N84-32805

NASA Technical Memorandum

NASA TM- 86459

LASER FURNACE TECHNOLOGY FOR ZONE REFINING

MSFC Center Director's Discretionary Fund
Final Report, Project No. 82-26

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August 1984

National Aeronautics and
Space Administration

George C. Marshall Space Flight Center

MSFC - Form 3190 (Rev. May 1983)

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TM-86459		

4. TITLE AND SUBTITLE	5. REPORT DATE
LASER FURNACE TECHNOLOGY FOR ZONE REFINING MSFC Center Director's Discretionary Fund Final Report, Project No. 82-26	August 1984
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Donald B. Griner	8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS George C. Marshall Space Flight Center Marshall Space Flight Center, Alabama 35812	10. WORK UNIT NO.
	11. CONTRACT OR GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D.C. 20546	13. TYPE OF REPORT & PERIOD COVERED Technical Memorandum
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Information and Electronic Systems Laboratory.

16. ABSTRACT

A carbon dioxide laser experiment facility was constructed to investigate the problems in using a laser beam to zone refine semiconductor and metal crystals. The hardware includes a computer to control scan mirrors and stepper motors to provide a variety of melt zone patterns. The equipment and its operating procedures are described.

17. KEY WORDS	18. DISTRIBUTION STATEMENT
Laser Furnace Zone Refining Beam Scanners Optical Scanner Laser Heating	Unclassified — Unlimited

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	30	NTIS

MSFC - Form 3292 (May 1969)

For sale by National Technical Information Service, Springfield, Virginia 22151

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TECHNICAL MEMORANDUM

LASER FURNACE TECHNOLOGY FOR ZONE REFINING

SUMMARY

A carbon dioxide laser system was developed to investigate the problems in using a laser beam for zone refining. The system has a computer to control a high speed scan mirror which generates a narrow line melt zone and a slow speed, very precise, stepper motor drive to move the melt zone along the crystal. The melt zone can be up to 1 cm in width and move a maximum distance of 10 cm. The laser spot at sharpest focus is about 0.5 mm in diameter. The maximum laser power is 85 W but can be varied from 10 W up to the maximum 85 W. Attempts were made to melt both semiconductor and metal crystals. Silicon wafers were successfully melted at power settings of about 50 W, but there was not enough power to melt the nickel metal super alloy crystals.

INTRODUCTION

The effort to investigate the feasibility of using a focused laser spot to zone refine crystals was a Center Directors Discretionary Fund (CDDF) activity (No. 82-26) titled "Advanced Furnace Technology for Materials Processing in Space." The activity was started by the design group of EP12 at the Marshall Space Flight Center (MSFC). The group had worked for years to design new and better furnaces for the Material Processing in Space Program. One of the major problems is to generate very precise melt zones with precision control of temperature gradients around the melt zone. They felt it might be possible to take advantage of laser beams for ease of position control and the ability to focus high power in very small spots. They enlisted the help of the Optical Systems Branch to research the problems and evaluate the possibilities.

The CDDF activity started in May 1982 and ran for two years. The first year was used to design and procure the hardware. The second year was used to set up the equipment and run the experiments. A summary of the schedule and programmatic data is given in Appendix D.

The hardware developed for the CDDF activity was intended for research and development only and no attempt was made to design a realistic furnace. The goal of the activity was to acquire background knowledge and experience in working with lasers to melt and zone refine crystals. The long range goal is to design a furnace that could be proposed for a flight experiment.

The low gravity environment of space will allow better control of thermal convection currents, unusual melt zones and less complicated ways to hold samples without physically touching them. Small unusual crystals that have not even been imagined at this time will be required for advanced detectors and semiconductor devices. Only experiments in space will reveal what possibilities are practical. The task now is to develop experience that will allow the best furnace design when the requirements are known. The next stage of effort would be accomplished under an RTOP effort for the Materials Processing in Space Program.

TEST APPARATUS

The concept selected for the CDDF activity was to generate a melt zone by rapidly scanning a focused laser beam. Other methods were considered, such as shaped beams which would generate a fixed melt zone without scanning, but the scanning of a focused spot was selected because the method offered flexibility at a low cost and very little of the laser power was lost in the optics. As long as the scan speed was fast compared to the thermal flow of the material, the effect should be a smooth continuous heating over the complete zone.

A block diagram of the system is shown in Figure 1. The laser beam is directed through beam steering mirrors to the galvanometer-driven scan mirror mounted on the stepper motor-driven linear translation stage. The scan mirror directs the beam through a lens that focuses the spot down on the sample surface. The angle that the beam strikes the surface can be changed by remounting the scan mirror and lens at various predrilled holes on the translation stage.

The lens used to focus the beam is mounted on a small-stepper motor-driven linear-translation stage to allow control over the focused beam spot size. By moving the stage, the beam can be defocused to heat a larger area at any one instant in time. The laser beam at the lens is about 1 cm in diameter and the lens has a focal length of 24.5 cm. By measurement, the sharpest focus gives a spot about 0.5 mm RMS in diameter which is larger than a perfect diffraction limited spot by about a factor of two.

Opposite the lens is a second stepper motor-driven linear stage. It is used to hold an absorber to trap the reflected beam or to position a concave mirror to focus the beam back down to the surface to increase the energy absorbed in the sample. The concave mirror produces a spot that scans back and forth 180 deg out of phase with the original spot, but in the same zone.

A vacuum chamber was built to hold the sample. The chamber was designed to allow the beam to enter at 45 deg or at normal incidence. Salt windows are used to transmit the beam into the vacuum chamber. The normal mode of operation is to send the laser beam in at 45 deg and to view the sample through the top window with a pyrometer for temperature measurements. The vacuum chamber does not move and the small windows allow only a 2-cm scan distance on the sample.

All parts of the scan system are controlled by a microprocessor control computer. The computer is a single board system based on a Motorola 6809 microprocessor. The computer uses the FLEX operating system. XBASIC is used for most of the programming but some routines are written in assemble language. The system has a real time clock, analog to digital circuits to read the laser power meter and drivers for the stepper motors, scan mirrors, and laser beam shutter. Peripherals include a keyboard, CRT display, printer, and dual 5.25 double sided, double density floppy disc drives. The major components of the system were supplied and assembled by Penn Research Corporation (PRC) of Kennesaw, Georgia.

Figure 2 gives a summary of the major components of the system and their manufacturers. Figure 3 is a photograph of the complete system. Figure 4 is a close up of the scan system showing the galvanometer scan mirror and the focusing lens. The analog readout of the laser power meter is at the upper left and the stepper motor for the large linear translation stage is just below it. In the upper center is the pyrometer and the fold mirror used to view the sample surface. Figure 5 is a photograph of the vacuum chamber sample holder. The metal flanges on each side are used to bolt the chamber to the frame of the laser cabinet. At the top are the three windows used to pass the laser beam and to view the sample surface. There are two vacuum flanges, one shown in the center of the chamber and one hid on the opposite side. One is used to attach a vacuum pump and the other is used to mount a window to view the back side of the sample, if required.

OPERATION OF HARDWARE

The procedure to turn on the laser and to shut it down are given in Appendix A and B. A photograph of the control panel is shown in Figure 6. The gas control panel is shown in Figure 7. Once the laser is on and operating the shutter has to be switched open to allow the beam to reach the scan optics. When the shutter is closed the beam is blocked by a metal trap. Even at full power the shutter will trap the beam continuously without overheating. The power meter is located at the rear cavity mirror and operates by measuring the small percentage transmitted by that mirror, therefore the power meter will read the correct power even when the shutter is closed.

The laser power can be optimized by adjusting the cavity mirrors at each end of the laser tube. Figure 8 shows the location of the front cavity mirror adjustment knobs. There are actually two knobs at each end to adjust the mirrors in two axis. One of the knobs can be seen in Figure 8 right above the fold mirror that directs the laser beam to the scan system. The second knob is hid behind the mirror fixture. The knobs at the rear cavity mirror are similar in appearance. The maximum power is obtained when the cavity is set for a "doughnut" mode (TEM01). Thermal image plates are used to locate the invisible carbon dioxide laser beam and tell when the best alignment is achieved. A small ultra-violet lamp is used to illuminate the thermal image plates causing them to fluoresce. The 10.6 micron laser beam will stop the fluorescence and appear as a dark image.

