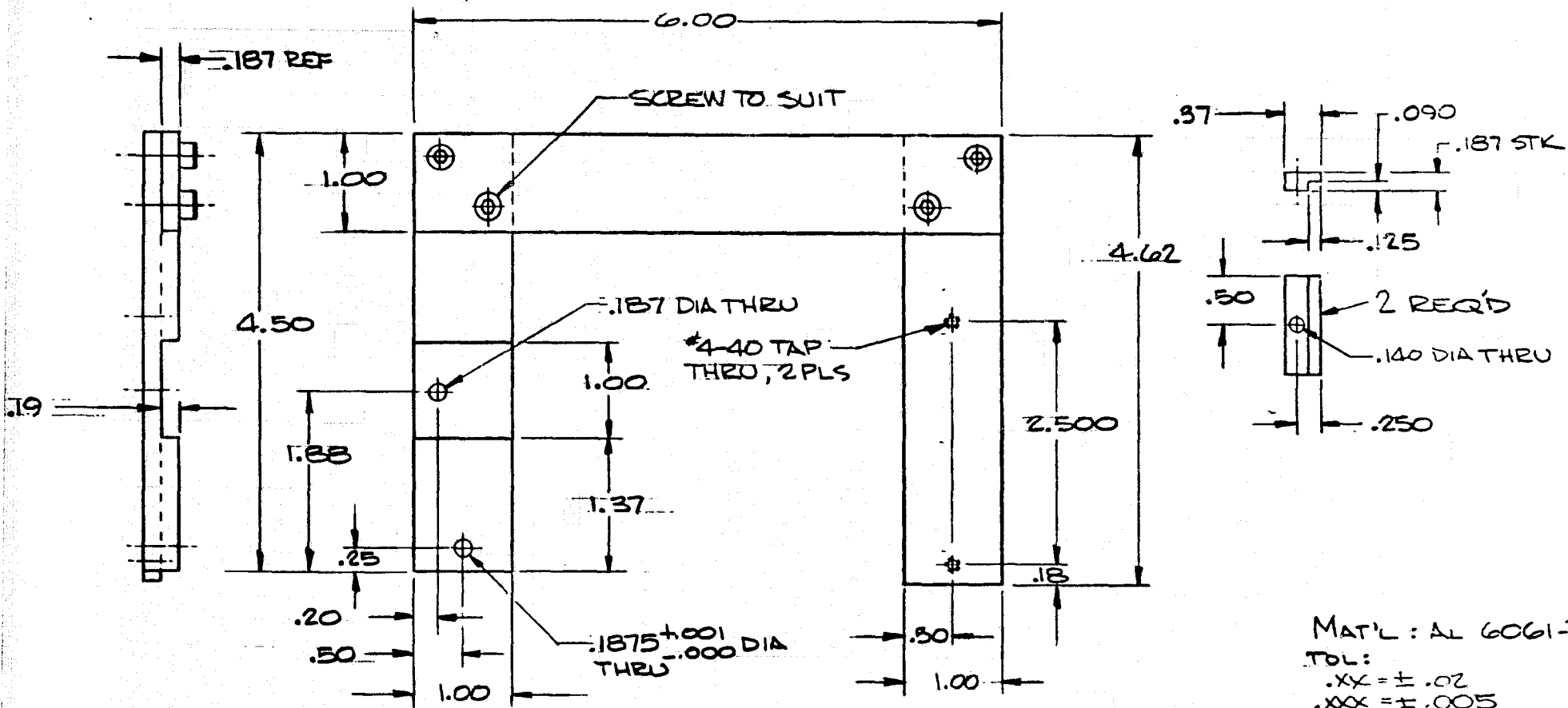


.281 DIA
THRU, 2 PLS

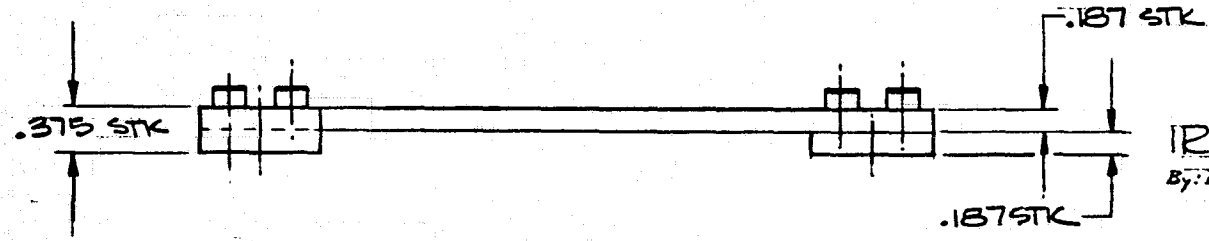


MAT'L: 6061-T6 AL ANGLE
4x4-x/4
TOL:
.XX = ± .02
.XXX = ± .005
ANGLES ± 1°

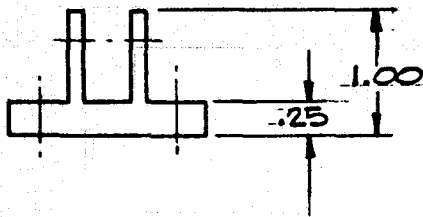
