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DEVELOPMENT AND FABRICATION OF A SOLAR CELL JUNCTION PROCESSING SYSTEM

Quarterly Progress Report No. 3

October 1980

Work Performed Under Contract No. NAS-7-100-955640

Spire Corporation
Bedford, Massachusetts

U.S. Department of Energy

Solar Energy

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Report Number QR-10073-03
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This work was performed for the Jet Propulsion Laboratory, California Institute of Technology sponsored by the National Aeronautics and Space Administration under Contract NAS7-100.

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Project Engineer

Approved by: ______________________
Program Manager

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SECTION 1
CONTRACT OBJECTIVES

The basic objectives of the program are the following:

1. To design, develop, construct and deliver a junction processing system which will 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 chamber where the ion implantation and pulsed electron beam annealing processes take place.
3. To integrate, test and demonstrate the system prior to its 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 modified, government-owned, JPL-controlled ion implanter into a Spire-developed pulsed electron beam annealer and wafer transport system. Figure 1 presents a conceptual drawing of the junction processing system. When modified, 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.

At the present time, authorization has been given to perform work only on Task 1. The performance of Tasks 2, 3, 4 and 5 has been deferred until a written "Notice to Proceed" with one or more of these deferred tasks is received from JPL.

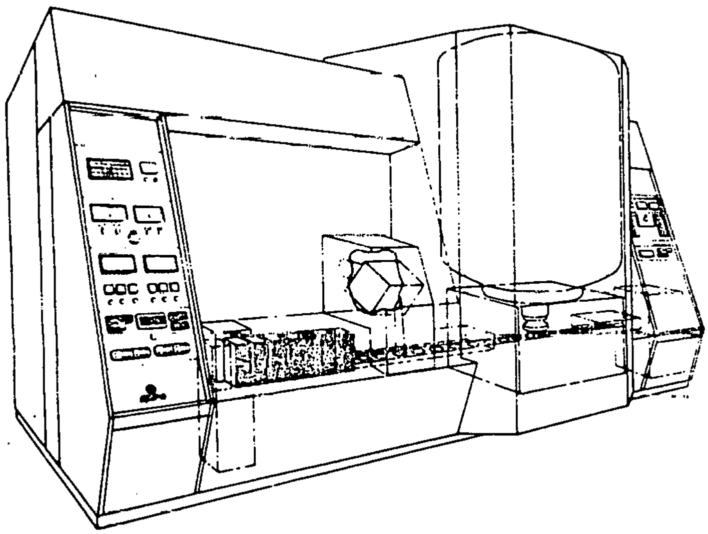

FIGURE 1. SPIRE/JPL JUNCTION PROCESSOR

SECTION 2
SUMMARY OF WORK PERFORMED

2.1 INTRODUCTION

This Quarterly Report covers the period from July 1 through September 30, 1980 for Task 1 of a contract for the development and fabrication of a solar cell junction processing system. The engineering design and major component fabrication efforts are well underway for the development of the pulsed electron beam annealing machine subsystem.

2.2 DEVELOPMENTAL TESTING

During this reporting period there were no scheduled beam control or diode geometry experiments carried out using the existing SPI-PULSE 5000. Tests on the larger 4-inch-diameter beams must wait until the new SPI-PULSE 7000 electron beam subsystem is operational.

Preliminary high voltage bench testing was carried out using a flame-sprayed zinc coated storage line. These tests were performed to evaluate the flame-sprayed zinc metallization technique with regard to liner surface conductivity and voltage standoff characteristics.

Initial testing of the collimating magnet showed pole saturation effects which limited the maximum flux density to half of its design goal of 5000 gauss.

2.3 PULSER DESIGN

The major mechanical engineering design has been completed with minor detail redesign follow-up work being performed as required due to changes in parts procurement substitutions or assembly problems.

Verification of the electronics system control design is awaiting preliminary testing after assembly and integration of the mechanical components.

2.4 PULSER FABRICATION

Major components such as the magnet, pressure vessel, vacuum chamber and energy storage lines are in various stages of fabrication. As subsystem components are received and kitted, subassemblies are being started when these kits are 50 percent complete.