To operate the computer, power is turned on and the reset button is pushed. The computer displays a message asking if the discs are ready. The operating system disc is placed in drive zero and the data disc is placed in drive one. Typing a "U" will instruct the computer to load the operating system. When the operating system is loaded the computer will give the time and date and display the FLEX system ready message. The control program is written in basic so the basic language has to be loaded. The operator loads basic by typing "XBASIC" and hitting the carriage return key. When the ready message is displayed the actual control program is loaded by typing "load "NASA3"(return)". Once the ready message is again displayed the operator can run the program by typing "RUN"(return).

The control program displays a Menu Option table. An example is shown in Figure 9. An option is selected by entering the number below each selection. To make an experiment run the parameters must first be stored in a data table. An example of a data table is shown in Figure 10. The table build option allows the operator to generate a new data table. The computer will ask for a name for the data file and then ask for each parameter one at a time. After the values are entered the computer will ask if the file is to be saved or printed. When the file is saved, the menu option will again be displayed and the operator can select the execute table option. The computer will ask for the file name to run and then ask if any changes to the parameters are required. By entering the letter beside the parameter the operator can change the table before running it. There is also an option to save or print the parameters as they are now on the screen. The computer automatically stores any table on disc after the command is actually given to run the table. The disc file is called "lastrun" and is insurance that the last run data can be retrieved.

In the data table, Figure 9, the assembly stage start and stop positions are in centimeters as are the mirror stage positions. The assembly stage velocity units are time intervals between motor steps. Figure 11 is a table relating the number to the translation stage velocity. The galvanometer frequency units are related to the scan frequency period. Figure 12 gives the relation between the values and the scanner frequency. The galvanometer amplitude units are values fed to a programmable gain amplifier. Dividing the maximum of 800 by 18 gives the multiplication factor to obtain the movement in centimeters. In option (L), the wait for the zone to melt is a number used by the computer to do dummy loops. The largest interger allowed by the computer is 32000 and will give a wait period of about 1 sec. Experience has shown that the wait period needs to be much longer and so it is planned to rewrite this routine in the near future. The last parameter in the table is the number of times the melt zone will be moved through the sample.

The sequence of events that happen after the instruction to execute the run table is listed below:

1) The lens and reflector stages are positioned to the locations specified in the data table. Both motors appear to run at the same time.

2) The main translation stage is positioned to the zero reference point, i.e.; driven to the extreme left position.

3) The scan mirror is started. (The shutter is not opened.)

4) The main translation stage is moved to specified start position.

5) The shutter is opened and the laser beam is allowed to strike the sample.

6) The main translation stage is held stationary for the specified wait period.

7) The main translation stage starts to move and drives to the final position specified.

8) The shutter is closed.

9) The stage is driven back to the zero reference position if it is the last run or to the melt zone start location if additional cycles are specified.

10) The cycle is repeated the specified number of times.

A galvanometer is used to drive the scan mirror instead of an oscillating band so that a linear sweep can be produced. The wave form generated by the computer is a triangle wave and the galvanometer will fatefully follow the signal up to about 60 Hz. Above the frequency the scan becomes more and more sine shaped as the frequency is increased. Figure 13 shows the scan pattern achieved below 60 Hz.

The laser power is varied by changing the dial on the current control variable resistor. The actual power obtained for any one setting varies from day to day.

The exact reason has not been established but is probably related to the gas mixture and temperature conditions. Figure 14 gives two curves which were obtained during attempts to calibrate the dial settings. Penn Research recommends that a setting less than 20 not be used because lower settings produce higher voltages across the laser tube. Settings lower than 20 may produce voltages high enough to break down the insulators that isolate the tube from ground. Dial settings above 80 are not recommended due to the high currents through the tube. The laser is rated at 85 W but the maximum power has ranged from 70 up to 95 W.

DISCUSSION OF TEST

Two major experiments were planned to verify the operation of the equipment. They were to experiment with silicon as a semiconductor material and with a nickel based super alloy (MARM-246) as a metallic crystal. Silicon was selected because its properties were well known and several articles had been published relating experience in using carbon dioxide lasers to melt or cut the material. Nickel based super alloys were of interest because of their importance in rocket engines and high temperature turbines.

Initial attempts to melt silicon revealed a number of problems with the system. Many problems with the computer software had to be worked out but the major problem that held up experiments for a long period was related to loss of laser power through the optical train. All of the beam alignment was done at low power setting and what was not realized for a long time was that when the power was increased the beam diameter also increased. The scan mirror had a safety graphite absorber around it to trap the beam if the alignment moved. Because of the doughnut mode of the laser when the beam diameter increased the graphite absorber blocked the outside diameter and the power transmitted to the sample actually went down. When the situation was finally realized, the hole in the graphite absorber was increased and a larger scan mirror was placed on the galvanometer. With that fix the silicon wafers were melted for the first time. In fact it was discovered very quickly that any power setting over 50 W heated up the sample too rapidly and the wafer shattered. Measurement of the optical system transmission efficiency to determine the maximum power that could be placed on the sample revealed that all the mirrors reflected more than 99 percent but that 20 percent of the laser power was lost at the focus lens due to surface reflection. Therefore, at any reading of the power meter, the actual power on the surface was 20 percent less.

The silicon samples used were integrated circuit wafers 24 cm in diameter and 13 mil thick. At the 45 deg angle of incident the wafers transmitted 50 percent of the incident energy and reflected 37.5 percent leaving 12.5 percent to actually heat up the material. As the temperature of the sample increases, the absorption increases. The data recorded seemed to agree very well with published data. At power settings of 40 W, melt zones 5 mm wide were generated and moved along the sample. The main translation stage speed had to be slower than 1 mm/sec or the melt zone could not be maintained.

Attempts to melt the metal crystals were not successful. The laser power was not high enough to melt the size sample available. The samples were rods about 5 mm in diameter and 49 mm long. The high reflectivity of the metals indicate that several hundred watts may be required to initiate the melt.

CONCLUSIONS AND RECOMMENDATIONS

A carbon dioxide laser system with the beam under computer control has been placed into operation. The system will place over 50 W on a sample surface focused to a spot as small as 0.5 mm. The beam can be linearly scanned at frequency from 0.04 to 60 cy/sec. The width of the scan can be up to 1.8 cm and the scan zone can be moved at speeds from 0.001 to 25 cm/sec. The basic goals for the beam control were achieved.

The experience gained during the activity shows that a laser beam can provide very localized heating with extreme control. A practical furnace would probably utilize conventional means for overall sample temperature control and the laser to provide the melt zone or gradients around the melt zone. Most near term programs for crystal growth in space would be with small samples to show feasibility. For thin samples a beam to focus on each side would be best while round samples may require shaped beams. There is an argument that the laser is too inefficient and massive to be considered for space use. At worst, the Carbon Dioxide laser is 10 percent efficient. Many small samples can be melted with less than 100 W, requiring less than 1000 W of spacecraft power, a large value, but not out of reach. The size of the laser used in the CDDF activity is large and massive as are most ground based systems. It was selected because of its low cost and industrial grade reliability. Penn Research is now designing a carbon dioxide laser for space application that would provide 1000 W of power and fit in three shoe boxes. Special lasers could be developed for space that are much smaller and more efficient than most systems now on the market.

The recommendation for the near time is to continue experiments with the present system. Other semiconductor materials such as germanium, gallium arsenide and mercury cadmium telluride can be used as samples. An RTOP will be prepared for the Material Processing in Space Program giving recommendations and proposing changes that can be made to the system. Two changes that are needed immediately are to upgrade the computer and to replace the laser electronics to place the laser power under computer control. Penn Research offers the computer upgrade and the laser power control electronics for about 30K. The upgrade package offered by Penn Research includes a pulse option that is extremely useful for working with metals in that at shutter open command the laser will put out a powerful pulse to start a melt and rapidly drop back to the melting setting.

An important, but less immediate need, is to improve the temperature measurement system. The control of the melt zone and the gradients around the melt zone depend on accurate, high speed measurement of the temperature. The pyrometer presently used does not have enough accuracy nor range. No off-the-shelf equipment is known that will meet the requirements. An effort will be continued to define a better temperature measurement system. A possible concept is being studied under a related CDDF activity titled "Remote Measurement of Surface Temperature."