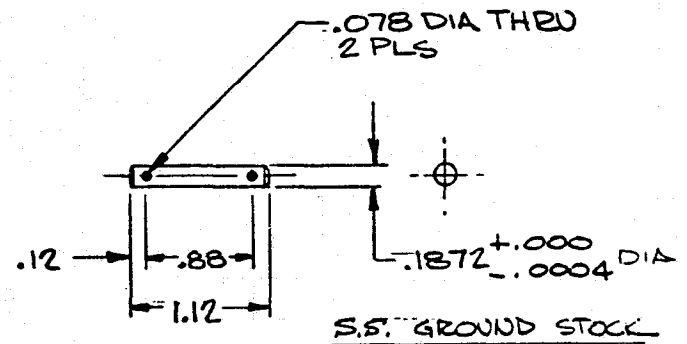
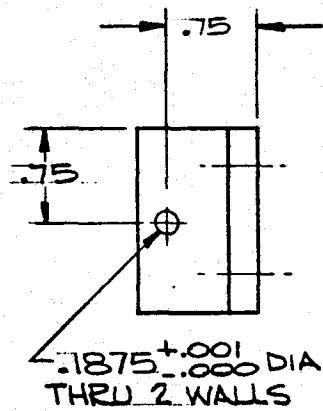
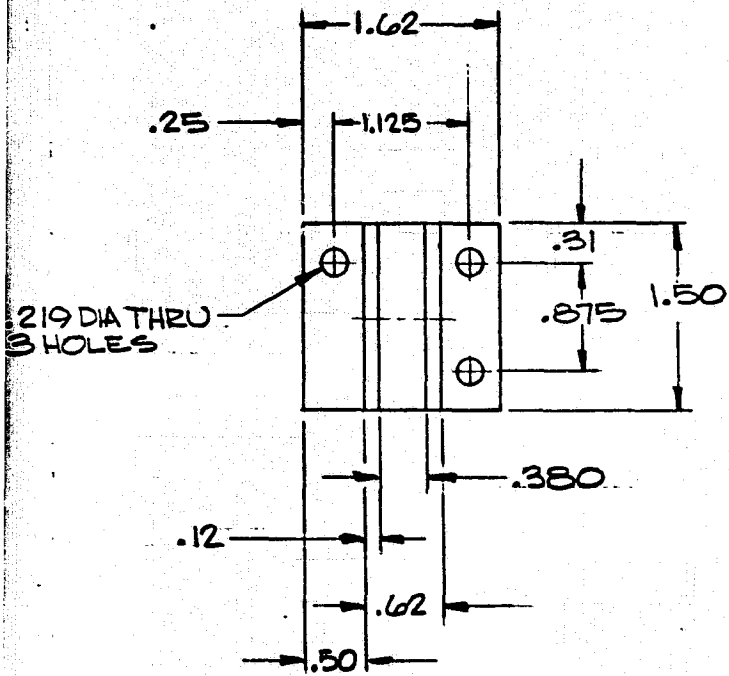
IRCON HEAD MOUNT
By D. Doss 2-13-76 SCALE: FULL
R-021076-10



