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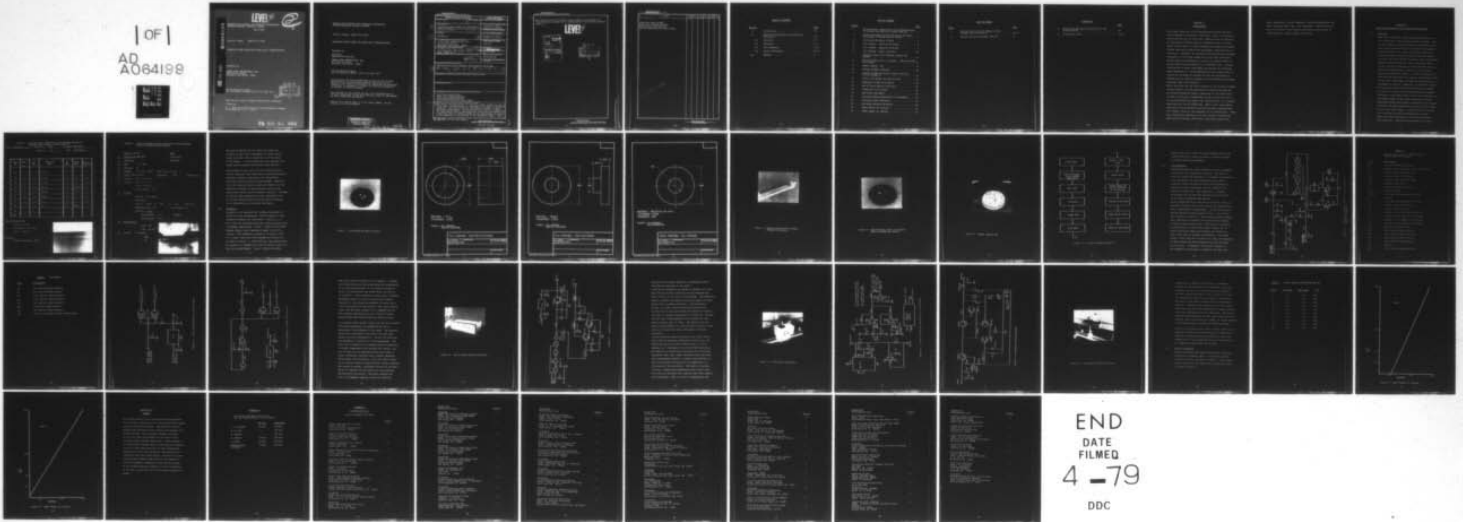
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MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING  
PROGRAM QUARTERLY TECHNICAL REPORT

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Contract Number DAAB07-76-C-0040

INJECTION LASER DIODES FOR FIBER OPTIC COMMUNICATIONS

Prepared by:

LASER DIODE LABORATORIES, INC.  
205 Forrest Street  
Metuchen, New Jersey 08840

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Fourth Quarterly Report  
for the Period 30 March 1977 to 30 June 1977

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PROGRAM QUARTERLY TECHNICAL REPORT

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Prepared by:

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Applications Engineer

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Fourth Quarterly Report  
for the Period 30 March 1977 to 30 June 1977

This project has been accomplished as part of the US Army Manufacturing and Technology Program, which has as its objective the timely establishment of manufacturing processes techniques or equipment to insure the efficient production of current or future programs.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The design and fabrication of injection laser diodes for use in fiber optic communications is discussed with regard to material synthesis, chip configuration, and device assembly in manufacturing environment. The opto-electronic source is based on the GaAs-GaAlAs double heterojunction structure and consists of a parallel array of lasers formed by the application of triple stripe geometry to the surface of the epitaxial wafer. The		

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monolithic triad of discrete lasing elements is mounted in a high frequency package which incorporates a high quality optical window.

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## SECTION I

### INTRODUCTION

The primary objective of this Manufacturing Method and Technology Engineering Program is threefold. First, the Injection Laser Diode for use in Fiber Optic Communications as outlined in Specification SCS-516 must be transferred from a developmental device type to a volume manufactured commercial product without adversely affecting the performance characteristics of the device. Secondly, the manufacturing methods and techniques necessary for the volume production of the laser diode must be developed and implemented to insure the highest degree of device quality and reliability at a reasonable cost. Thirdly, verification of device performance and quality for injection lasers produced in a volume manufacturing environment must be carried out by means of rigorous testing and evaluation to demonstrate the technical adequacy of the manufacturing methods developed under this contract.

Major objectives for the fourth quarter of the program included growing material for and fabrication of devices suitable for the second engineering sample, completion of the first group of burn-in positions, commencement of the initial burn-in of the second engineering sample, and identification of a suitable substitute for the ITT F4000 tube. Work on the e-gun system continued to be frustrated by arcing and other problems which will require return of the equipment to its manufacturer. Other work continued on fabrication of test fixtures required for specification testing, particularly transistor pulsers for

power, wavelength, thermal impedance, emission distribution and other operating tests, and a new goniometer. Further work was done on the burn-in rack design, particularly with regard to distribution of trigger pulses and cooling.

## SECTION II

### MANUFACTURING METHODS AND TECHNOLOGY ENGINEERING

#### 2.1 Materials

Additional wafers were grown and evaluated for use in the fabrication of the second engineering sample. Two of these wafers yielded satisfactory evaluation devices with average characteristic 27°C emission wavelengths of 819 nm and 811 nm. Broad area lasers fabricated from these wafers exhibited average threshold current densities less than  $3\text{KA}/\text{cm}^2$  and single ended differential quantum efficiencies of over 30%. Based upon these initial results, processing of wafer DHA-106 (Figures 1 and 2) was completed and a quantity of triple stripe lasers were fabricated from it. Initial evaluation of these devices indicated a pre burn-in yield of about 65% to the power, wavelength, and angular distribution requirements of SCS-516. Therefore, a sufficient quantity of devices were fabricated from this wafer to permit the start of testing of the second engineering sample. Problems in chip mounting due to the close proximity of the lasing region to the solder interface are being addressed through the possible incorporation of integral gold heat sink pads selectively plated onto the p-side of the triad laser module. Cleaving rails 50  $\mu\text{m}$  wide may be defined via photolithography after stripe definition and metallization of the epi wafer have been completed. Gold pads approximately 10  $\mu\text{m}$  thick

Figure 1. Epitaxial Melt Compositions and Photomicrograph of Cleaved Cross-section of Wafer DHA-106.

Run # DH-A-106 Crystal # 7780 Program MMT 0040  
 Slice # 54 Type TRI-STRIFE

Bin #	GaAs gm.	Ga gm.	Dopants mg.	Al mg.	Time min.	Layer Thickness $\mu\text{m}$
1	1.0	5.0	1.0 Te	0.0	5	1.6
2	1.0	5.0	5.0 Te	3.5	10	1.2
3	1.0	5.0	1.0 Te	7.0	10	0.8
4	1.0	5.0	10.0 Si	1.0	30 Sec.	0.3
5	1.0	5.0	100 Ge	7.0	15	1.9
6	1.0	5.0	500 Ge	0.0	15	2.7
7	1.0	5.0	0.0	0.0	5	1.4
8	1.0	5.0	0.0	0.0	Wipe	--
9	--	--				
10	--	--				

Growth Conditions:

Vacuum: 160  $\mu\text{m}$

Flow Rate: 150 cc/min.

Time: 3.25 hrs.

Results:

Surface Condition: Good

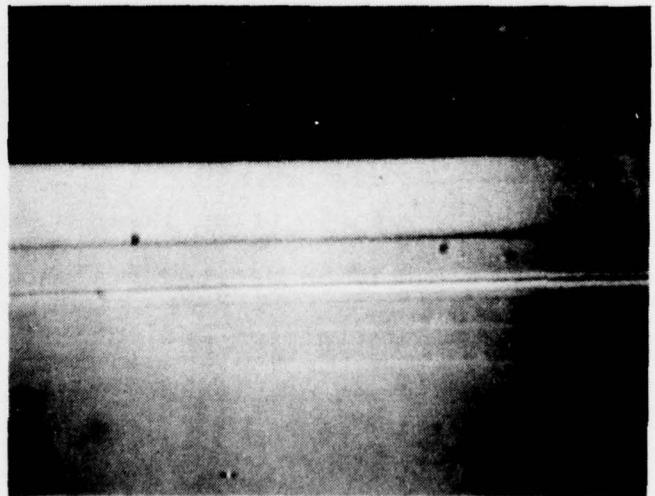
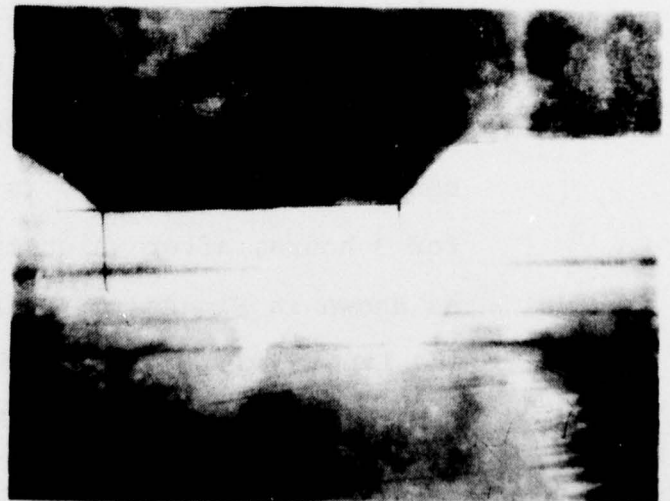


Figure 2. Photolithographic Stripe Definition and Photomicrograph of Etched Contact Channel.