An upgrade that will be recommended is to add additional power to the laser. The upgrades offered by PRC is to replace the present laser tube with a three tube system or to add a second laser system with an independent beam control to heat both sides of a thin sample. The second laser could be of the same type or a more powerful unit with up to 1000 W. In order to experiment with metallic crystals the 1000 W class laser is required.

A 1000 W laser would also add the capability to experiment with laser welding. The present beam building equipment designed to demonstrate continuous beam building in space had many difficulties with the spot weld electrodes. Penn Research has suggested that a laser could do the spot welds faster and more uniformly without massive transformers or electrode problems. Seam welding is also possible but would require more continuous power. PRC claims to have spot welded thin aluminum of the type used in the beam builder with about 700 W of Carbon Dioxide laser power. Since experiments with aluminum need inert gases or vacuum, the present system, with a more powerful laser, could be used to experiment with small samples. Large samples would require a larger vacuum chamber. The possibility has been discussed with James Ehl of the MSFC Materials Laboratory and he felt it would be worth exploring.

The laser system build up under the CDDF activity offers capability for a variety of experiments. The Optical Systems branch has assembled the system and will maintain and operate it. The facility will be made available to all members of the Materials Processing in Space Program or to other interested members of the NASA community on a first come basis.

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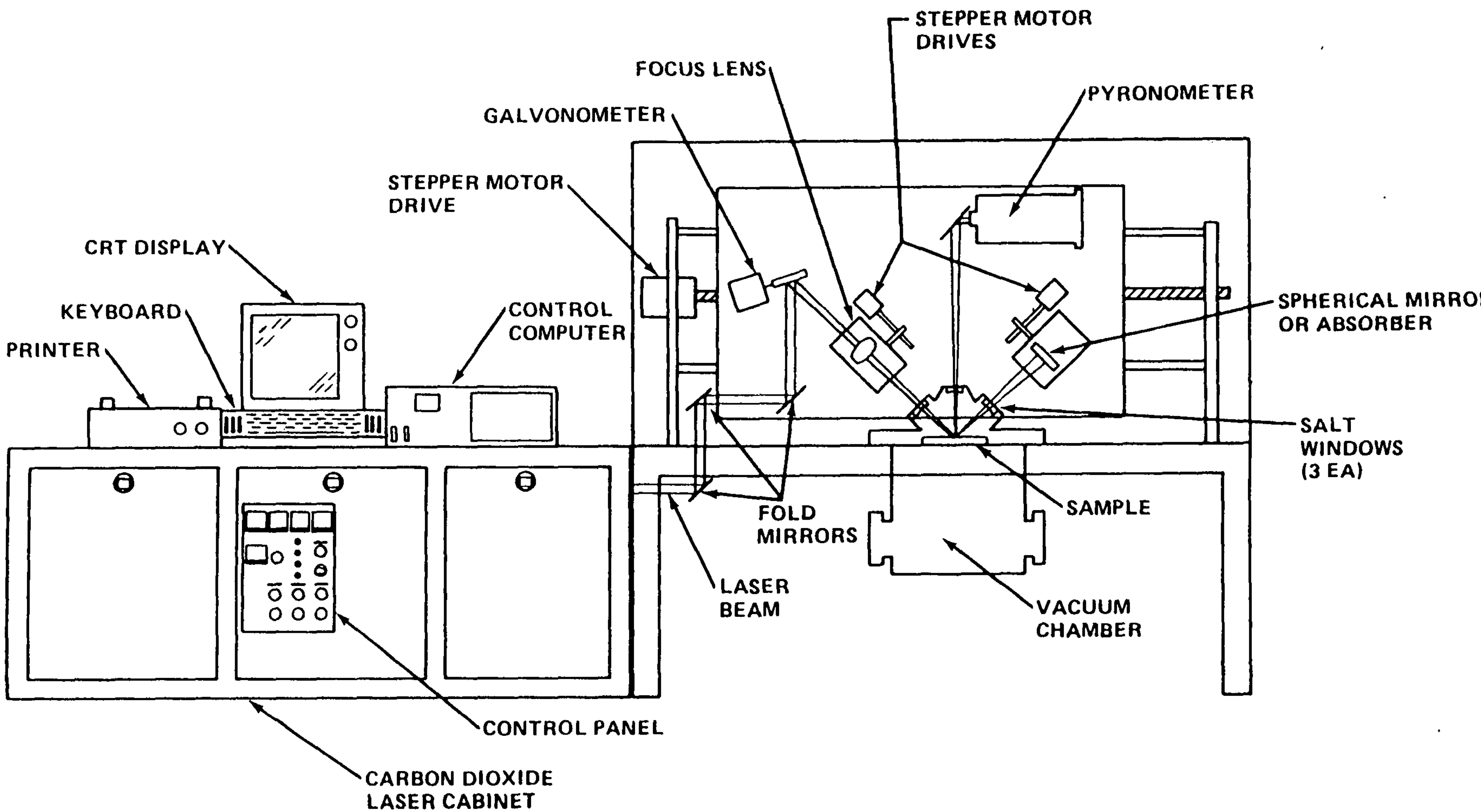


Figure 1. Layout of laser furnace CDDF activity No. 82-26.

1.	LASER	PRC "LASERblade PRoCessor TM" MODEL CL-1-M 85 WATTS CW
2.	COMPUTER	PRC 6809 SPECIAL SYSTEM. FLEX OPERATING SYSTEM, XBASIC MAIN LANGUAGE, 2 5.25 in. D/S D/D DISC DRIVES.
3.	PRINTER	BASE2 INC., MODEL 800
4.	DISPLAY	PANASONIC MODEL NO. TR-120M1P 80 X 24 GREEN SCREEN.
5.	SCAN MIRROR	GENERAL SCANNING MODEL 6115 WITH MODEL AX-200 DRIVE AMPLIFIER.
6.	LENS DRIVE	NORTH AMERICAN PHILIPS CONTROL CORP. AIRPAX SERIES 4SH 12 VOLT 1.8 DEGREE PER STEP.
7.	TRANSLATION .... STAGE	COMPUMOTOR (TM) MODEL m83-135 10,000 STEPS PER REVOLUTION.
8.	PYROMETER..............	IRCON MODLINE TWO COLOR MODEL R16C05

Figure 2. Summary of system components.