SECTION 3

PROGRESS ON TASK 1 - DEVELOPMENT OF PULSED ELECTRON BEAM SUBSYSTEM

3.1 DEVELOPMENTAL TESTING

In the prototype development program for the pulsed electron beam annealing machine, various mechanical and electrical experiments are being undertaken to verify engineering design and material selections.

3.1.1 Flame-Sprayed Metal Coatings

As a result of evaluations of a metallizing technique using flame-sprayed materials such as aluminum and zinc, it was decided to coat the interior walls of the steel pressure vessel and 5-foot-diameter capacity support plate with a 7 to 10 mil thick zinc coating. The zinc layer will insure corrosion resistance and establish a good electrical ground path. Flame-sprayed aluminum, even though it has higher electrical conductivity, was ruled out due to its loose surface granularity. Mobile aluminum dust contamination is undesirable in the high field stress regions as well as the pressure gasket sealing surfaces.

For reasons of a similar surface granularity as well as a lower application temperature, zinc was chosen as the outer conductor material for the dielectric storage lines. As a further refinement to the metallizing technique, the zinc is now being applied to the liners with an electric arc spray gun. The molten zinc arc is atomized by a high velocity air stream which propels the atomized zinc particles onto the surface of the dielectric line. It was found that a smoother metal to epoxy interface resulted from the electric arc spray when compared to that of the flame spray. With zinc coatings of 5 mils or better, surface resistivities of less than 20 milliohms per square can be achieved with application costs as low as $1.09 per square foot.

Electrical high voltage testing of a prototype zinc coated liner was carried out in a test chamber held at 100 psig of nitrogen. At applied high voltages through 100 kV, no dielectric discharge or surface corona breakdown problems were observed. Further high voltage testing will continue when the matrix of storage lines is installed in the main SPI-PULSE 7000 pressure vessel.

3.1.2 Collimating Magnet

The general design requirements for the SPI-PULSE 7000 electromagnet called for a large conventional C-magnet with an adjustable magnetic field with a maximum flux density of 5000 gauss. In the final testing stages at ANAC, Inc., just prior to shipment to Spire, it was discovered that the maximum flux density saturated at about 2500 gauss.

In early August, engineering modifications were instituted to mitigate this saturation problem. These proposed changes are illustrated in Figure 2. Since the magnet power supply was already received, the replacement coil was specified to conform to the initial full power rating of 50 amperes at 38 volts. The added iron in the modified magnet brought the total weight to 2230 pounds, which then necessitated structural changes to be made in the base support frame.

After these modifications were made, the maximum flux density measured peaked out at 4200 gauss. Since any further modifications would cause an extensive delay in delivery, ANAC, Inc. was authorized to ship the magnet in its present configuration. Anticipated arrival for the magnet subsystem is in late October or early November.

3.2 PULSER FABRICATION

The overall assembly and test schedule for the SPI-PULSE 7000 is diagrammed in Figure 3.

3.2.1 Pressure Vessel, Energy Store Lines and Support Structure

The 4000-pound pressure vessel is being fabricated by Buffalo Tank Company, a division of Bethlehem Steel Corporation. Delays by the Buffalo Tank Company in the vessel delivery schedule are attributed to the consolidation of their operations by shifting the vessel fabrication from the Dunellen, N.J. plant to Buffalo, N.Y. The revised delivery date is now late November. The majority of the hardware for the main frame has been fabricated, and the final assembly schedule has been shifted to accommodate the revised arrival date of the pressure vessel.

The upper and lower support plates for the capacitor stack have been received and have been assembled with the steel tie rods. Completion of this stack is awaiting the production run of the dielectric energy store lines. The manufacturing sequence from right to left for these lines is shown in Figure 4.