	<u>Wafer#</u> DHA-106	<u>Date</u>
X	<u>Application</u> MMT 0040	Job # 2043
	<u>Operation</u>	Comments:
X	<u>Mask</u> 12 $\mu$ TRAD	
X	<u>Cleaning</u> st	
X	<u>Prebake</u> st Temp. 100°C	Time 25 min. In Vac. X
X	<u>Resist type</u> l370Dip	<u>Spin</u> 4000 RPM Time 40 sec.
X	<u>Exposure:</u> Time st 60 sec.	
X	<u>Develop:</u> Time st 6 sec.	
	Stripe Alignment ok	
	Stripe Width 14.5 $\mu$	
X	<u>Etching</u>	
	Etchant 3:1:1 HPO <sub>4</sub>	
	Etch Rate ~	
	Time 1) 22sec, 2) sec. 3) sec. Total sec.	
	Blocking Layer 1.4 $\mu$ ; P Cap Layer 2.7	
	Cleaving: <u>Stain</u>	
	Stripe Width 14 $\mu$	PHOTOS
	Stripe Depth 2.8 $\mu$	
X	<u>Resist Strip</u>	
	Temp. 25°	
	Time 25 sec.	
X	<u>Process</u> acceptable	
	<u>Yes</u>	
	No	



may than be plated over the entire epi wafer and oriented so that each triad module is covered with a single gold heat sink to within 25  $\mu\text{m}$  of the edges of the module. It is believed that this approach will reduce device mounting difficulties significantly.

Installation of the e-gun into the vacuum system was finally completed after many delays reported previously. Operation, however, continued to be frustrated by electrode arcing within the vacuum chamber. Additionally, the emission current control was found to be not properly calibrated to specification, and the beam positioning control did not function correctly. Attempts to resolve these problems have been unsuccessful and it has been decided that the system must be returned to its manufacturer for checkout and repair.

## 2.2 Packaging

Assembly of the optimized pill package previously reported has been standardized. Various aspects of this assembly procedure are illustrated. Figures 3, 4, 5 and 6 show the electrodes and mylar bonding preform prior to assembly and milling. Figure 7 shows the electrode bonding fixture and 15 packages clamped in place for bonding. This assembly is placed in an oven at 125°C for 3 hours, after which the packages are milled flat as shown in Figure 8. After milling, the package faces are lapped to a standard 4L finish to insure a good surface for window bonding. Figure 9 shows the rubber

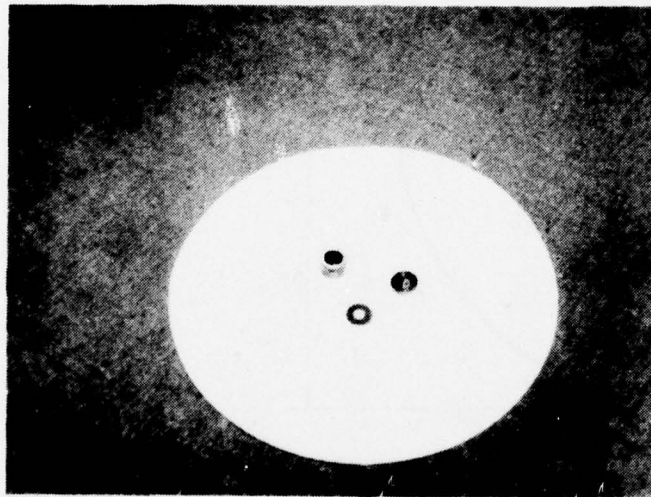
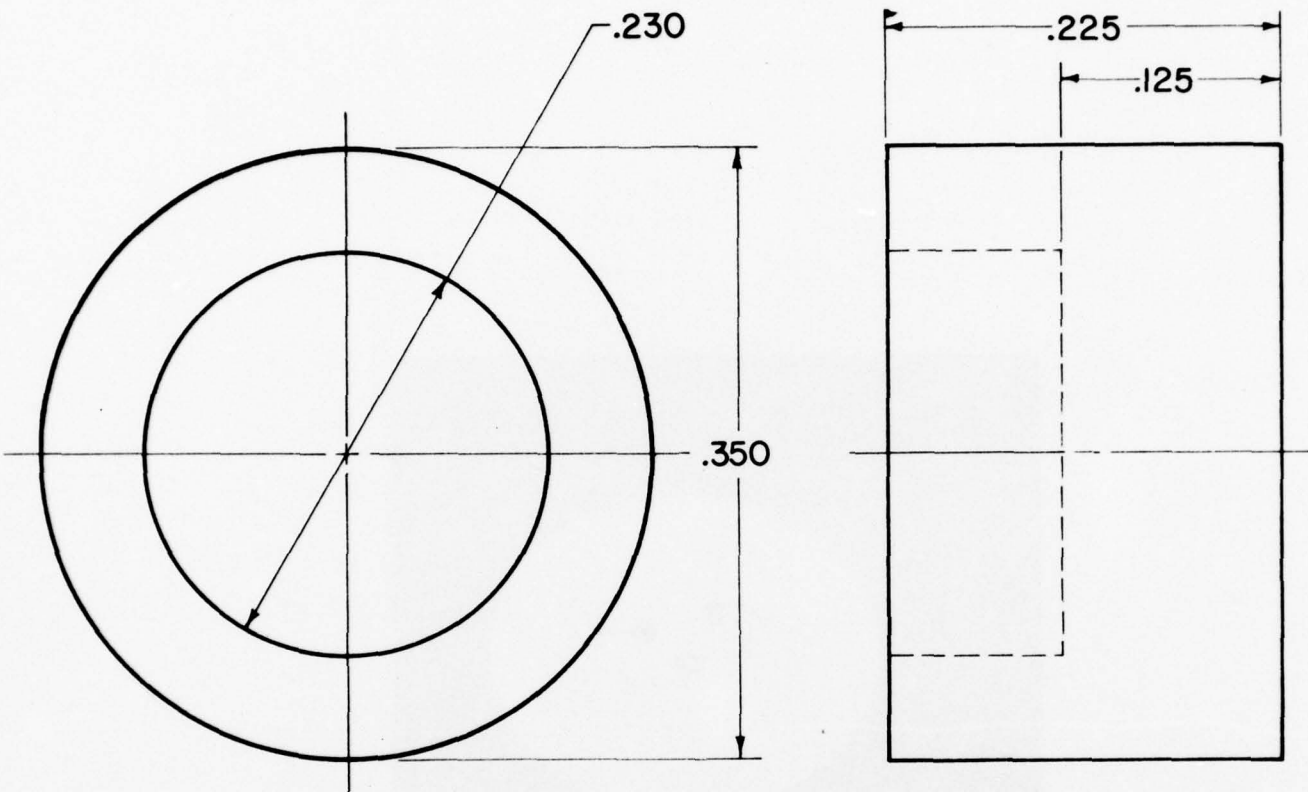