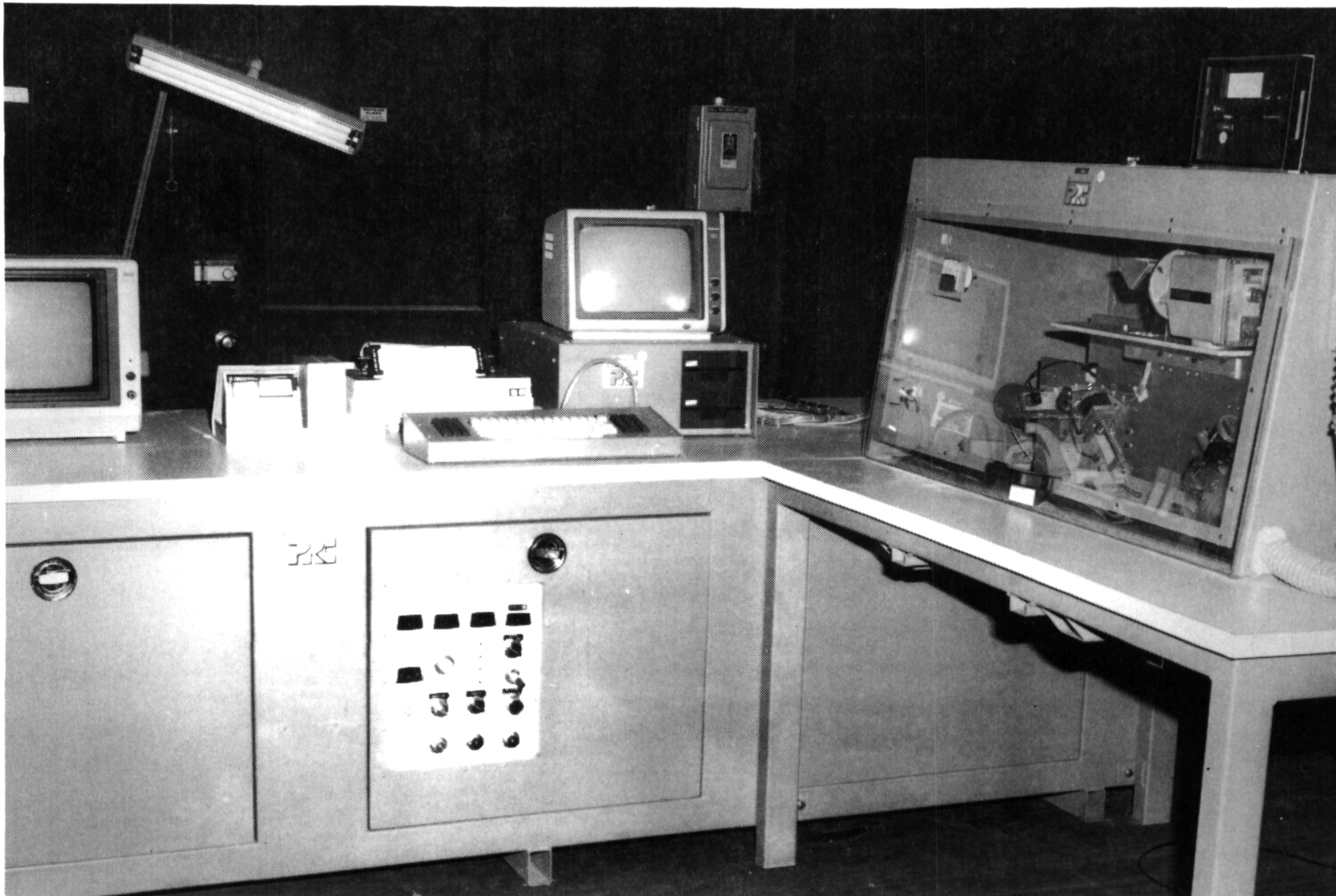


Figure 3. Photograph of complete system.

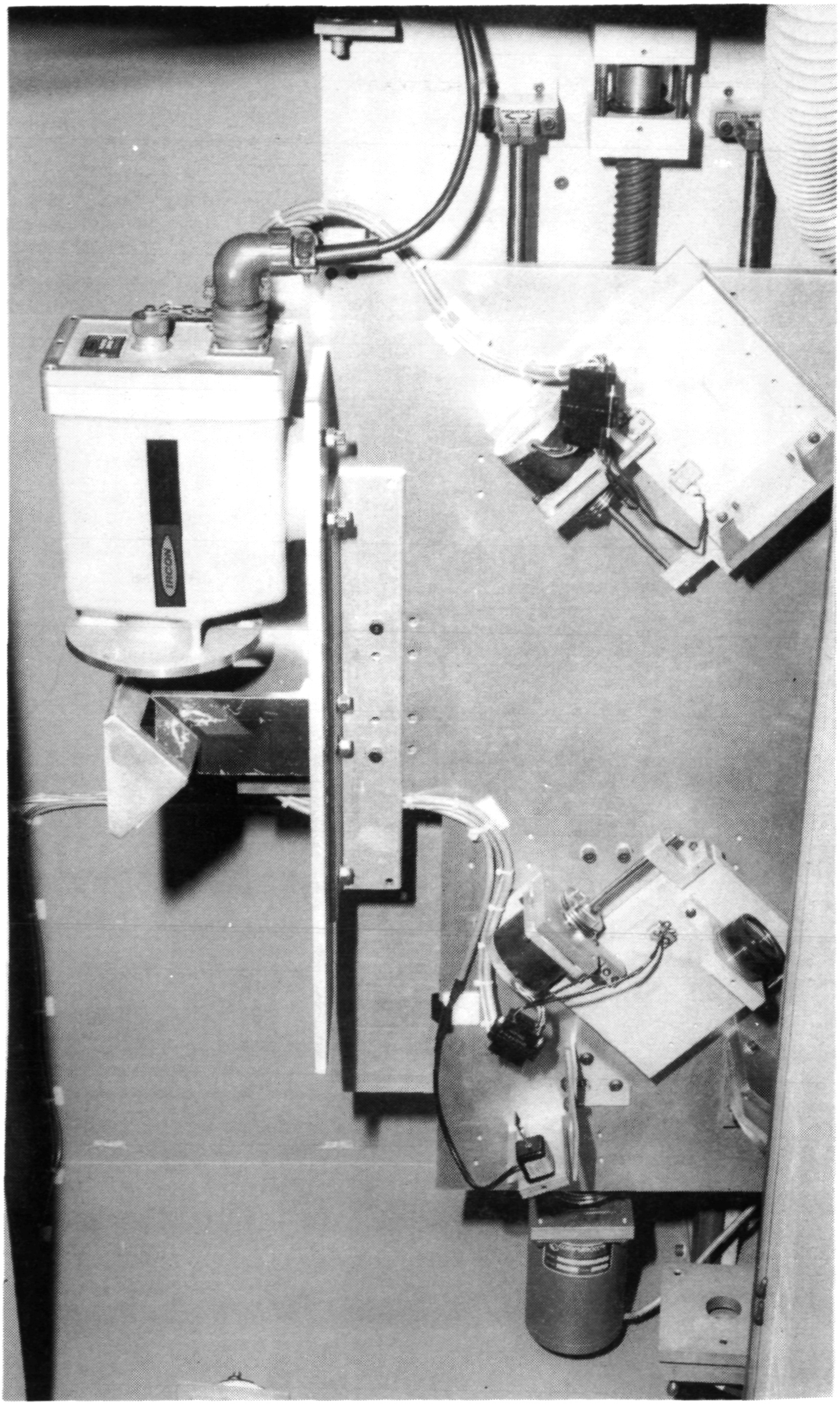


Figure 4. Close up of scan system.

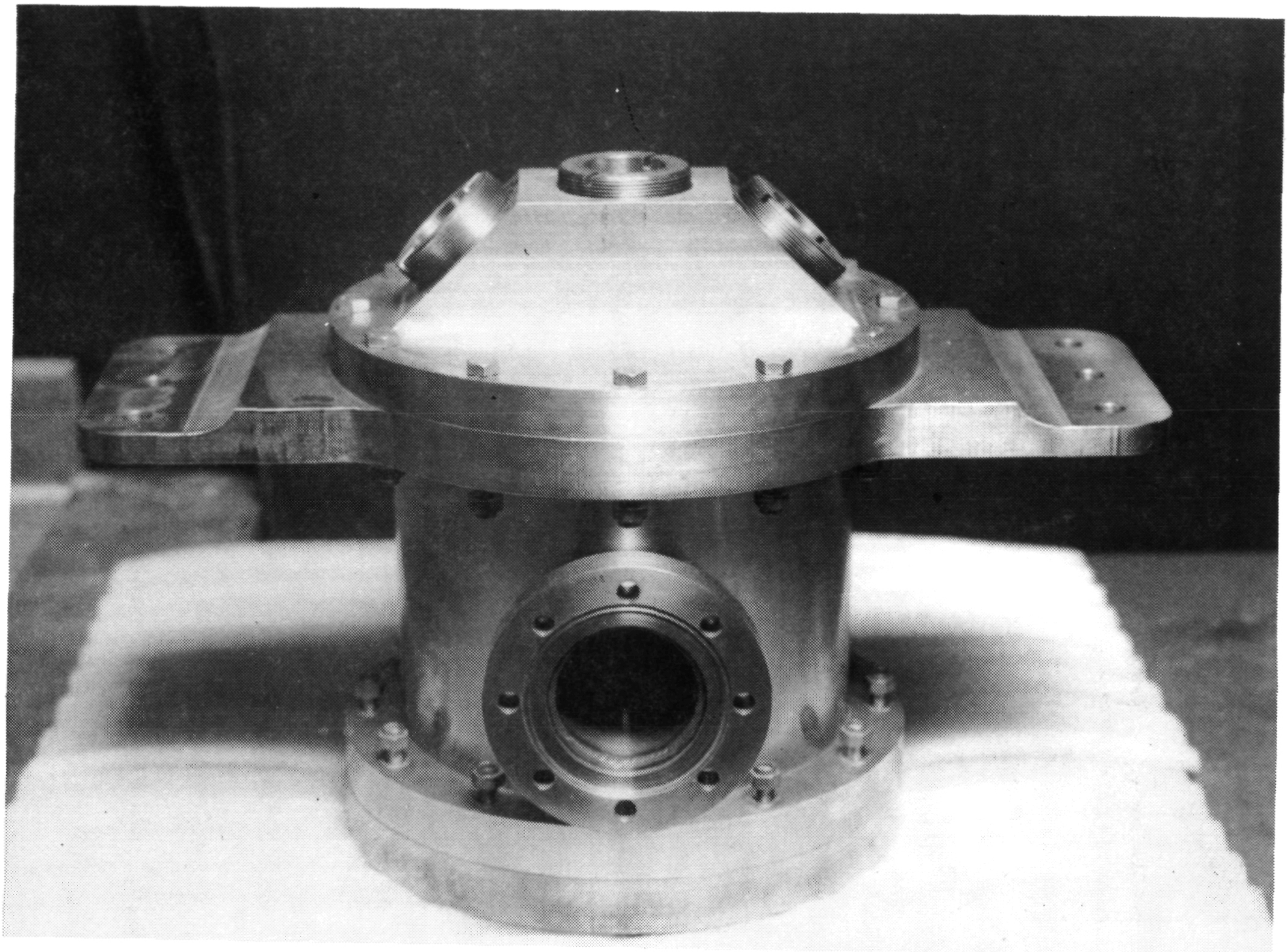


Figure 5. Photograph of vacuum chamber sample holder.

