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DEVELOPMENT AND FABRICATION OF A SOLAR CELL JUNCTION PROCESSING SYSTEM

QUARTERLY PROGRESS REPORT NO.8

JANUARY 1982

THE JPL FLAT PLATE SOLAR ARRAY PROJECT IS SPONSORED BY THE U.S. DEPARTMENT OF ENERGY AND FORMS PART OF THE SOLAR PHOTO-VOLTAIC CONVERSION PROGRAM TO INITIATE A MAJOR EFFORT TOWARD THE DEVELOPMENT OF SOLAR ARRAYS. THIS WORK WAS PERFORMED FOR THE JET PROPULSION LABORATORY, CALIFORNIA INSTITUTE OF TECHNOLOGY BY AGREEMENT BETWEEN NASA AND DOE.

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SECTION 1
CONTRACT OBJECTIVES

The basic objectives of the program are the following:

1. To design, develop, construct, and deliver the components of a junction processing system which would be capable of producing solar cell junctions by means of ion implantation followed by pulsed electron beam annealing.

2. To include in the system a wafer transport mechanism capable of transferring 4-inch-diameter wafers into and out of the vacuum chambers where the ion implantation and pulsed electron beam annealing processes take place.

3. To test and demonstrate the system components prior to delivery to JPL along with detailed operating and maintenance manuals.

4. To estimate component lifetimes and costs, as necessary for the contract, for the performance of comprehensive analyses in accordance with the Solar Array Manufacturing Industry Costing Standards (SAMICS).

In achieving these objectives, Spire will perform five tasks:

Task 1 - Pulsed Electron Beam Subsystem Development

Task 2 - Wafer Transport System Development

Task 3 - Ion Implanter Development

Task 4 - Junction Processing System Integration

Task 5 - Junction Processing System Cost Analyses

Under this contract the automated junction formation equipment to be developed involves a new system design incorporating a spire-designed ion implanter with a Spire-developed pulsed electron beam annealer and wafer transport system. Figure 1 presents a conceptual drawing of the junction processing system. When constructed, the ion implanter will deliver a 16 mA beam of $^{31}P^{+}$ ions with a fluence of 2.5×10^{15} ions per square centimeter at an energy of 10 keV. The throughput design goal rate for the junction processor is 10^{7} four-inch-diameter wafers per year.