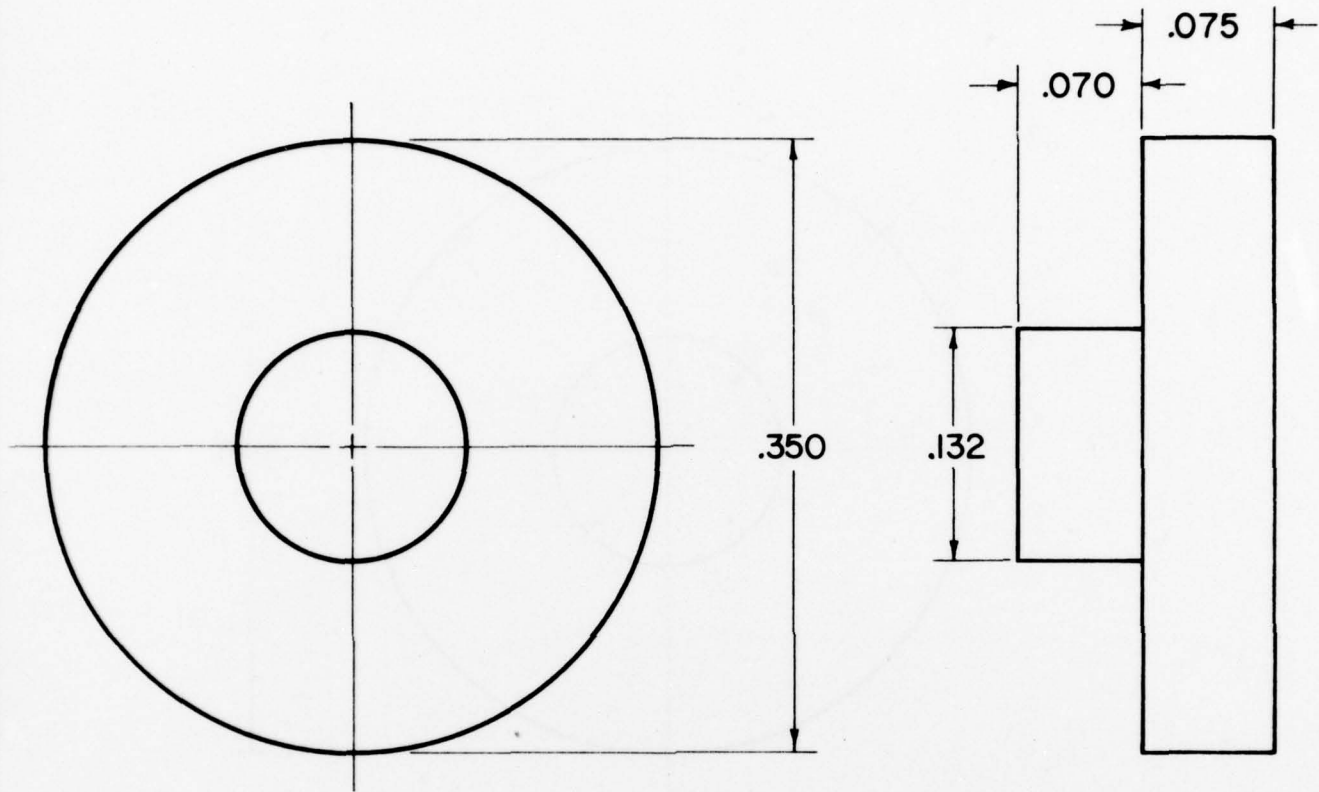
Figure 3. Electrodes and Mylar Preform.



MATERIAL - Te Cu  
 TOLERANCE:  $\pm .002$

FIGURE 4. PILL PACKAGE -  
 POSITIVE ELECTRODE

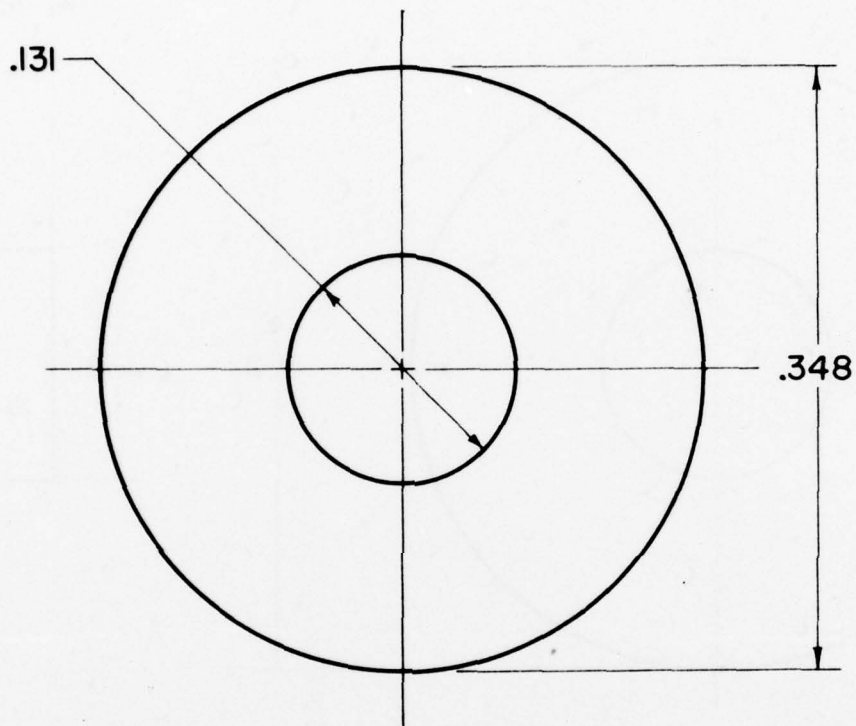
PILL PACKAGE - BOTTOM ELECTRODE		
SCALE: 10 X	APPROVED BY	DRAWN BY R. JOBES
DATE: 6-20-77		
		DRAWING NUMBER



MATERIAL - BRASS  
 TOLERANCE:  $\pm .002$

FIGURE 5. PILL PACKAGE -  
 NEGATIVE ELECTRODE

<b>PILL PACKAGE - TOP ELECTRODE</b>		
SCALE: 10 X	APPROVED BY	DRAWN BY R. JOBES
DATE: 6-20-77		
		DRAWING NUMBER



MATERIAL - ABLEFILM 539 TYPE I  
 TOLERANCE:  $\pm .002$   
 THICKNESS: .005

FIGURE 6. PILL PACKAGE -  
 MYLAR INSULATOR

<b>EPOXY PREFORM - PILL PACKAGE</b>		
SCALE: 10X	APPROVED BY	DRAWN BY R. JOBES
DATE: 6-20-77		
		DRAWING NUMBER

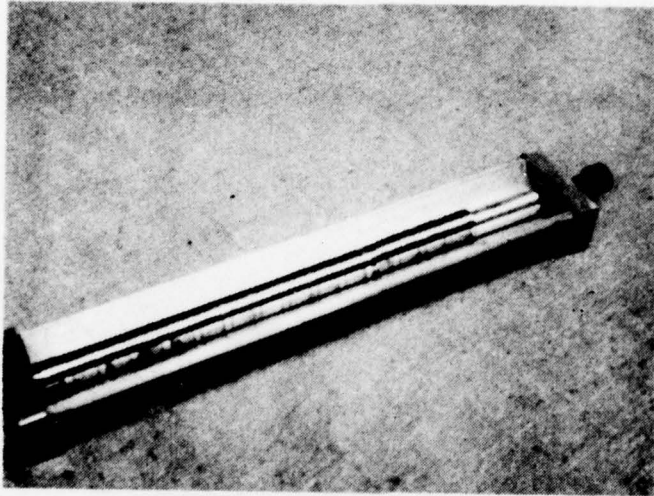


Figure 7. Bonding Fixture with Packages  
Clamped for Bonding.

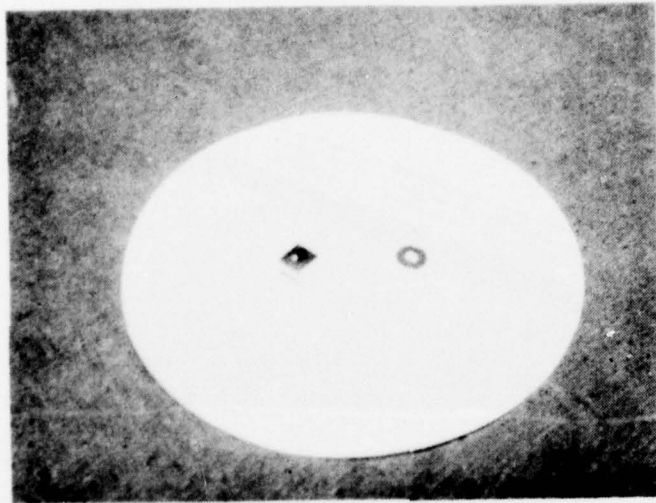


Figure 8. Milled Package Prior to Lapping.  
(Mylar Preform Also Shown.)