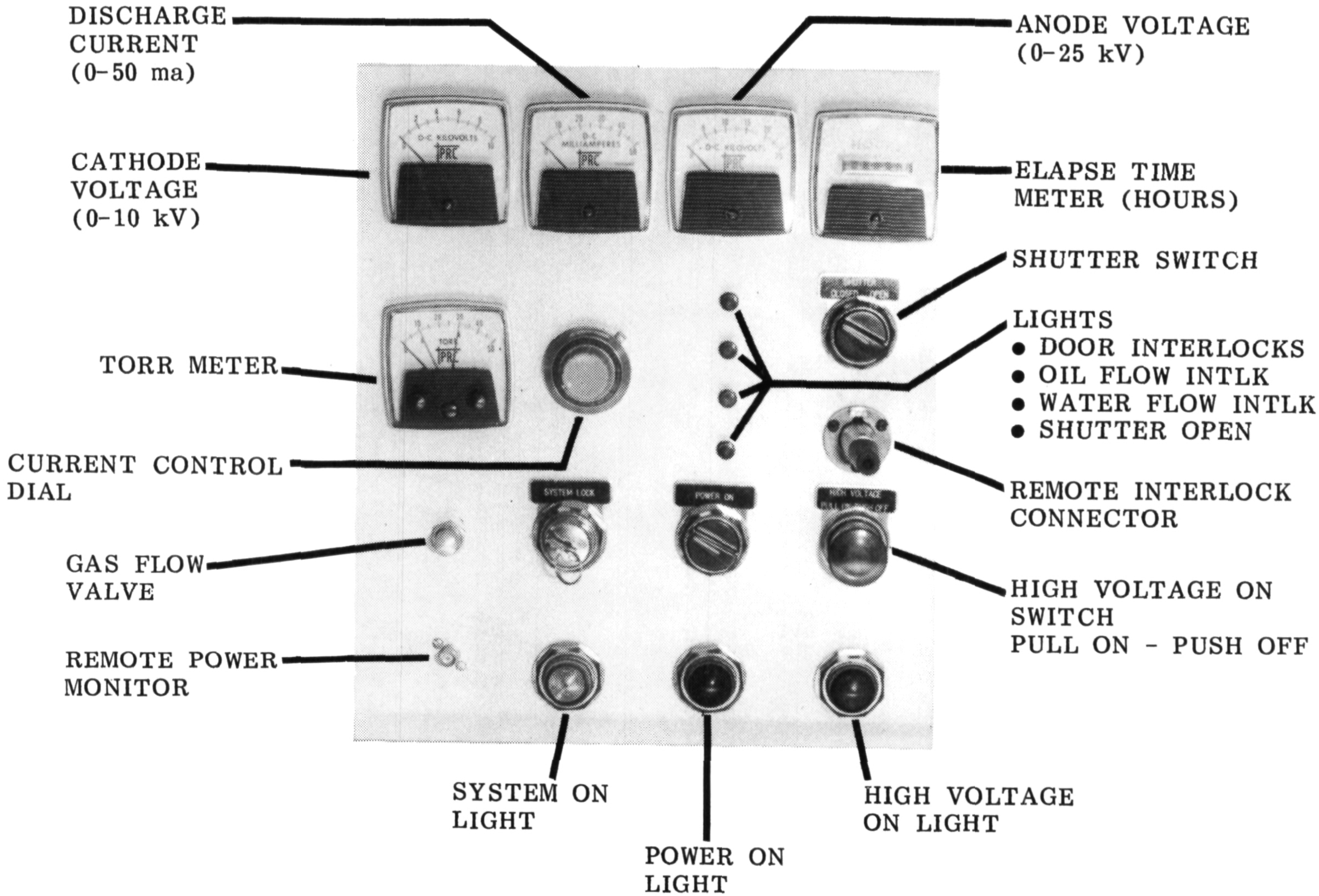


Figure 6. Photograph of control panel.

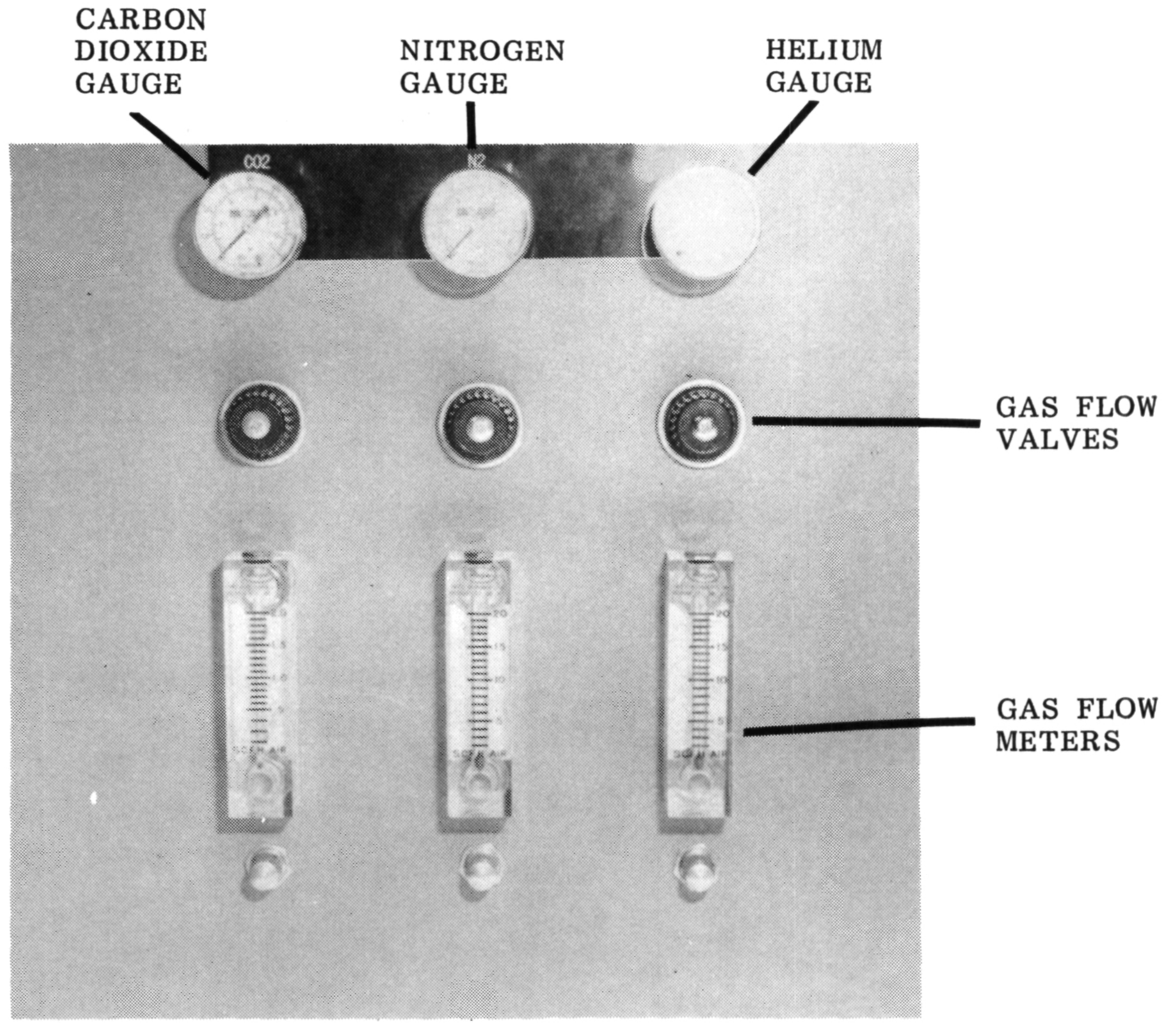


Figure 7. Gas control panel.