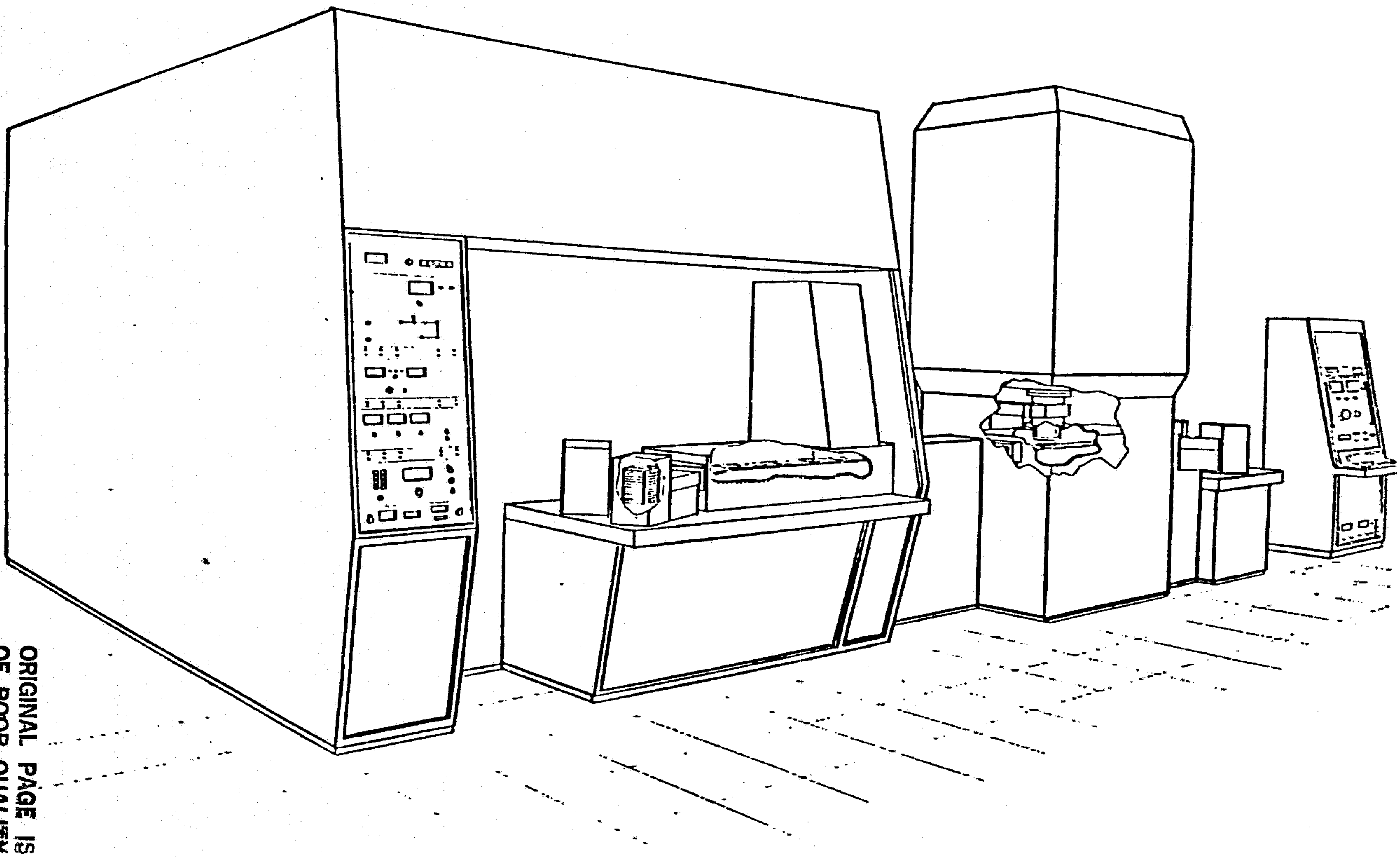

FIGURE 1. SPIRE/JPL JUNCTION PROCESSOR

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At the present time, authorization has been given to perform work only on Tasks 1 through 3. The performance of Tasks 4 and 5 has been deferred until a written "Notice to Proceed" with one or more of these deferred tasks is received from JPL.

SECTION 2
SUMMARY OF WORK PERFORMED

This quarterly report covers work performed during the period 1 October 1981 through 31 December 1981 on Tasks 1 to 3 of the contract for development and fabrication of a solar cell junction processing system. Due to the temporary unavailability of funds during this period, work has consisted largely of maintanence of the electron beam processor and the experimental test unit of the non-mass analyzed (NMA) ion implanter. Some work has been completed toward improving the reliability of the wafer transport system and continuing the diagnosis and understanding of the electron beam. No new technical work has been performed on the ion implanter.

SECTION 3
PROGRESS ON TASKS 1-3

3.1 DEVELOPMENT OF THE PULSED ELECTRON BEAM SUBSYSTEM

3.1.1 Pulser Fabrication

The majority of the work on the electron beam annealer system has been restricted to system upgrades, repair, and maintanence. Figure 2 shows a diagram of the unit for reference. The following items were corrected during this reporting period.

1. The wafer transport was found to unload wafers onto the walking beam track in an unreliable fashion. The step distance between each position in the dispenser was found to be variable due to a rapid deterioration in the oil valves used to sense the dispenser's position. It was concluded that an optical position sensing system would be more consistent over extended usage, and the control mechanisms were altered to suit this change. A small additional electronic interface was also constructed to obviate the need for reprogramming the end stations' local computers. The modification has been found to greatly improve the performance of the transport system.

2. The walking beam transport requires medium velocity motors for operation. The vendor supplied high speed motors with an electronic circuit to slow the speed. If the circuit fails, the resultant high velocity causes considerable damage to the track mechanism. This has occurred on two occasions, and steps have been taken to prevent a recurrence by using lower velocity motors.