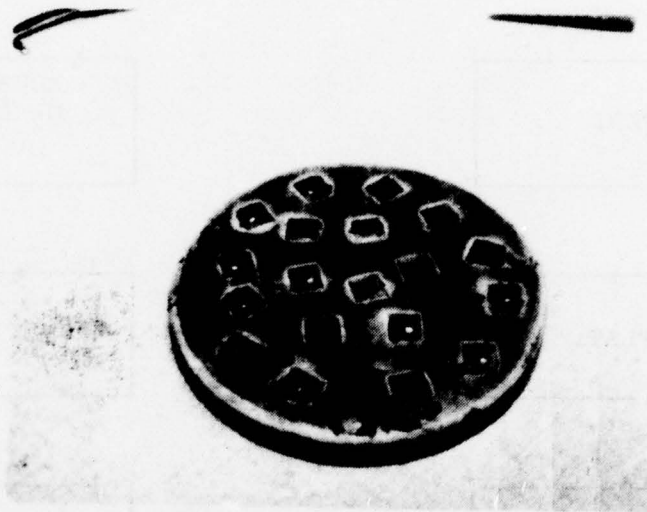


Figure 9. Rubber Lapping Pad.

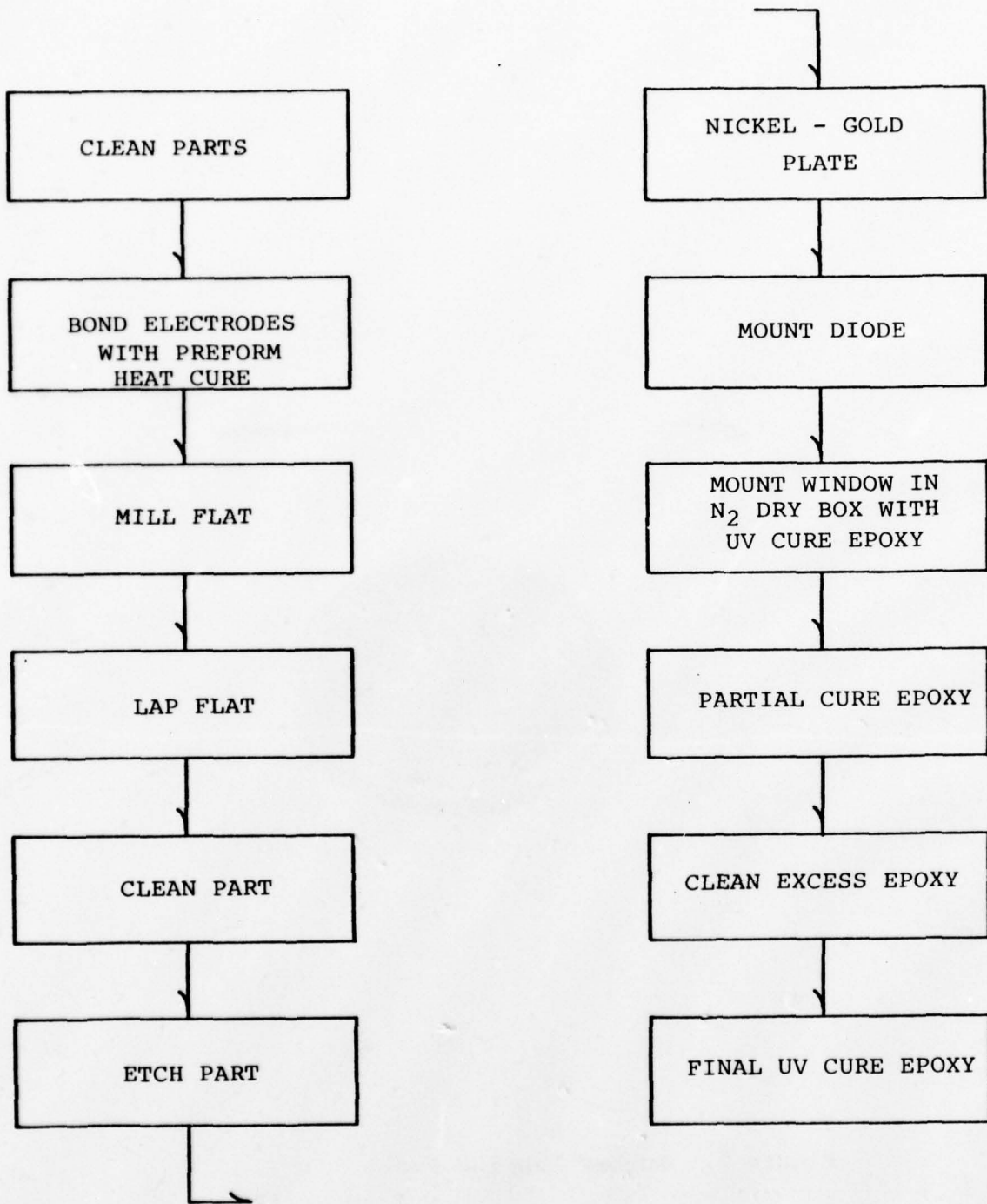


Figure 10. Package Assembly Sequence.

lapping pad used to hold the milled packages during the lapping operation. Figure 10 shows the essential steps in package and device assembly.

### 2.3 Test Equipment

Significant progress toward completion of test equipment required for this program has occurred. The burn-in rack has finally been refined to a workable configuration, a new goniometer has been designed and built and a transistor pulser has been selected and optimized for testing of power, wavelength, thermal impedance and emission distribution. Most important, a suitable replacement for the ITT F400 phototube has been found in the Texas Instruments TIED 88 APD.

Further modification to each burn-in position (Figure 11) has been effected, both in the interest of simplification and in improvement of performance. R5 and C3 have been deleted and R4 has been changed to 470  $\Omega$ . C8 also has been changed to 0.0015  $\mu$ F. These changes permit slightly more conservative operation of Q2 and Q3 while thereby yielding a better pulse shape. Each row of 8 positions is now driven by a local clock buffer (Figure 12) to insure good pulse shape and eliminate the effects of long clock lines to multiple terminations. The common clock to drive the burn in rack in its final configuration is under design and some breadboard work has been done on it as well. A temporary clock source (Figure 13) for immediate use has been in operation for some time



TABLE 1

Revised Parts List for 10MHz IL Driver  
(Single Burn-In Position)

<u>Item</u>	<u>Description</u>
Q1	Fairchild 2N3906 Transistor
Q2	Communications Transistor Corp. D3-28 Trans.
Q3	Siliconix VMP-1 Mospower Fet
IC1	Fairchild 7806 6V Regulator
IC2	Fairchild 9S00 TTL Quad. Nand
D1,2	1N4004 Silicon Diode
D3	Fairchild FD600 Silicon Diode
LED1	Visible Red LED
C1,2,4	0.1 $\mu$ F GMV 50V Epoxy Monolithic Cap
C3	Deleted
C5	0.1 $\mu$ F GMV 100V Epoxy Monolithic Cap
C6	0.056 $\mu$ F $\pm$ 10% 80V Film Cap
C7	0.017 $\mu$ F $\pm$ 80V Film Cap
C8	0.0015 $\mu$ F $\pm$ 10% 100V Orange Drop Cap
L1	8 Turns on 1/2" Mandrel 18 gA Copper
L2	8 Turns on 1/2" Mandrel 18 gA Copper
L3	2 Turns on 1/2" Mandrel 18 gA Copper
F1,2	AGC 3/4" 0.75A 250V Fuse
R1	10K 1/2W 10% Carbon Resistor
R2	2.2K 1/2W 10% Carbon Resistor
R3	10K 1/2W 10% Carbon Resistor
R4	470 $\Omega$ 1/2W 10% Carbon Reistor
R5	Deleted
R6	470 $\Omega$ 1/2W 10% Carbon Resistor

TABLE 1 (Continued)

<u>Item</u>	<u>Description</u>
R7	10K 1/2W 10% Carbon Resistor
R8	1K 1/4W 10% Carbon Resistor
R9	8.2K 1/2W 10% Carbon Resistor
R10	2.2K 1/2W 10% Carbon Resistor
R11	10 $\Omega$ 1/2W 10% Carbon Resistor
R12	47 $\Omega$ 2W 10% Carbon Resistor
R13	10 $\Omega$ 1/2W 10% Carbon Resistor
R14	500 $\Omega$ 1/4 20% Carbon Trimmer Potentiometer