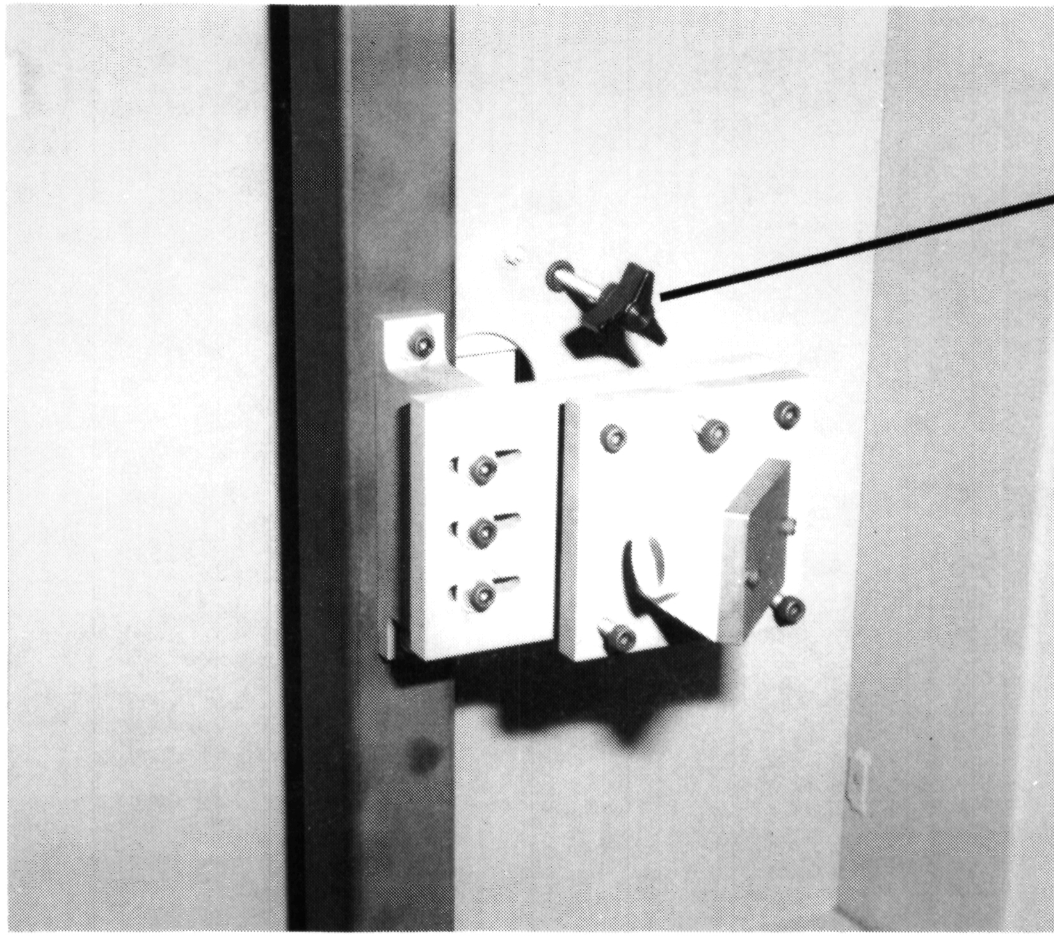


Figure 8. Mirror cavity adjustment.

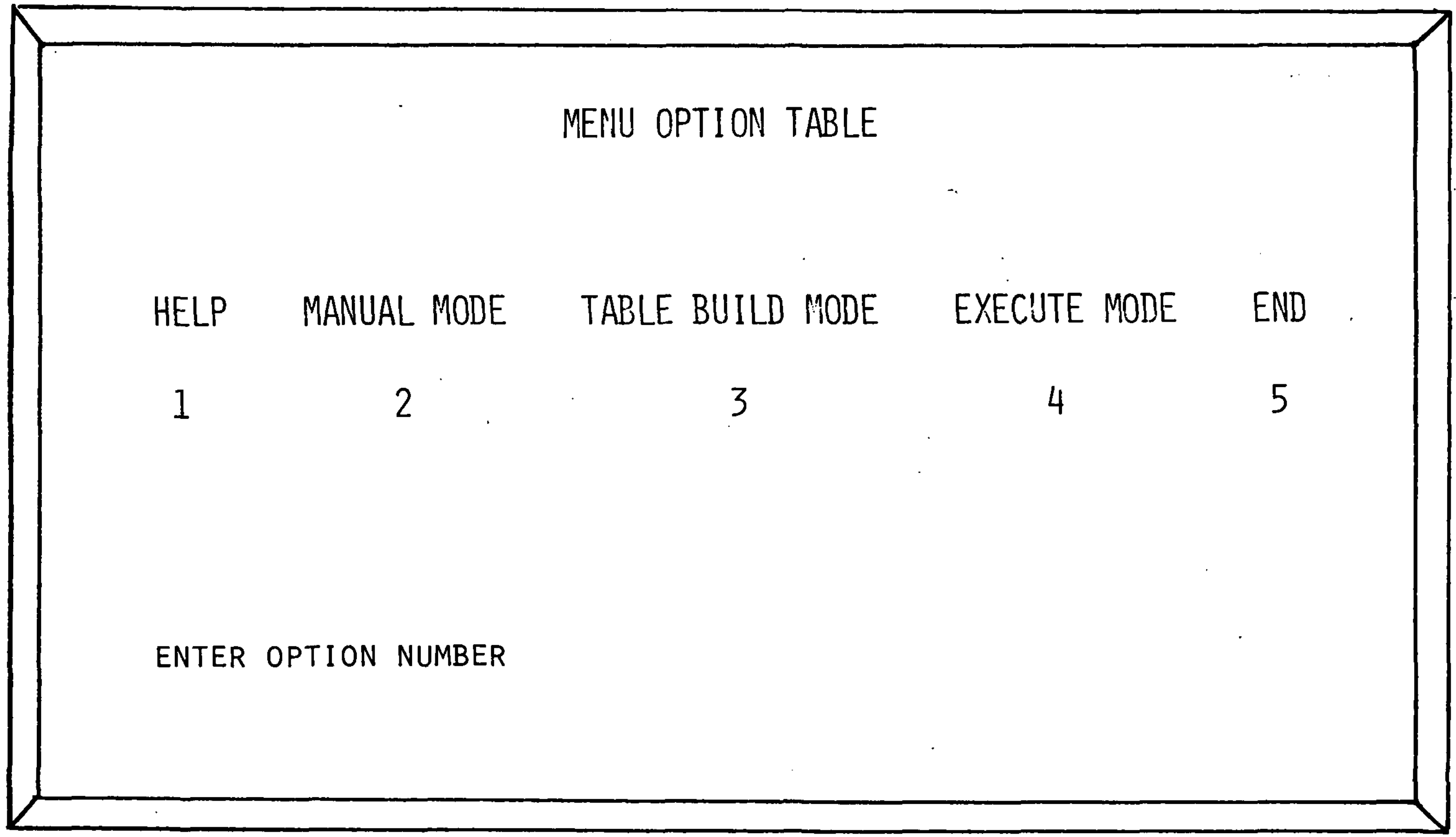


Figure 9. First control program display.

```
RUN TITLE:  lastrun
TIME:
POWER:  0
*******************************************************************
 A) ASSEMBLY STAGE START POSITION ...................... 1.0001
 B) ASSEMBLY STAGE FINAL POSITION....................... 9.0001
 C) ASSEMBLY STAGE VELOCITY ............................ 100
 D) LENS STAGE POSITION ................................ 1.4998
 E) MIRROR STAGE POSITION .............................. 1.4998
 F) PRIMARY SCANNER FREQUENCY .......................... 1000
 G) PRIMARY SCANNER AMPLITUDE .......................... 500
 H) PYROMETER X AXIS FREQUENCY.......................... 1
 I) PYROMETER X AXIS AMPLITUDE.......................... 1
 J) PYROMETER Y AXIS FREQUENCY ......................... 1
 K) PYROMETER Y AXIS AMPLITUDE.......................... 1
 L) INITIAL WAIT FOR MELT ZONE ......................... 32000
 M) NUMBER OF TIMES TO EXECUTE RUN ..................... 1
*******************************************************************
```

Figure 10. Example of data table.