3. The current of the magnet used to guide the pulsed electron beam in the annealer has been found difficult to set reproducibly due the nature of the controls on the power supply. Figure 3 shows a calibration curve derived for current based on a precision measurement of output voltage. Since the magnet is liquid cooled and not used near its rated capacity, the use of applied voltage to set the field has been found to be superior to setting the current.

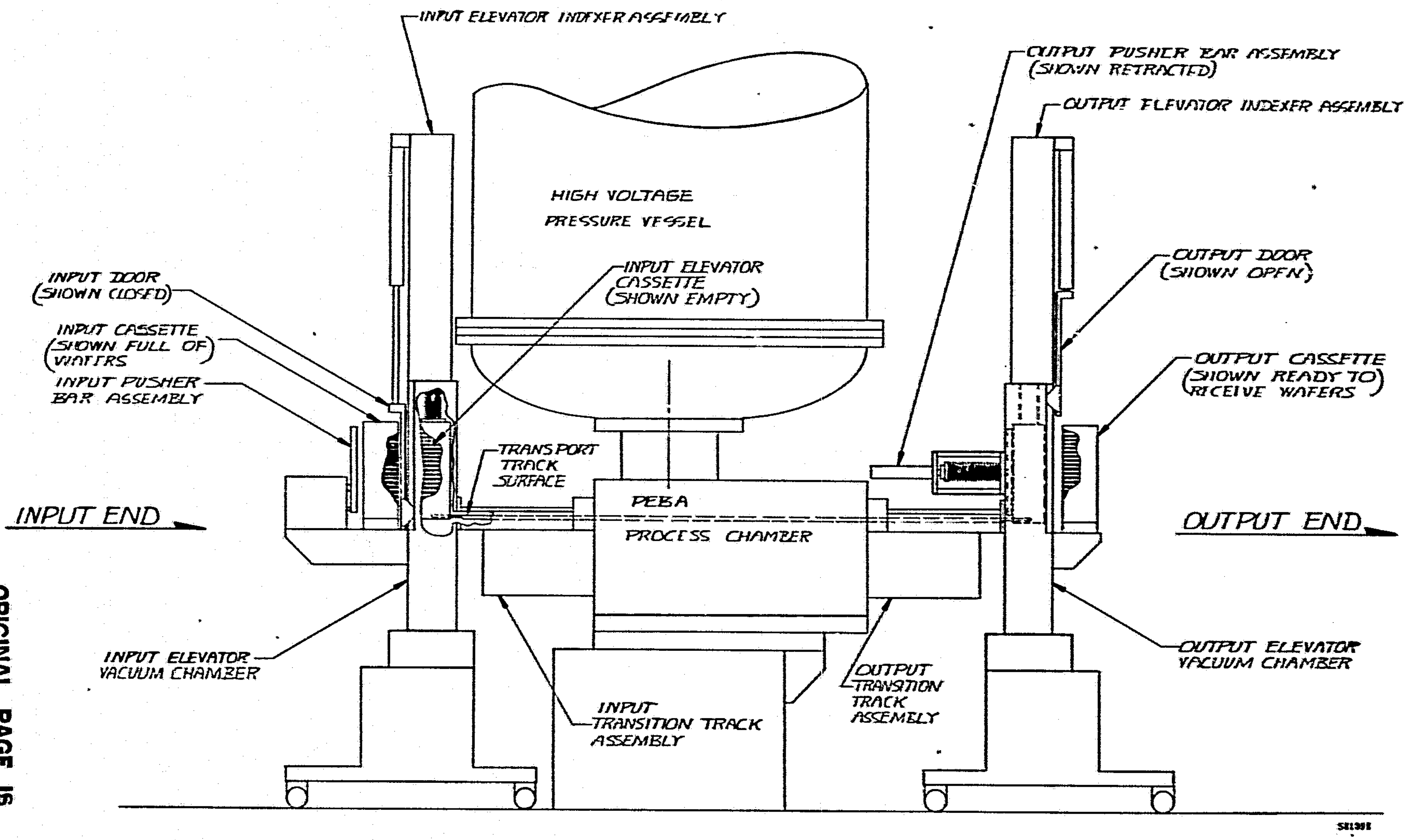

FIGURE 2. PULSER AND TRANSPORT

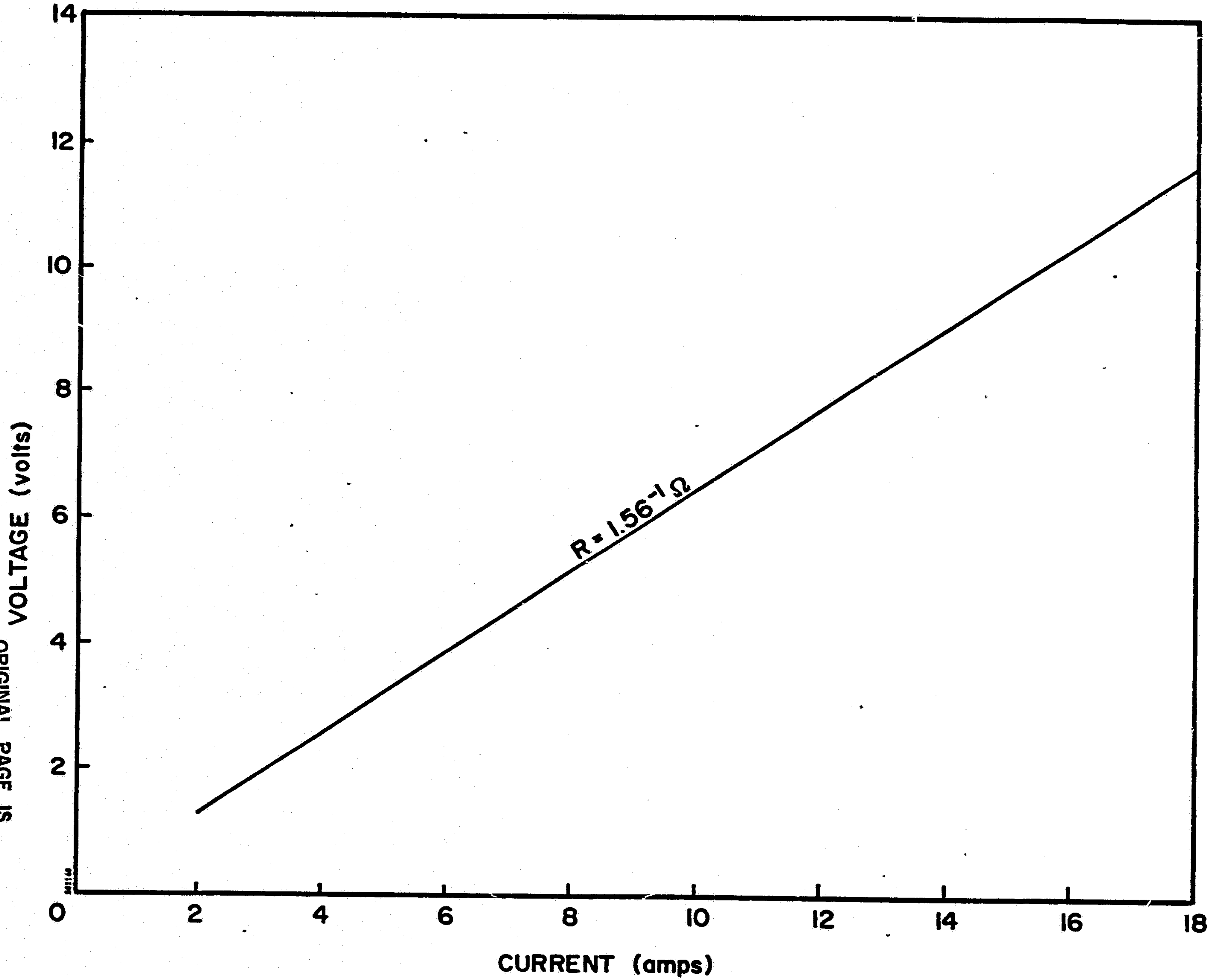

FIGURE 3. MAGNET POWER SUPPLY (Volts vs. Amps)

4. The high voltage cable that joins the 300 kV charging power supply with the annealer's energy storage capacitor bank has failed unexpectedly. The cable has only been used at two thirds of its rated capacity and only for a few thousand operations.