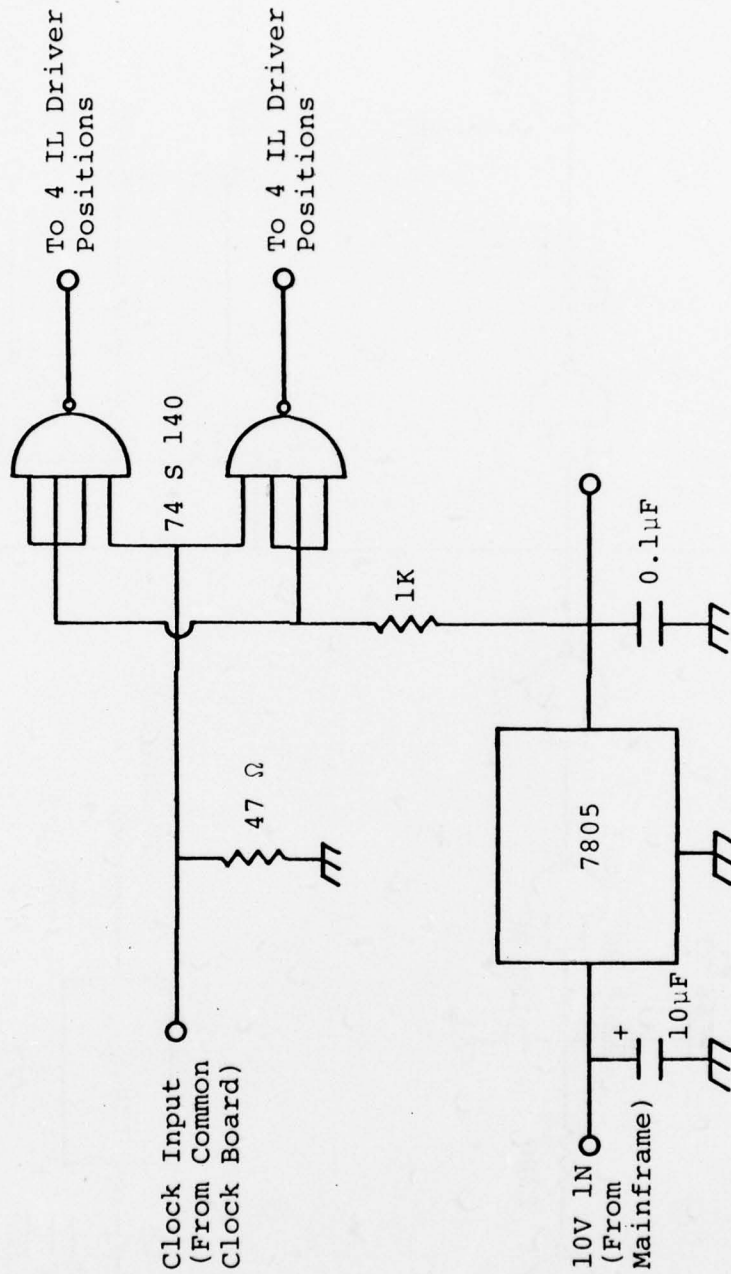


Figure 12. Local Clock Buffer for Burn-In Rack.

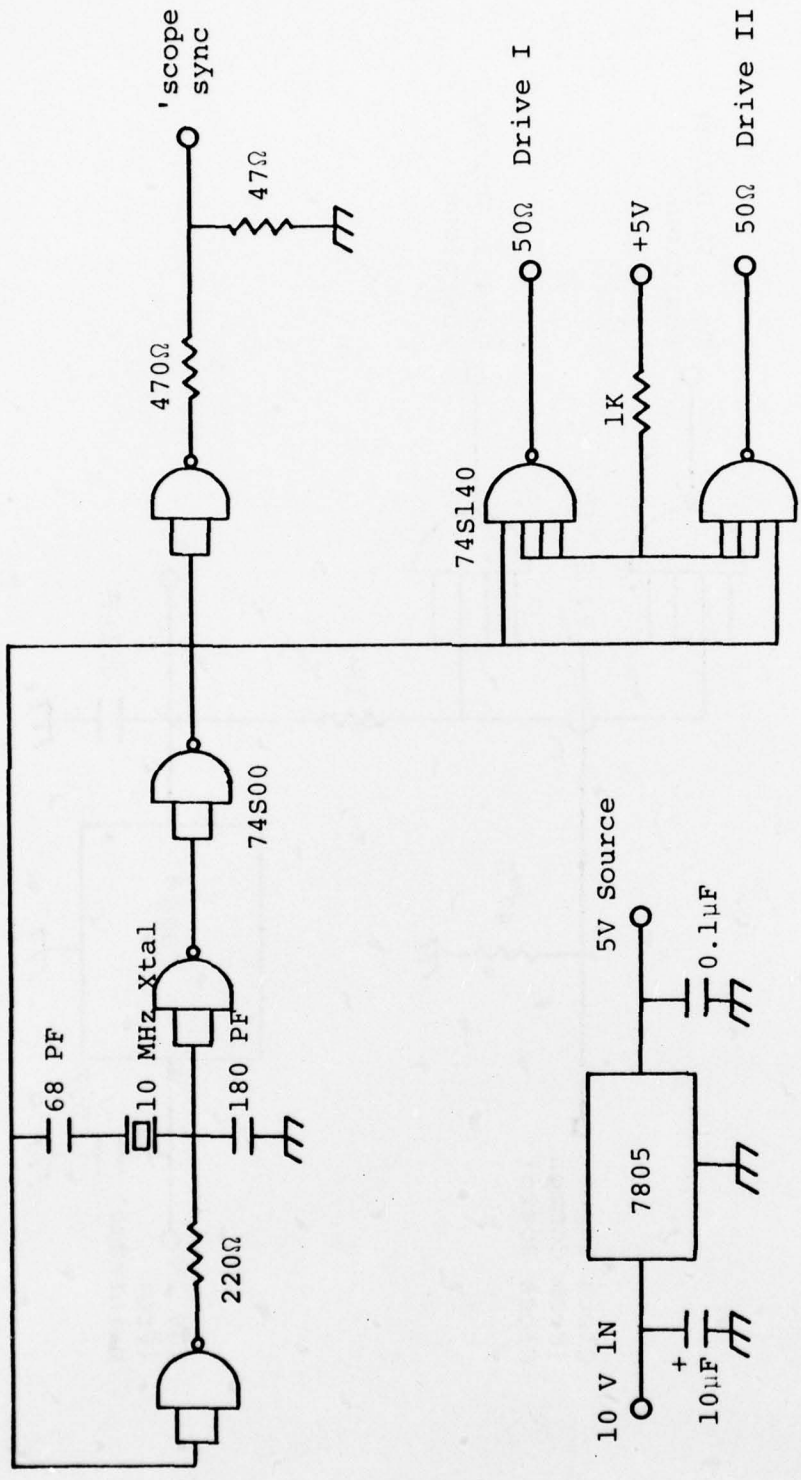


Figure 13. Temporary 10 MHz Clock Source.

and gives excellent results in all respects. Problems with board cooling are being addressed by incorporation of air deflection baffles in the cabinet designed to direct the airflow past the diodes while the rack is in operation. Close attention is being paid to thermal management within the rack to insure both reliable operation of the system and avoidance of device over-stress during burn-in and lifetest. The first group of eight rack positions (Figure 14) is complete and has been operated satisfactorily for a total of several hundred hours both with and without lasers in place.

A transistor pulser design (Figure 15) has been selected and tested extensively in breadboard for use in measurement of performance of the lasers. Two separate pulsers are anticipated, both having the same power supply and clock configuration. One will be used atop the goniometer to effect far field measurements. The other will be mounted in an assembly which incorporates a variable temperature pill package test fixture, and will be used for the remaining pulsed tests such as power, wavelength, spectral width, thermal impedance, stripe width, and uniformity. Parts for these pulsers are in various stages of specification, design, ordering, and receipt as needed. Breadboard testing of the basic design is complete and the pulser for the goniometer has been built and tested. The power supplies are still in breadboard awaiting arrival of cases but

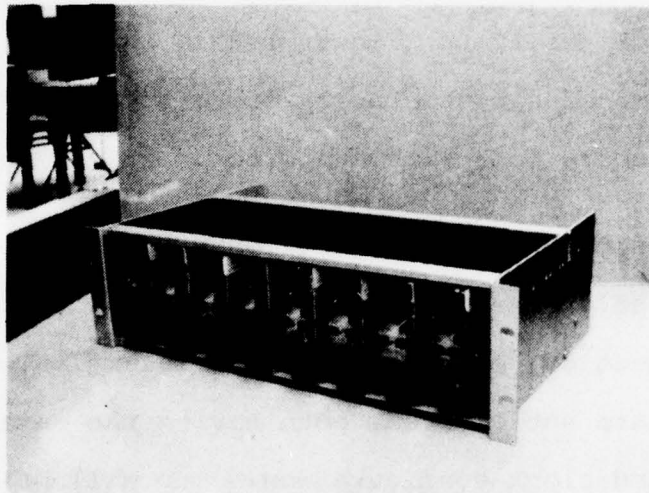


Figure 14. Row of Eight Burn-In Positions.