LINEAR STAGE CALIBRATION SPEED CALIBRATION

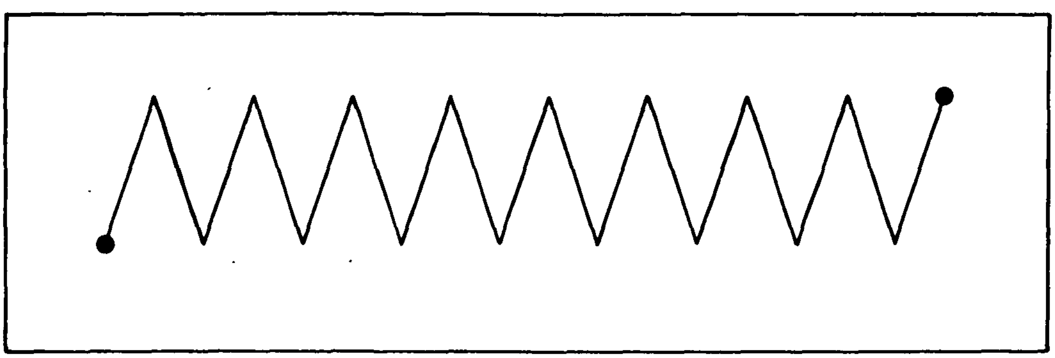
ITEM	VALUE	SPEED MM/SEC
1.	50	5.00
2.	100	2.90
3.	200	1.575
4.	500	0.664
5.	1000	0.338
6.	2000	0.171
7.	5000	0.069
8.	10000	0.034
9.	20000	0.017
10.	32000	0.0108

Figure 11. Table relating main translation table input parameters to table speed.

SCANNER FREQUENCY CALIBRATION

ITEM	VALUE	FREQUENCY (HZ)
1.	10	125.0
2.	20	62.5
3.	30	41.7
4.	40	31.2
5.	50	25.0
6.	60	20.8
7.	70	17.8
8.	80	15.6
9.	90	13.9
10.	100	12.5
11.	1000	1.25
12.	10000	0.125

Figure 12. Table relating scan mirror input parameter to scan frequency.



NOTE: SCAN IS TRIANGLE WAVE TO GIVE EQUAL TIME AT EACH SPOT ON THE SAMPLE. IN ACTUAL OPERATION THE BACK AND FORTH SCAN WOULD APPEAR AS A LINE THAT IS TRANSLATED ALONG THE SAMPLE.

Figure 13. Scan pattern on sample.

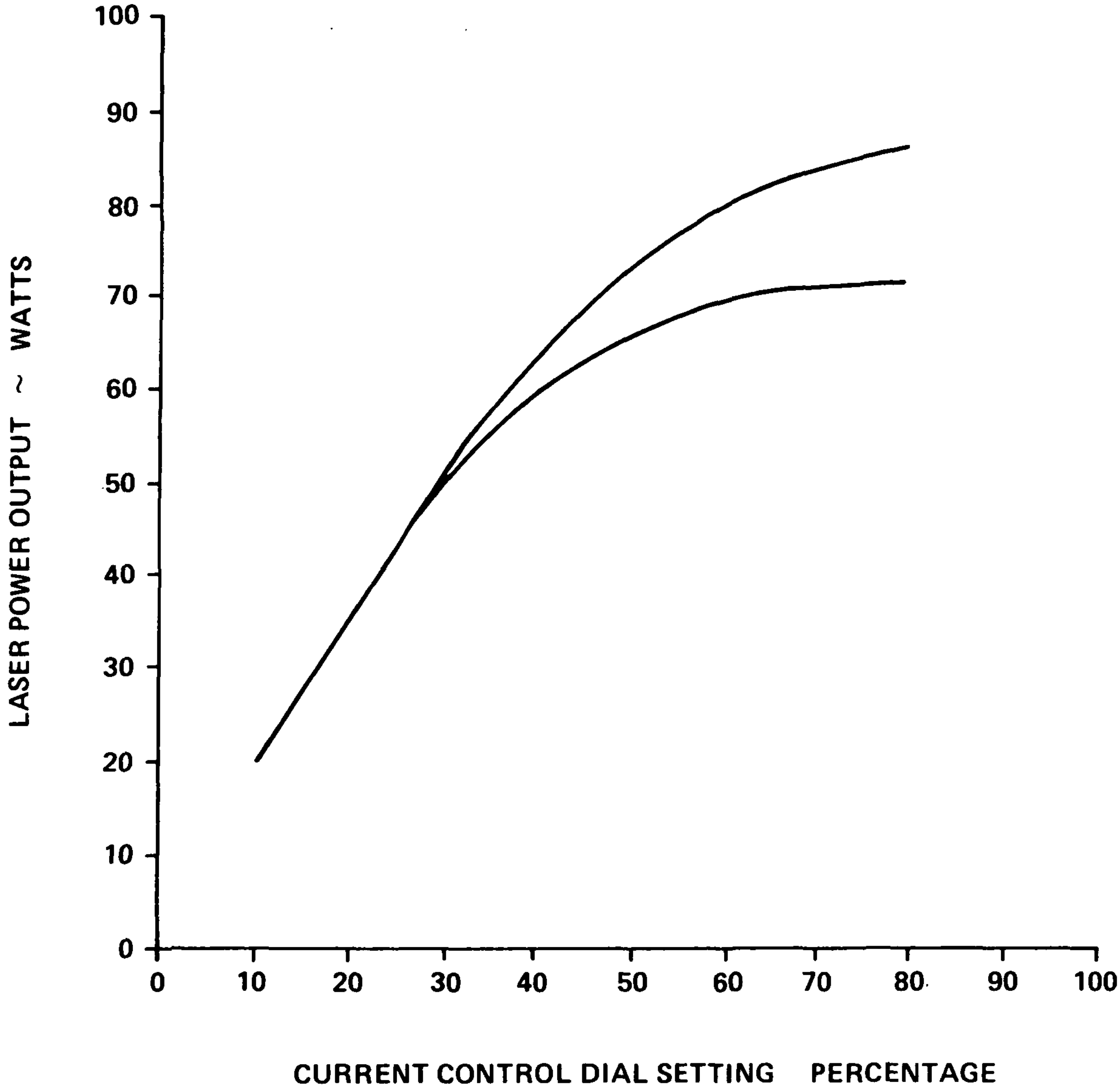


Figure 14. Laser power versus current control dial setting.

APPENDIX A. PROCEDURE TO TURN ON LASER

1. Inspect system to insure interlocks are engaged.

2. Close the wall breaker labelled "PNL. RA RECPT. LEFT".

3. Open the valve on the gas control panel. Inspect the flow meters to insure flow from each cylinder is within the premarked values.

4. Open the valve supplying water to the laser until water flow indicator is turning at a fairly fast rate. This should yield a flow rate of at least three GPM.

5. Turn the key switch (System Lock) to the on position.

6. Turn the power on switch (Power On) to the on position.

7. Watch the Torr meter and after a few seconds the reading should drop down to approximately 22 torr. If the reading does not drop, close the gas valve on the control panel by turning the knob clockwise. This will check the vacuum integrity of the laser. The reading on the torr meter should approach zero. If it does not the gas lines will have to be checked for leaks. During normal operation the parameter arrows on the torr meter are set at fifteen and thirty. The parameter arrows will shut the system down if the pressure exceeds the settings in either direction.

8. When the torr meter is in the correct range the light inside the High Voltage switch will come on indicating all interlock checks have passed.

9. Check to insure the shutter position switch is in the closed position.

10. Check the current control knob. The ten turn potentiometer dial should be less than 80 or greater than 10. A setting of 20 to 30 is recommended for starting.

11. Pull out and then release the High Voltage switch. This momentary switch locks in the high voltage contactor and subsequently initiates high voltage and a controlled discharge in the plasma tube.