The failure has been traced to a breakdown of the protection resistor which is in series with the cable. When the energy storage capacitors are discharged during the anneal, a ringing oscillation is induced which results in peak voltages in excess of the cable rating. The protection resistor is designed to isolate these oscillations from the cable and high voltage power supply.

The resistor failure occurred in the epoxy insulation and was caused by the existance of a large void. The actual insulation thickness that had been present was less than 3/16 inches, and it is surprising that it withstood as many operations as it had. The void was caused by atmospheric pouring of the resin due to the extremely high viscosity and short curing time of the selected epoxy.

A replacement resistor is presently being fabricated, and special fixtures are being designed to permit vacuum potting despite the technical problems associated with the special epoxy being used.

5. Experiments have been conducted to determine if there exist anode materials with equal performance but longer lifetime than the tungsten mesh currently in use. Copper and nickel were both tested. The copper mesh was damaged rapidly by the energy absorbed from the beam, despite its high thermal conductivity. The nickel nesh was observed to last indefinitely, but the beam propagation was significantly affected. It is speculated that the magnetic properties of the nickel were subtlely altering the electron beam trajectories as the particles passed near the mesh wires.

3.1.2 Pulse Annealing Tests

There are at least seven significant parameters governing the quality, intensity and uniformity of the pulsed electron beam in the annealer. Experience with earlier pulsed annealers has indicated that the desired performance can be attained after sufficient exploration of the parameter space. The previous quarterly report, #7, showed the results of the earliest samples obtained with specific wafers at that time.

Further tests have continued at a low level of effort with a more systematic approach. Figures 4 and 5 show some of the results obtained based on the resultant sheet resistance. Although these wafers appear visually well-annealed, the sheet resistance maps indicate that the center core of the beam contains more energy than the edges. This can usually be corrected by altering the drift distance between the anode and the wafer. Further tests will be made with this parameter variation.

3.2 NON-MASS ANALYZED IMPLANTATION

The halt in funding has prevented further work on the NMA implanter task. The test system used during the successful implants reported in Quarterly Report #7 has been partially dismantled and placed in storage pending reactivation of the program. Unlike the pulsed annealer, the NMA implanter test system requires no continuing maintanence.