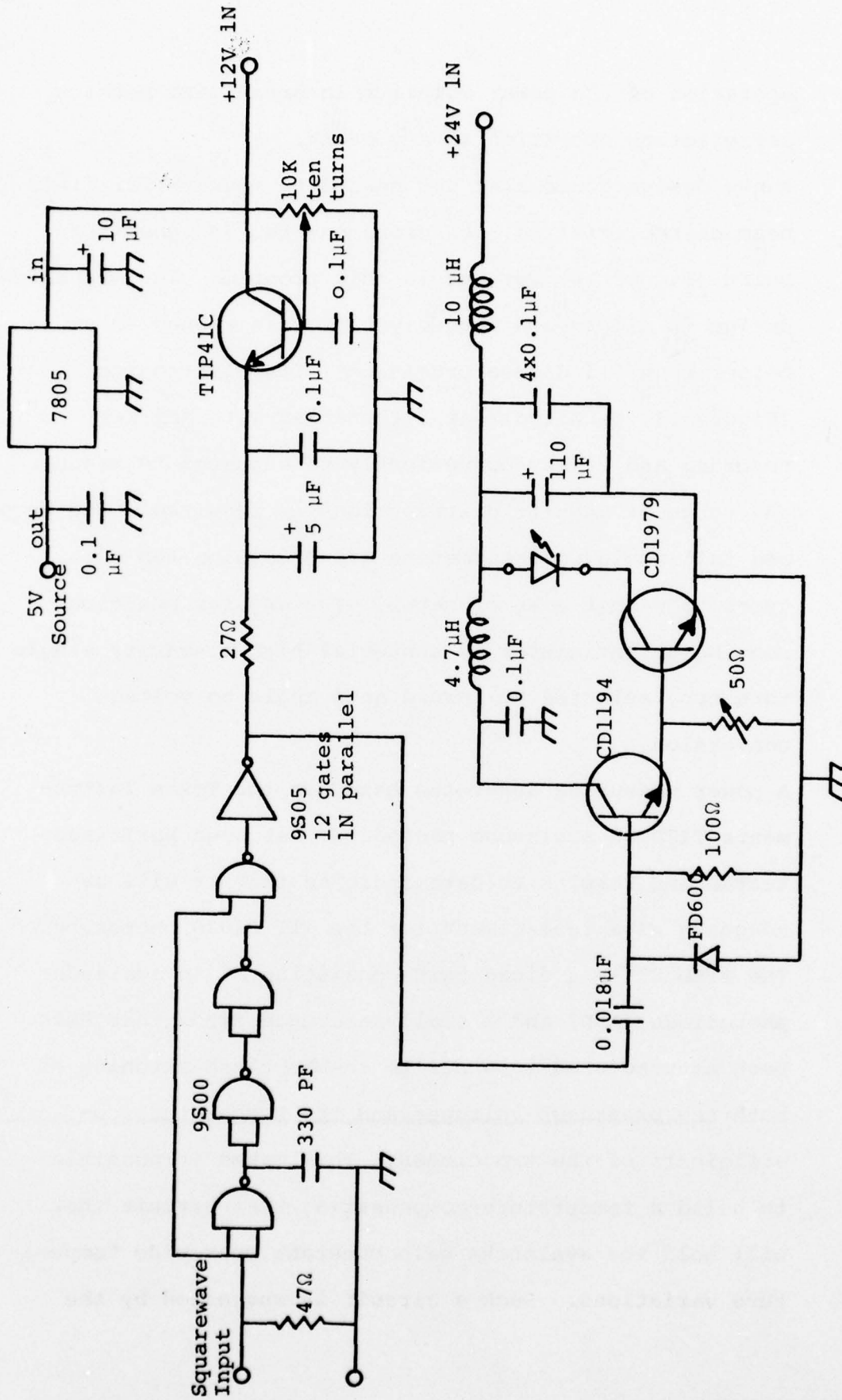


Figure 15. Transistor 10 ns Pulser.

operation of the power supplies in breadboard permits satisfactory operation in any event.

A new design goniometer was needed to measure far field beam characteristics, therefore one was designed and built (Figure 16) for use in this program. The mechanical design is simple and rugged yet precise enough to yield better than 0.5 degree precision. Its electronics (Figure 17) permit direct interfacing with any X-Y recorder and it may conveniently be adjusted to measure any range of angular distributions as required. The zero and full scale potentiometers are precision ten turn types to permit ease of setup. The angular position sensing potentiometer is a special high linearity single turn type selected to insure good angle to voltage conversion.

A power measuring apparatus based on the Texas Instruments TIED 88 avalanche photodiode has been built and tested and results to date indicate that it will be adequate as a replacement for the ITT F4000 phototube. The TIED 88 is a diode pair consisting of an avalanche photodiode (APD) and a small reference diode that have been manufactured together to ensure close matching of both the breakdown voltages and the temperature coefficients of the two diodes. This makes it possible to build a temperature-compensating bias circuit that will hold the avalanche gain constant over wide temperature variations. Such a circuit is suggested by the

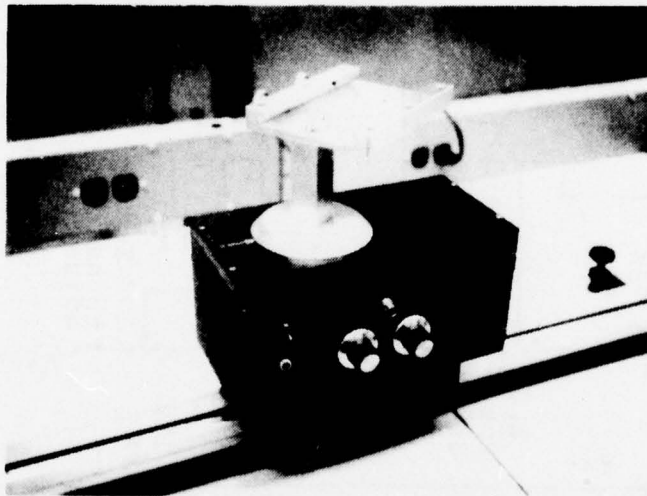
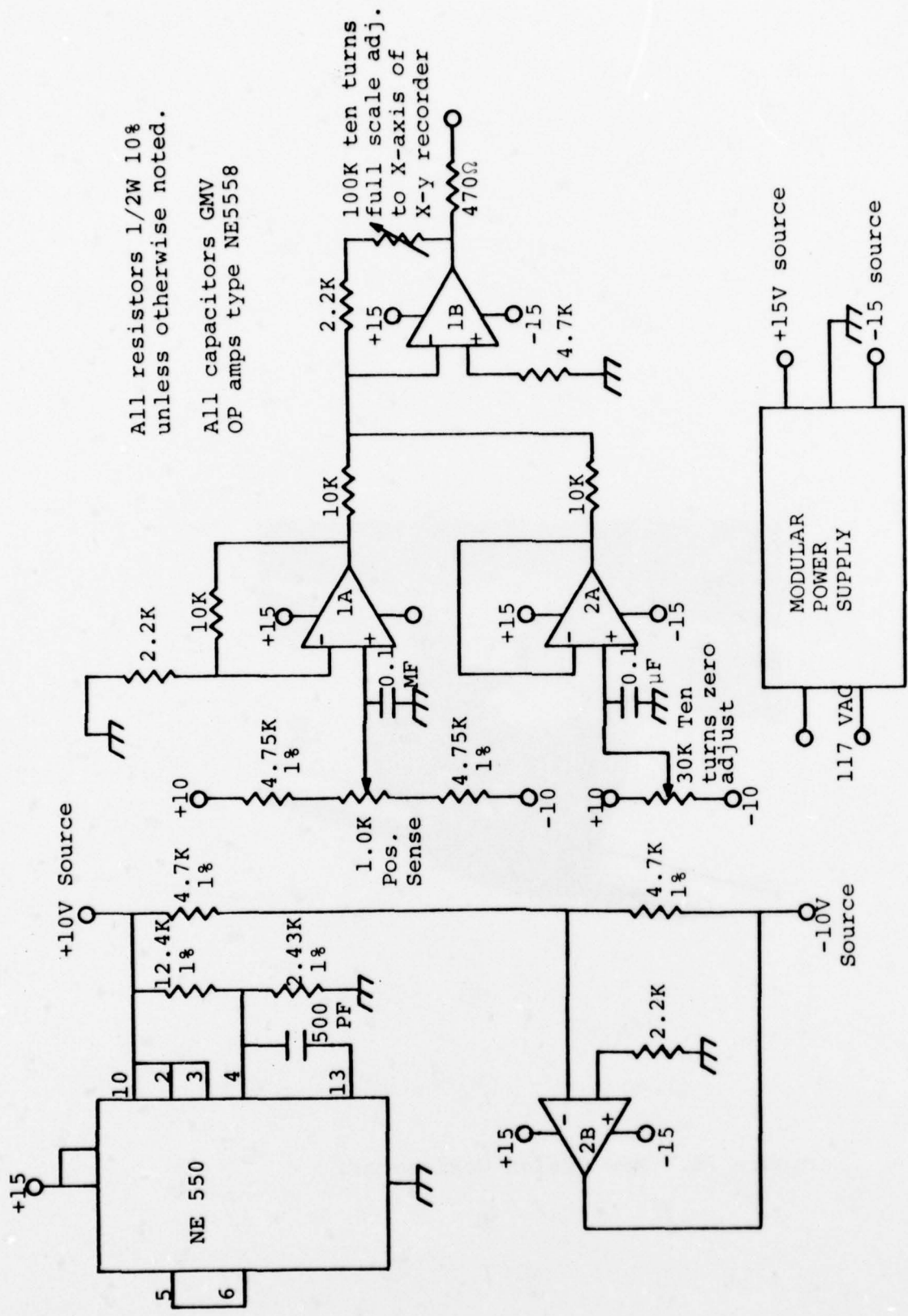