MAT'L : AL 6061-T6
 TOL :
 .XX = ± .02
 .XXX = ± .005
 ANGLES ± 1°



IRCON MIRROR HOLDER
 By: D. DMS E-13-76 SCALE: FULL
 R-021076-11

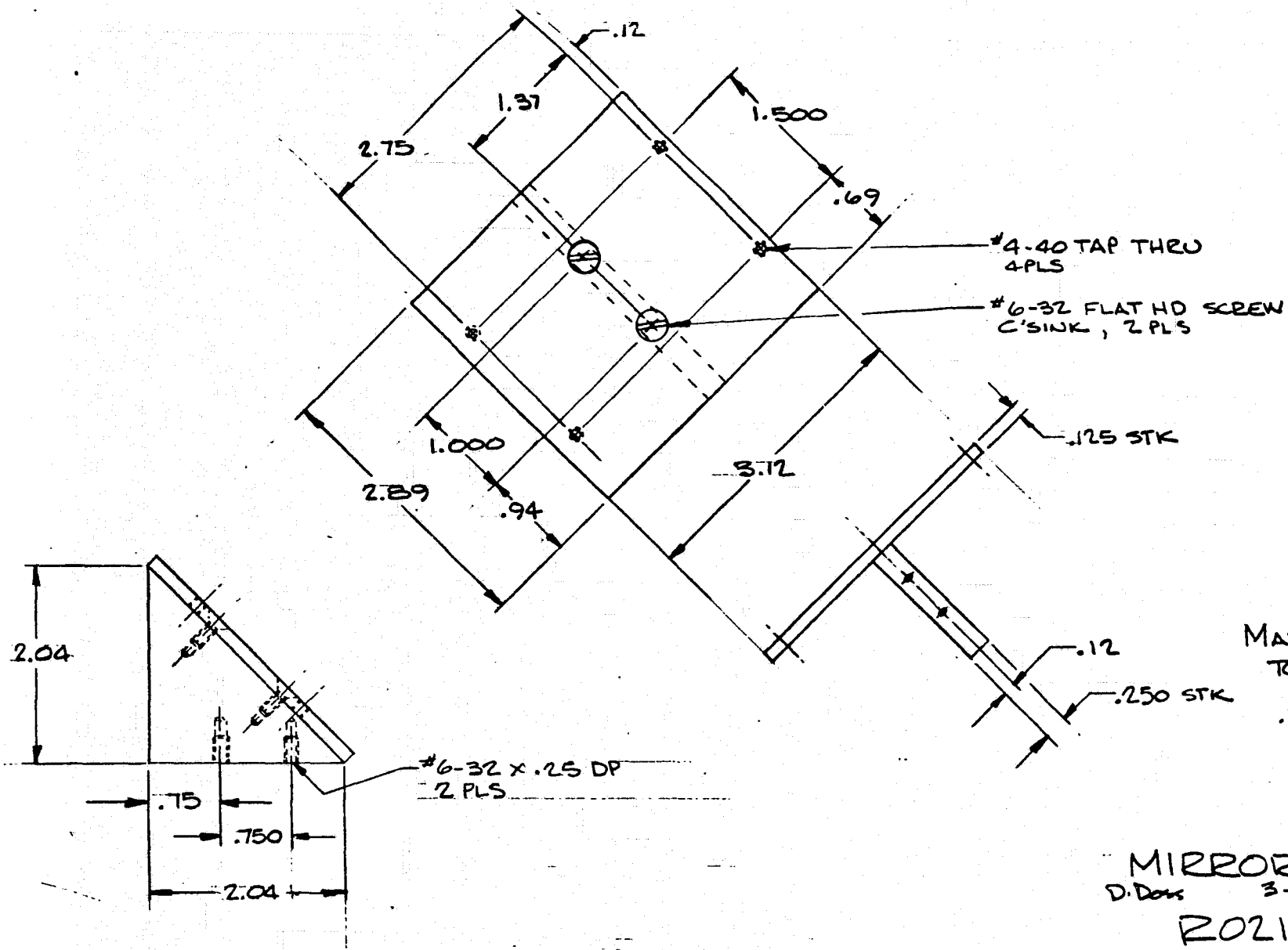


MAT'L : AL 6061-T6

TOL:

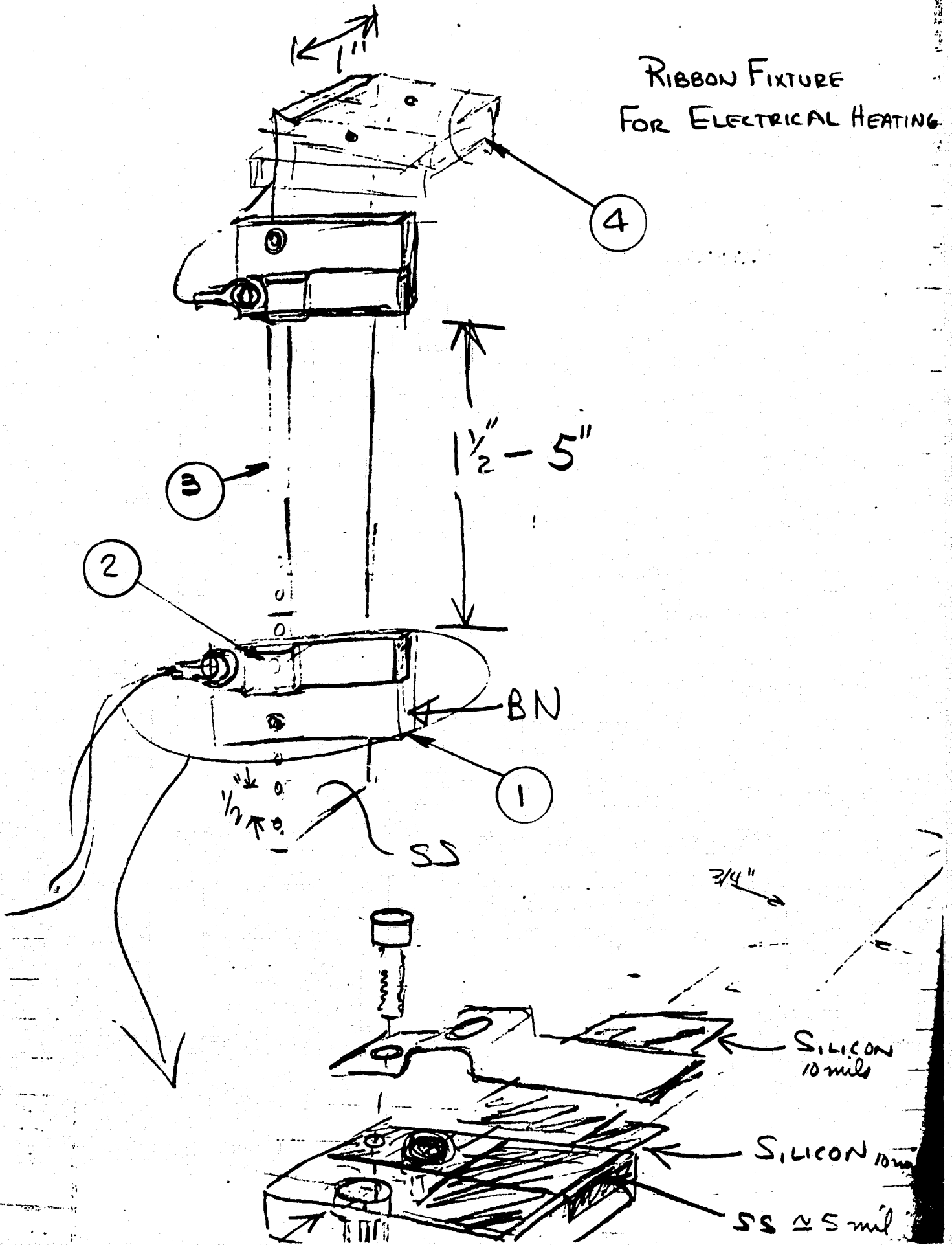
.XX $\pm .02$
 .XXX $\pm .005$
 ANGLES $\pm 1/2^\circ$