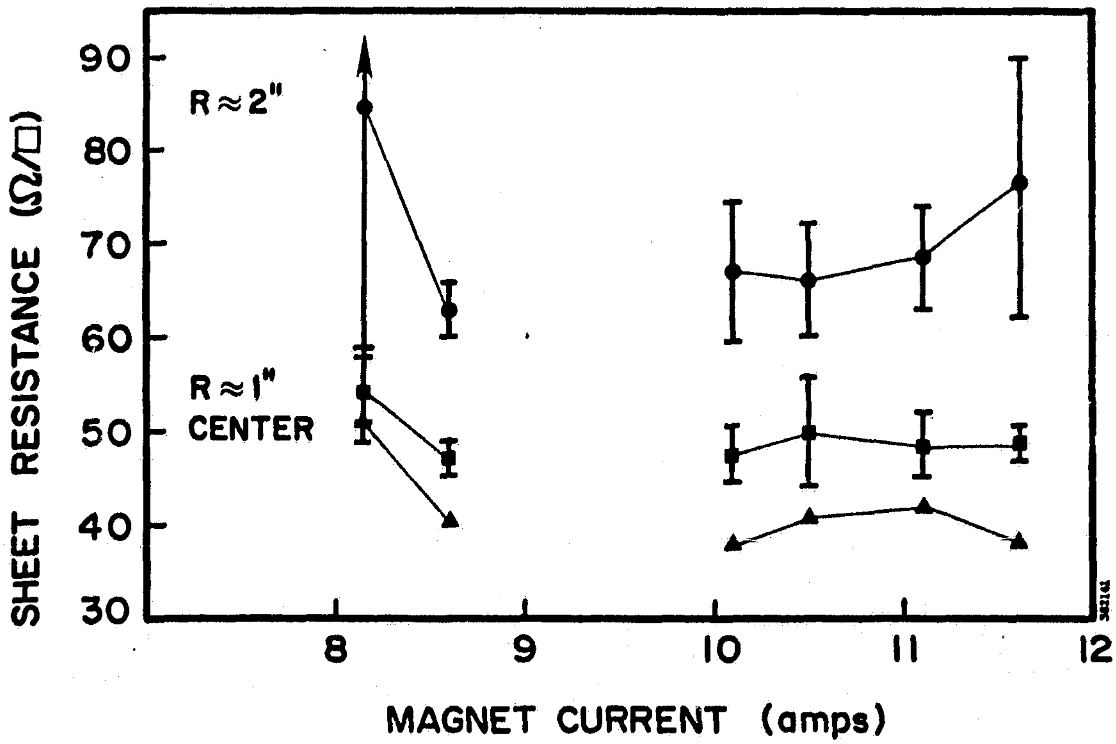

FIGURE 4. ANNEAL UNIFORMITY VERSUS MAGNETIC GUIDE FIELD

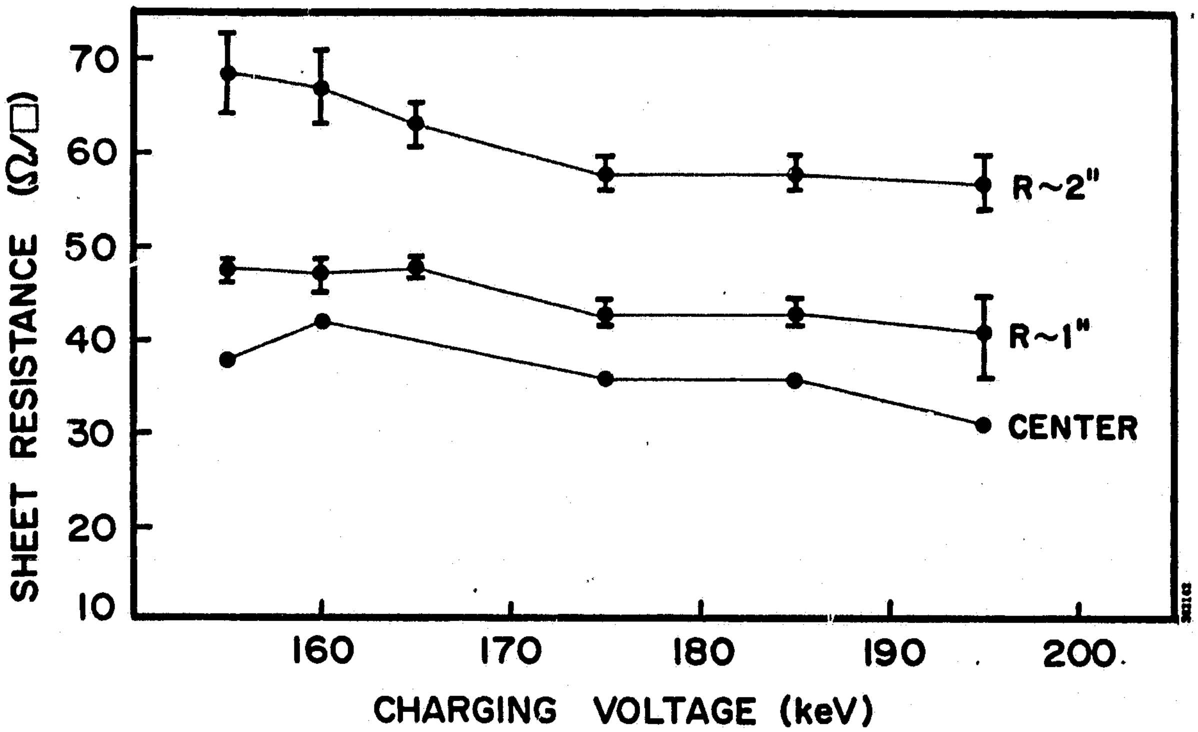

FIGURE 5. ANNEAL UNIFORMITY VERSUS CHARGING VOLTAGE

SECTION 4
SCHEDULE AND FUTURE WORK

The pulser and transport are now complete with the exception of minor tuneups and rework to improve system performance. More work is needed to identify proper conditions for operation of the pulser. The ion implanter task is only just beginning, and at least one further set of beam transport studies is required to provide a complete understanding before committing to the final design. In addition, the highly promising implant results have generated interest to pursue some further studies of implant parameters, particularly implant angle and energy. Figure 6 shows the current schedule for the implanter task pending the receipt of further funding.