Figure 16. New Design Goniometer.



All resistors 1/2W 10% unless otherwise noted.

All capacitors GMV OP amps type NE5558

Figure 17. Position Sensing Electronics in Goniometer.

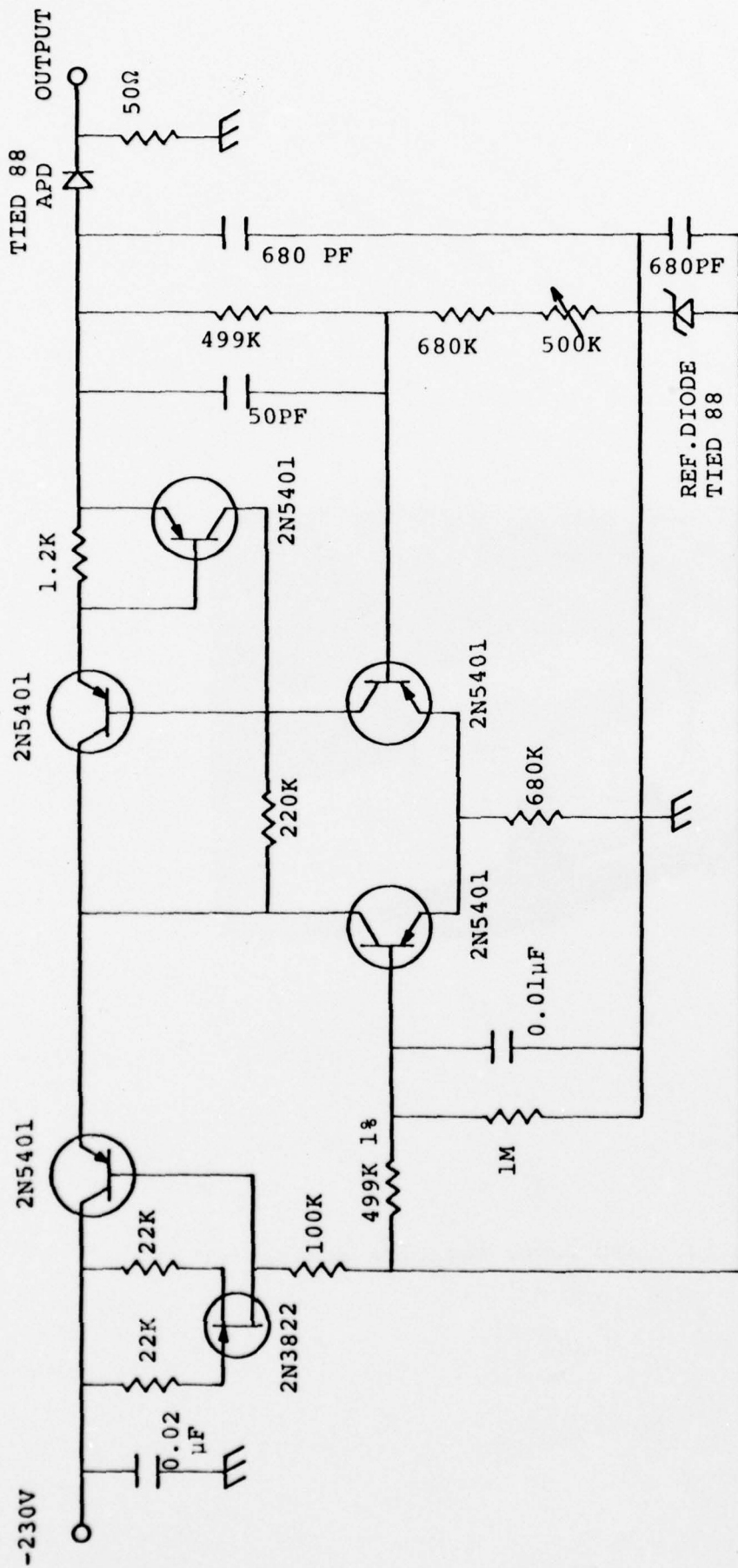


Figure 18. Avalanche Diode Regulator

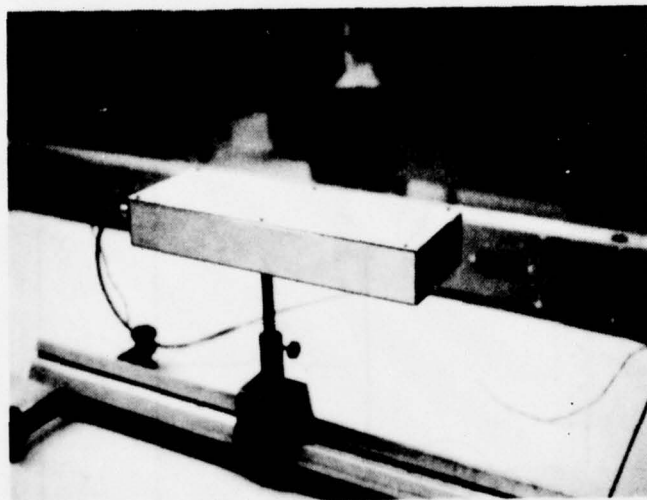


Figure 19. APD Power Detector Enclosure.

manufacturer. Based on this design, a regulator (Figure 18) has been built, together with a suitable enclosure (Figure 19) incorporating the rectangular aperture required by SCS-516 and a diffuser to allow the small diode active area to measure a signal proportional to the power incident upon the rectangular aperture. Stability and repeatability of this system have been good and allow measurements of better quality than those obtainable with the F4000 tube. The system has been calibrated with low duty cycle pulses of 10 ns width by cross correlation of a number of lasers measured on this system and a traceable ITT F4000 phototube.

Goals to be pursued in the future include completion of equipment currently in various stages of construction, addition of more positions to the burn-in rack, and construction of the transistor pulser to be used with the temperature controlled test fixture.

#### 2.4 Device Performance

Devices fabricated from wafer DHA-106 were tested for wavelength, threshold, and  $I_p$ . Results of typical acceptance devices are shown in Table 2. Power output versus current for two representative units are shown in Figures 20 and 21.

TABLE 2. TYPICAL DEVICES FROM WAFER DHA-106.