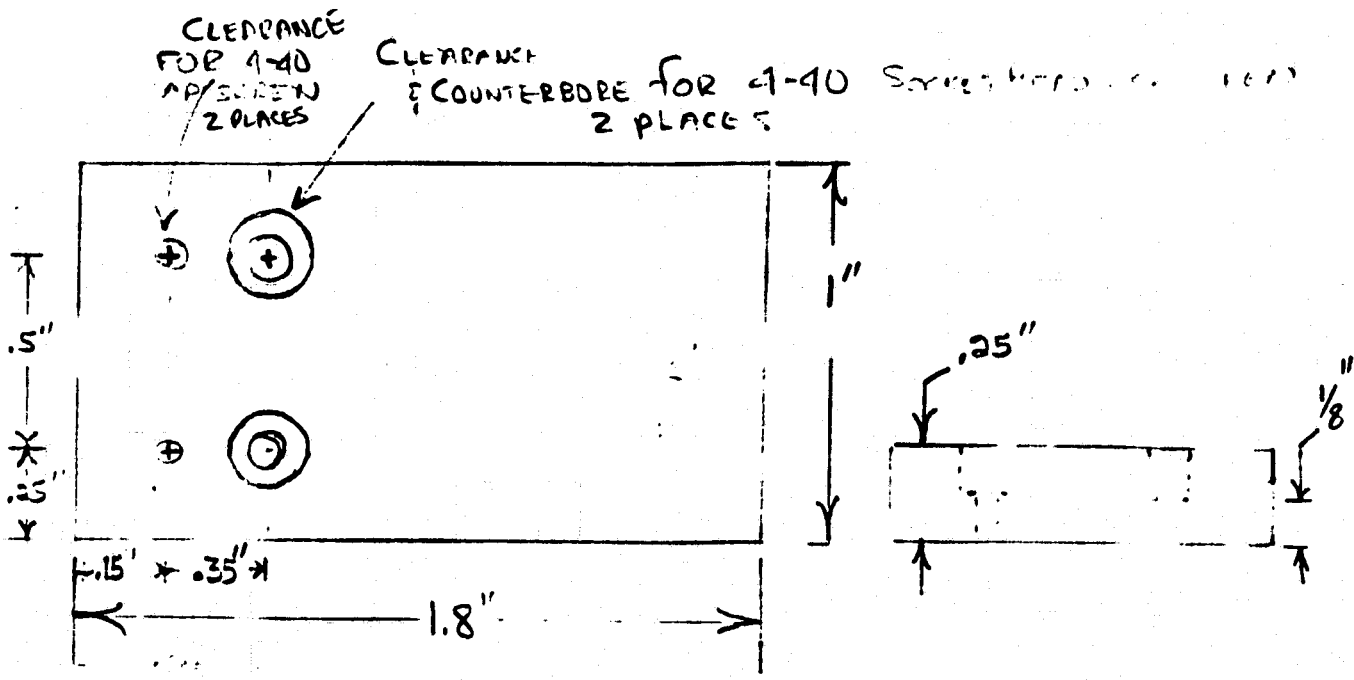
PIVOT MOUNT (IRCON)
 By D. Doss 2-13-76 SCALE = FULL
 R-021076-12