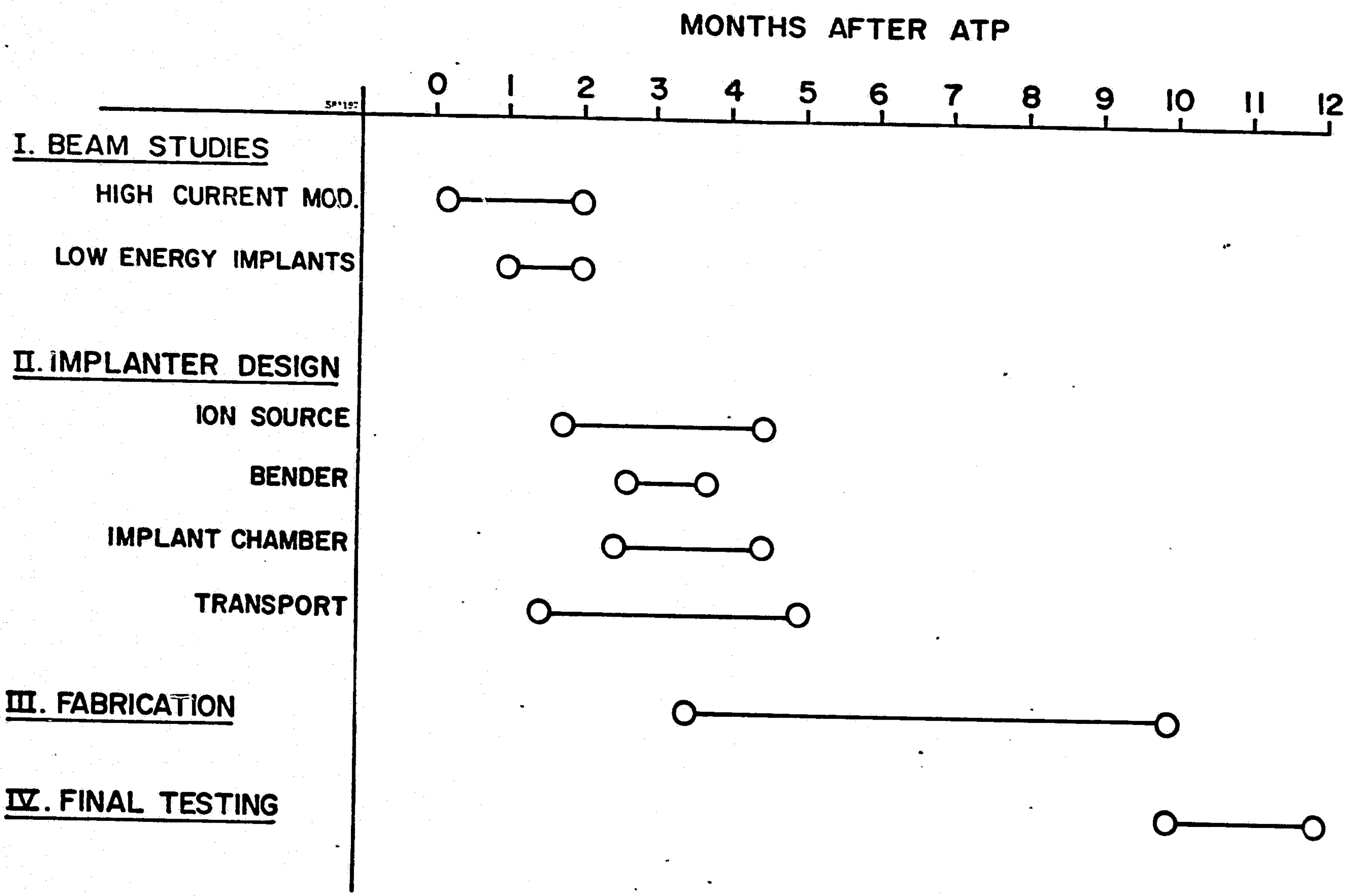

FIGURE 6. TASK 3 – NMA ION IMPLANTER FABRICATION