<u>Unit #</u>	<u>I<sub>th</sub>, Amps</u>	<u>I<sub>max</sub>, Amps</u>	<u>λ, nm</u>
1	1.9	2.6	820
2	1.7	2.5	816
3	2.1	2.9	822
4	2.0	3.0	819
5	2.1	2.9	823
6	2.1	3.0	815
7	2.0	2.9	823
8	1.8	3.0	820
9	2.1	2.8	819
10	1.8	2.6	817

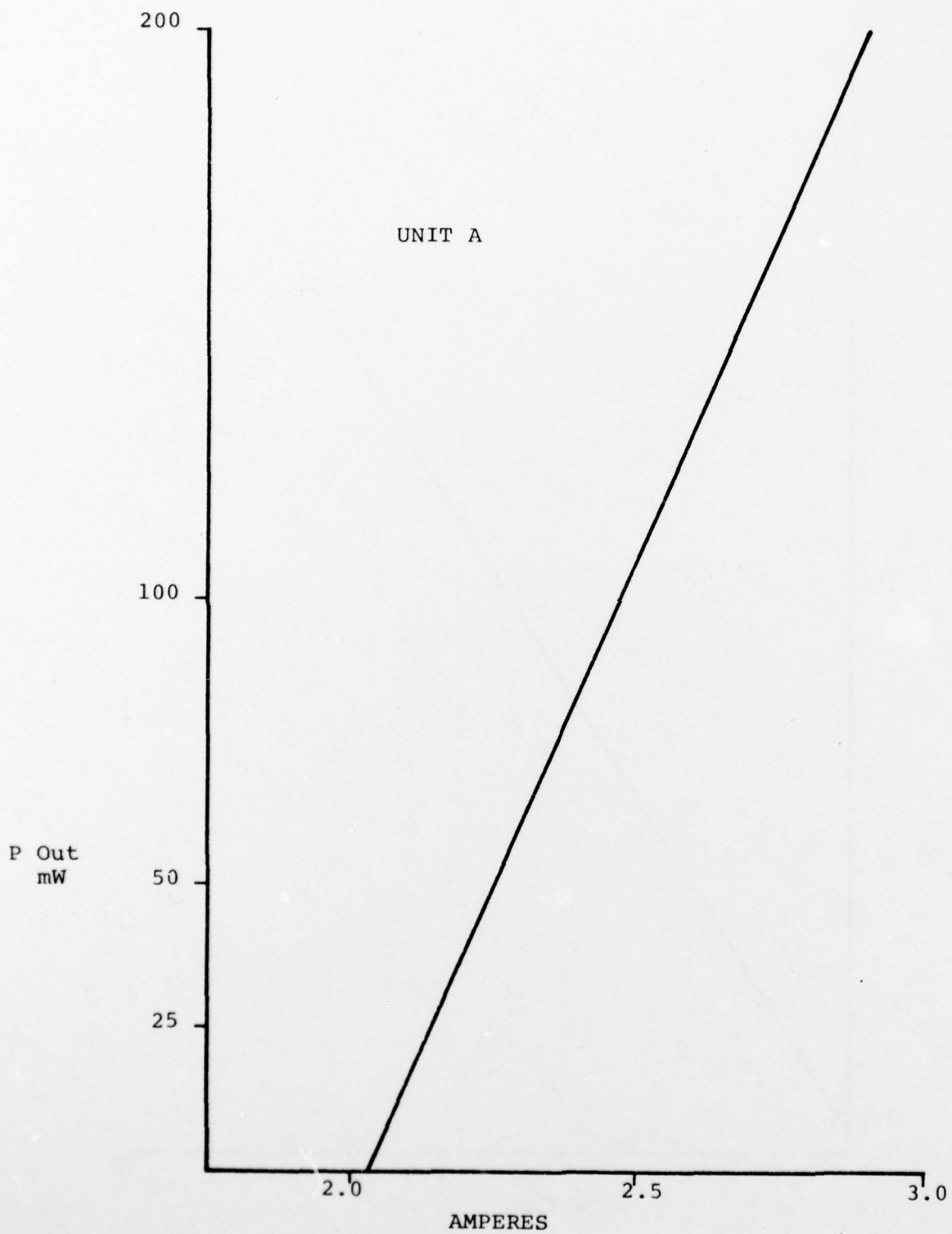


Figure 20. Power Output vs. Current.

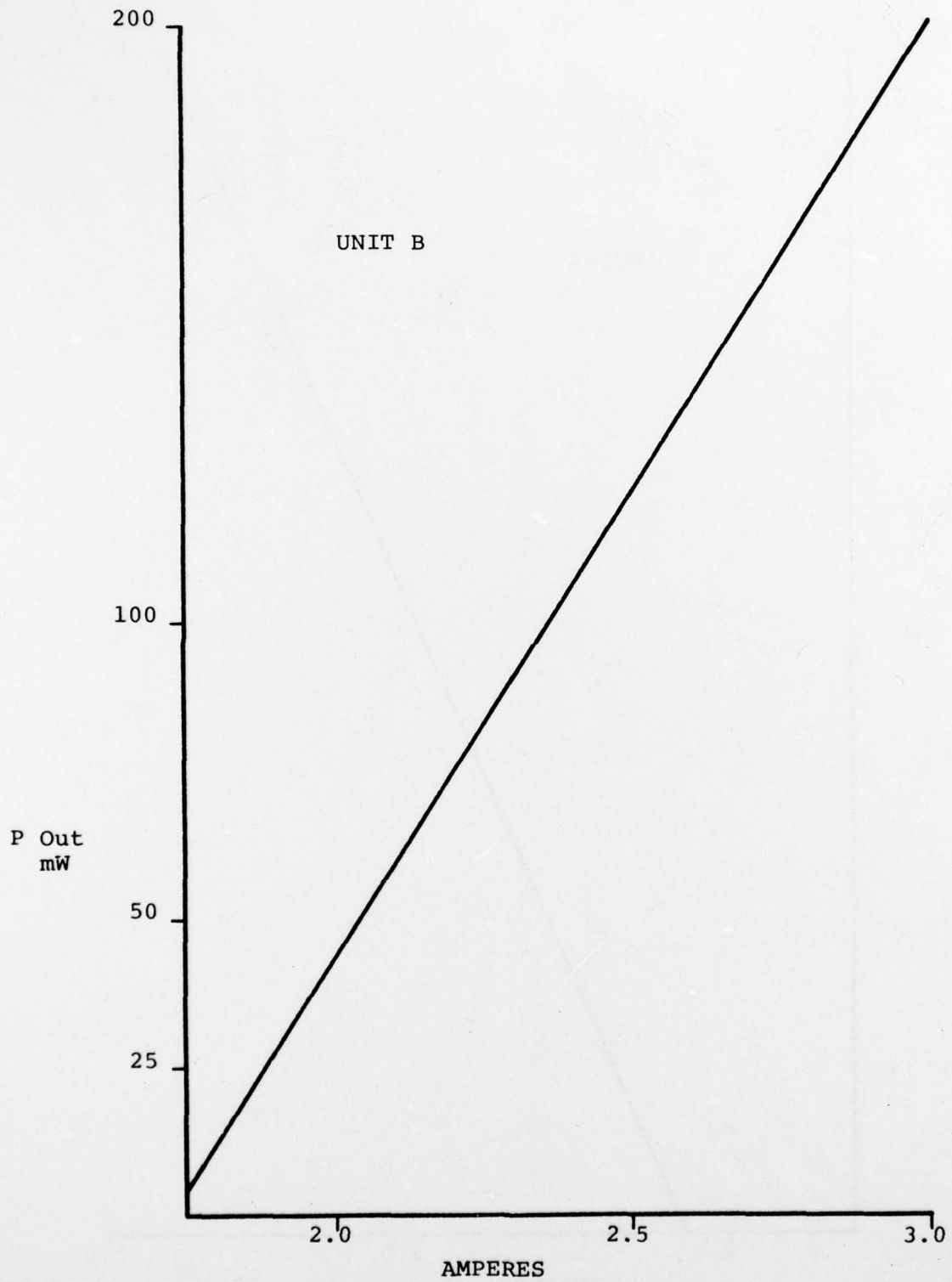


Figure 21. Power Output vs. Current.

### SECTION III

#### SUMMARY

The fourth quarter of this program has been productive on all fronts. Material for the second engineering sample has been grown and evaluated. Improvements in device mounting and fabrication were explored and assembly flow further defined. Test equipment assembly continues well in all areas, particularly in the burn-in rack which has finally become operational. Other progress of significance included choice, evaluation and construction of the APD based detector for power measurement, construction of the new goniometer, and selection of a transistor type test pulser design. Goals for the next report period include further work on all aspects of the test equipment, completion of pre burn-in testing of the second engineering sample as well as initiation of the burn in and life test of the second engineering sample.

APPENDIX A

Engineering Man-Hour Utilization  
for the Fourth Quarter of the Program.

	<u>4th Qtr.</u>	<u>Cumulative</u>
T. E. Stockton	176 Hrs.	784 Hrs.
R. B. Gill	-	138 Hrs.
A. Gennaro	-	371 Hrs.
R. Albano	64 Hrs.	590 Hrs.
S. Klunk	106 Hrs.	386 Hrs.
Manufacturing Personnel	50 Hrs.	1128 Hrs.

APPENDIX B

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