WARNING: THE LASER IS NOW IN OPERATION! ! !

12. The laser power meter on the scan system cabinet should be reading some value above 10 watts, indicating the laser is operating.

13. The laser power can be varied at any time by changing dial on the current control knob. The dial should be changed slowly so that the power supply can compensate for the changes in loading. Warning: Do not adjust the dial beyond 80.

14. If the computer does not have the shutter closed the beam can be manually turned on by opening the shutter control switch on the control panel. The computer can override the switch and shut the shutter even though the manual switch is on. For computer control the manual switch must be in the on position.

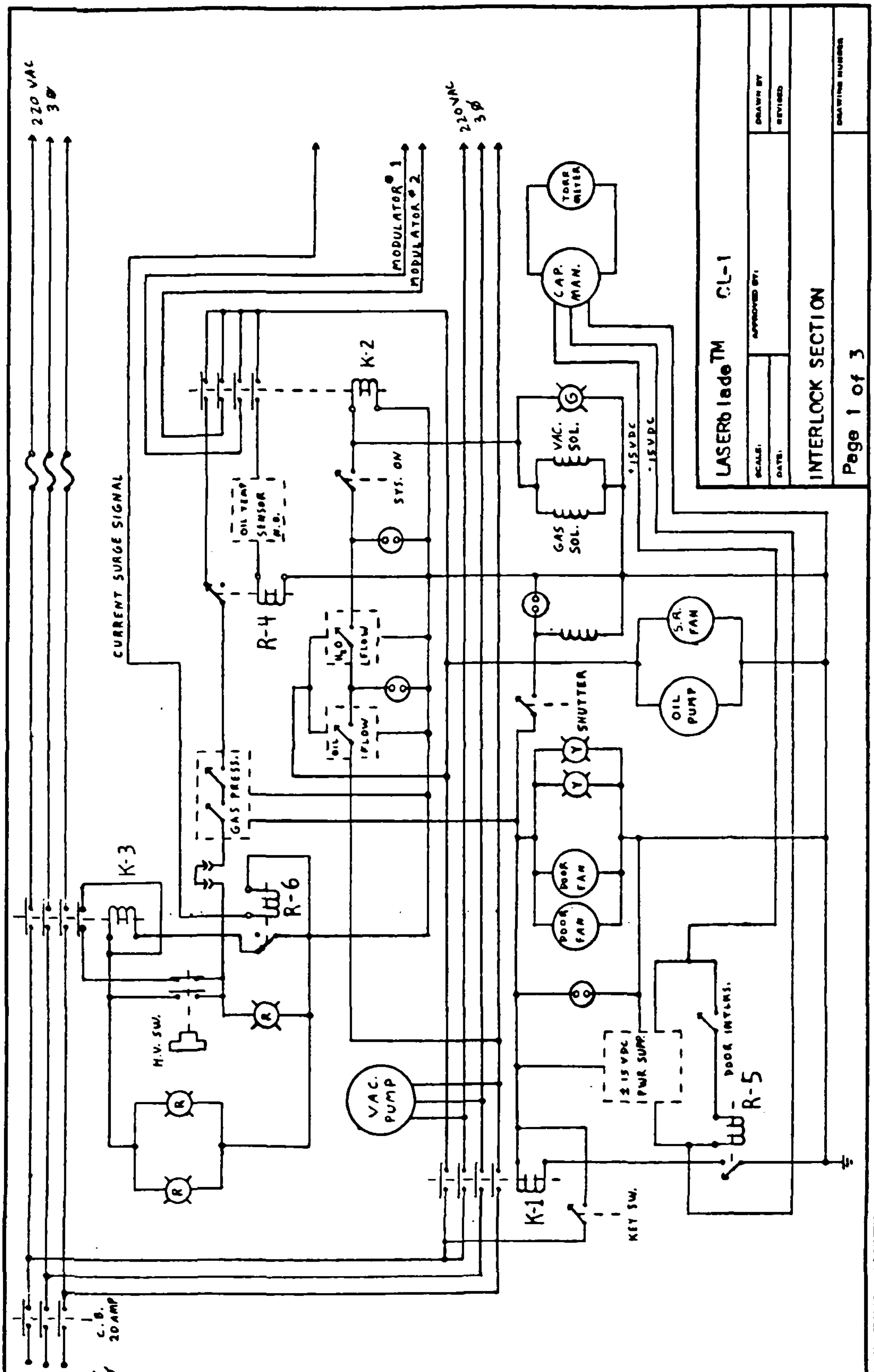
WARNING: THE LASER BEAM CANNOT BE SEEN BY THE EYE.

USE CAUTION WHEN THE SHUTTER IS OPEN.

APPENDIX B. PROCEDURE TO TURN OFF THE LASER.

1. Make sure the shutter is closed.
2. Shut off the high voltage by pushing in on the "High Voltage" switch. The light in the switch should go out indicating power to the laser tube is off.
3. Turn off the "Power On" switch.
4. Turn off the "System Lock" switch.
5. Turn off the laser gas valve.
6. Turn off the water supply to the laser.
7. Open the wall breaker.

APPENDIX C. INTERLOCK CONTROL CIRCUIT



APPENDIX D

CENTER DIRECTORS DISCRETIONARY FUND

FINAL REVIEW REPORT

JUNE 1, 1984

I. TITLE

Advanced Furnace Technology For Materials Processing in Space.

II. MSFC PROJECT NUMBER: 82-26

III. RESPONSIBLE INDIVIDUAL(S)/ORGANIZATION SYMBOL

EB23/D. B. Griner
EB22/W. T. Powers
EP44/J. L. Vaniman

IV. OBJECTIVE:

This effort was to investigate the problems in using lasers to melt and zone refine semiconductors or metal crystals. Emphasis was placed on techniques to control and maximize the absorption of laser power into the sample.

V. NEED FOR THE RESEARCH:

Advanced furnaces for materials processing in space will require unusual temperatures, temperature gradients and zone profiles. Conventional means may or may not be able to achieve the future goals. The use of laser beams to generate and control the gradients around the melt zones may offer unique capability. The main feature is the high degree of control; the beam can be controlled by beam shaping or scan dwell time. The use of lasers in growing and melting semiconductor crystals is new and shows exciting promise. The largest use now is in the growth of silicon ribbons and annealing of wafer surfaces. The need is to gain experience of the techniques and problems in using lasers to heat materials to use the knowledge to aid in designing furnaces for space payloads.

VI. APPROACH:

An experimental work station was designed to provide a capability of investigating the effects of scanning a laser beam on a variety of samples. A variable power carbon dioxide laser was selected because of the high efficiency and the low cost. The one selected can range between 10 and 85 W. A rapid scan system is used to move the focused laser beam to generate a narrow melt zone. A precision stepper motor moves the melt zone along the crystal. The hardware is under computer control to allow flexibility in experimentation. The goal is to investigate the requirements of power, scan dwell time and beam angle of incidence in producing well controlled temperature gradients and melt zones.

VII. PROGRESS:

The facility hardware has been received and installed. The computer software has been generated to control the system. Experiments have been performed on silicon and a nickel based super alloy labelled MARM-246. Melt zones were generated in silicon at a laser power setting of just under 50 W. The laser did not have enough power to melt the nickel crystal.

VIII. PLANNED FUTURE WORK:

An effort will continue to experiment with other semiconductor materials such as germanium, galium arsenide and mercury cadmium telluride. A plan is being laid out to continue the research under a Material Processing in Space Program RTOP. A design effort is underway to plan improvements to the system. The major improvements needed are enhancements to the computer, placing the laser power under computer control and improving the temperature measurement system.

IX. MANPOWER OBLIGATED TO DATE: 0.2 Manyear

X. FUNDING SUMMARY:

FY YEAR	AUTHORIZED	OBLIGATED	COSTED
1983	51.2K	50.0K	50.0K
1984	25.0K	26.2K	26.2K

TOTAL AUTHORIZED: 76.2K
CONTRACTOR: NONE
GRANTS: NONE

APPROVAL

LASER FURNACE TECHNOLOGY FOR ZONE REFINING

MSFC Center Director's Discretionary Fund
Final Report, Project No. 82-26

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

W. C. BRADFORD
Director, Information and Electronic
Systems Laboratory

☆U.S. GOVERNMENT PRINTING OFFICE 1984–746-070/10020