MIRROR HOLDER
 D. Davis 3-5-76 SCALE: FULL
 2021076-28

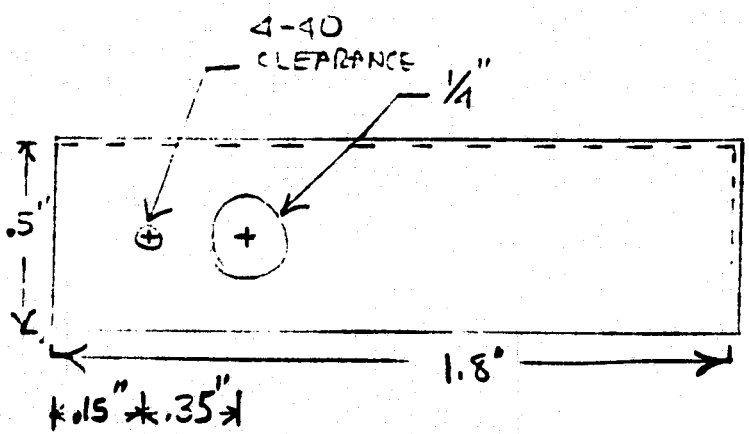
RIBBON FIXTURE FOR ELECTRICAL HEATING





INSULATING BLOCK

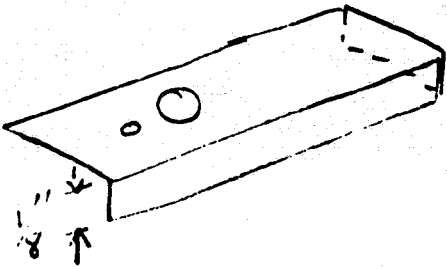
MATL: BORON NITRIDE
4 REQ'D



BOTTOM CONTACT Type A

MATL: STAINLESS
2 REQ'D

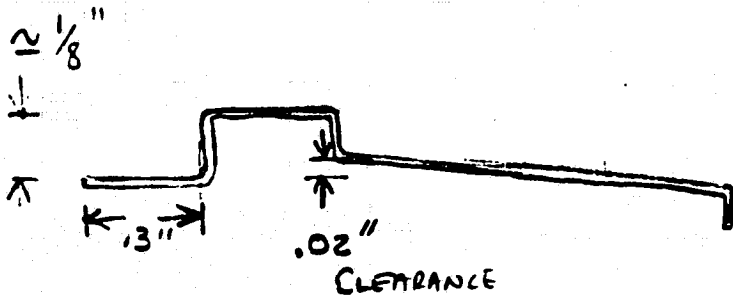
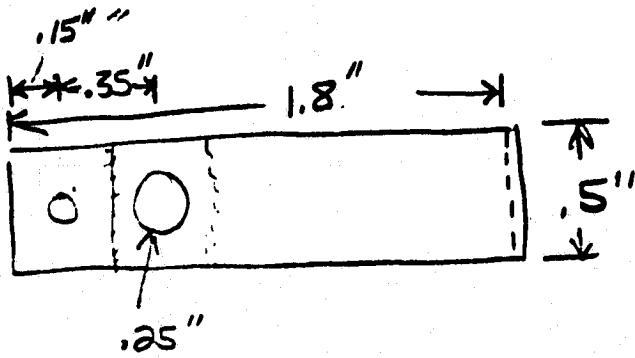
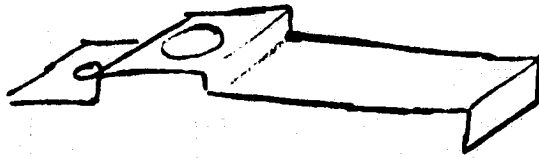
ORIGINAL PAGE IS
OF POOR QUALITY



BOTTOM CONTACT Type B

2 REQ'D

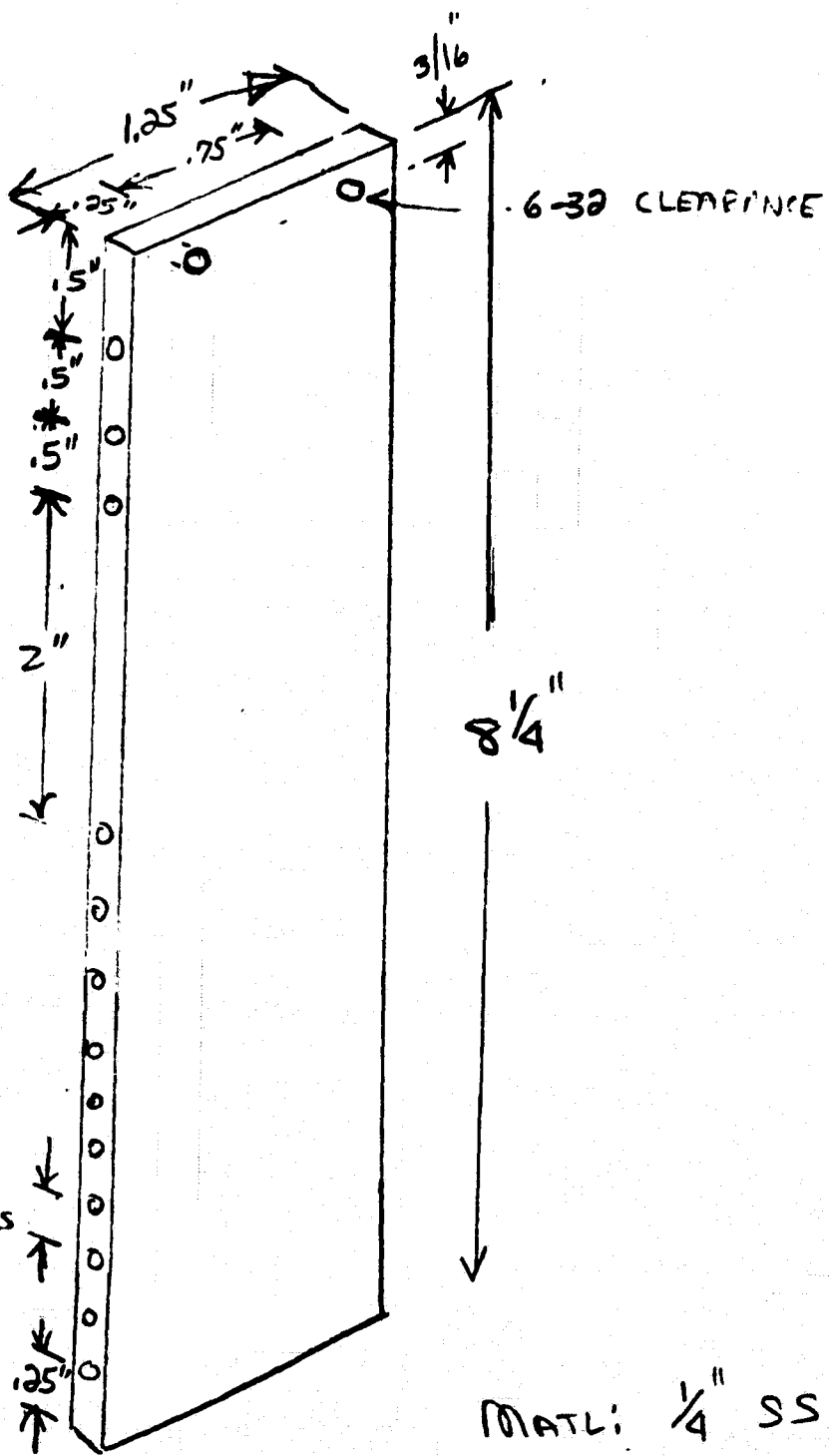
R-022876-1



TOP CONTACT

Matl: SS
+ REOD

R-022876-2

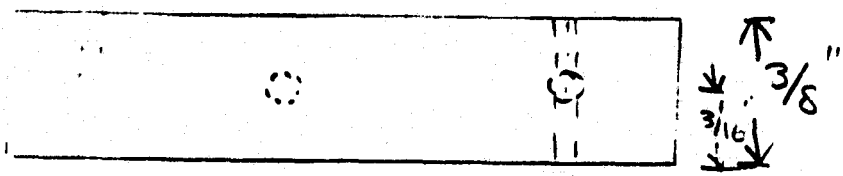
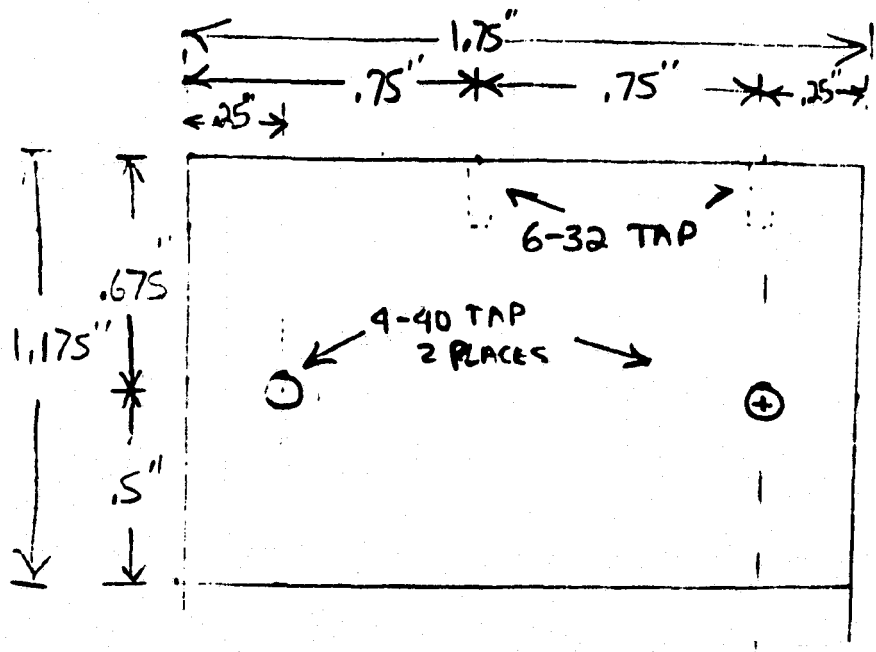


2 REQ'D

MATL: 1/4" SS

POSITIONER BLOCK

R-022876-3



MOUNTING BLOCK

2 REQD MATL: 3/8" SS