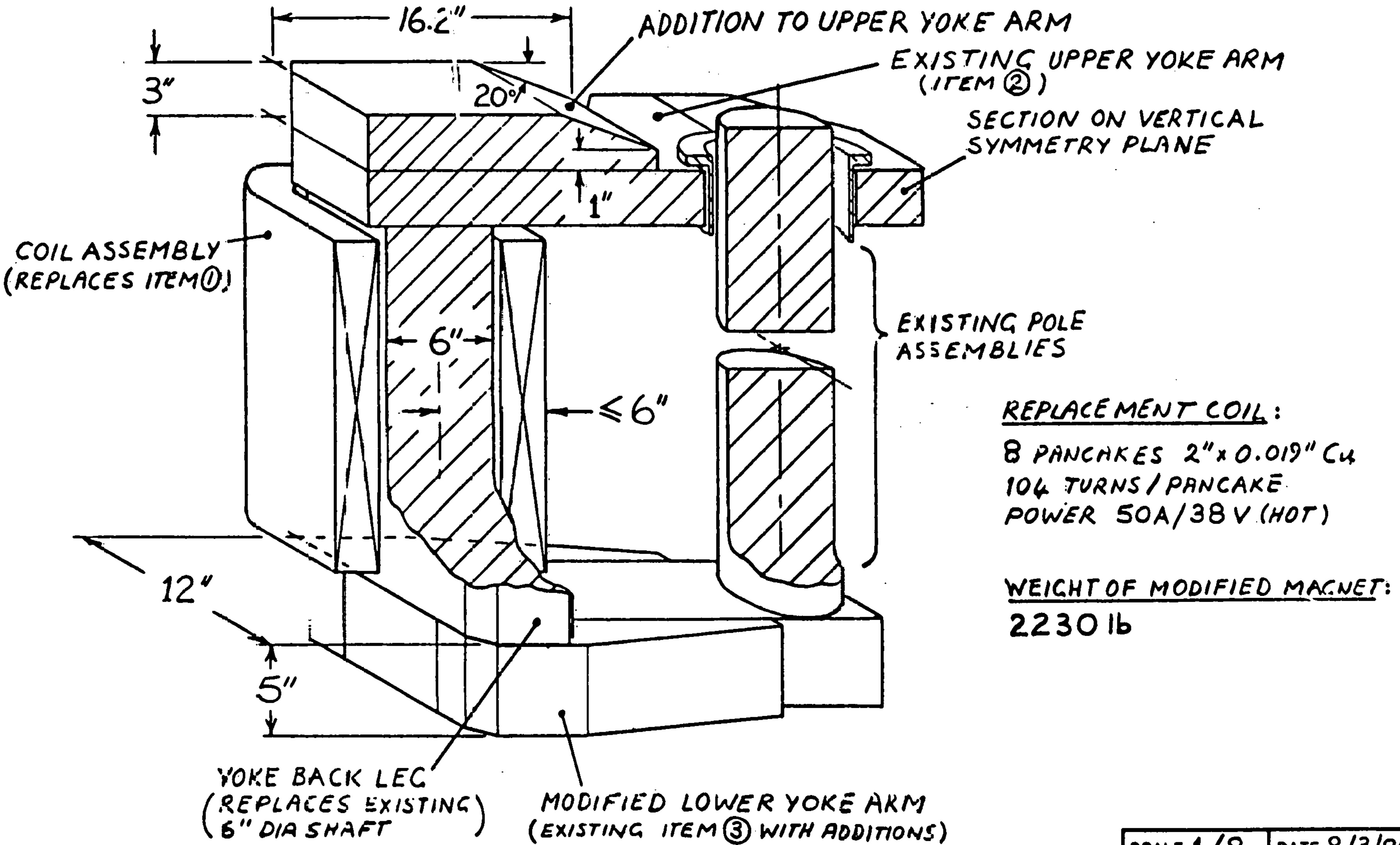

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FIGURE 2. MODIFIED MAGNET

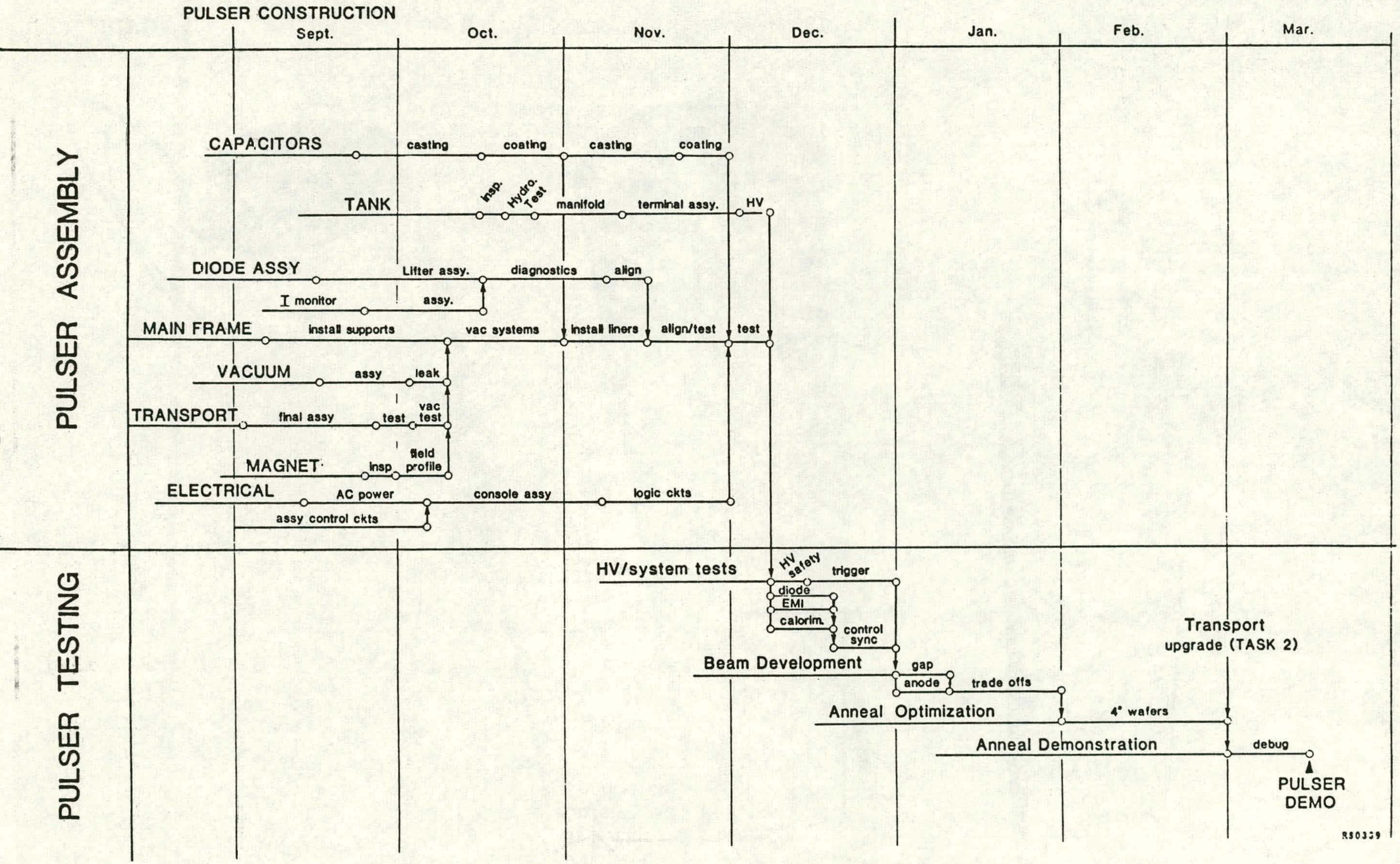

FIGURE 3. SPI-PULSE 7000 ASSEMBLY AND TEST SCHEDULE

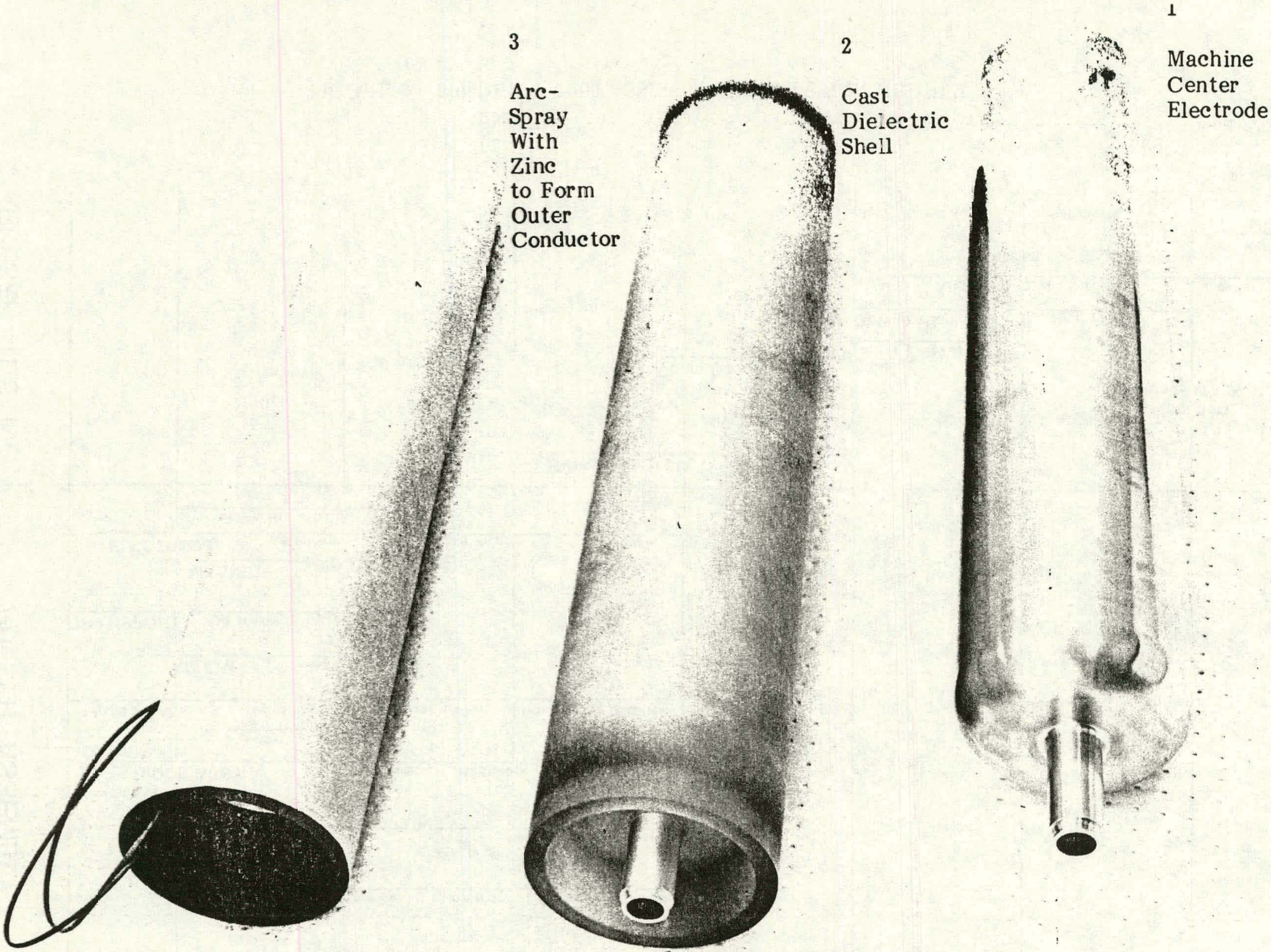

FIGURE 4.

SPI–PULSE 7000 ENERGY STORAGE CAPACITOR-MANUFACTURING SEQUENCE

3.2.2 Interim Wafer-Handling System

The interim wafer-handling system is being fabricated by Brooks Associates, Inc. Delays in the system design and fabrication have extended the delivery to sometime in mid-November. The 6-inch entrance and exit locks, which accommodate 5-inch-diameter by 0.150-inch-thick wafer platens, have been completed along with the track hardware and drive mechanisms. A schematic of the wafer transit path followed during the PEBA process is shown in Figure 5.

3.2.3 Electronic Control

The control console and power distribution center has been completely wired. The trigger control logic has been checked out using the 160 kV power supply in conjunction with a prototype dielectric storage line. The calorimetry electronics have been wired and bench tested. High voltage safety interlocks have been integrated into the overall control circuit design.

3.2.4 Vacuum System

A top view of the aluminum process chamber where the electron beam annealing occurs is depicted schematically in Figure 6. The chamber has been welded and finish machined. Leak testing of the chamber and assembly of the vacuum pumping system will be completed during the month of November.

SPI-PULSE 7000

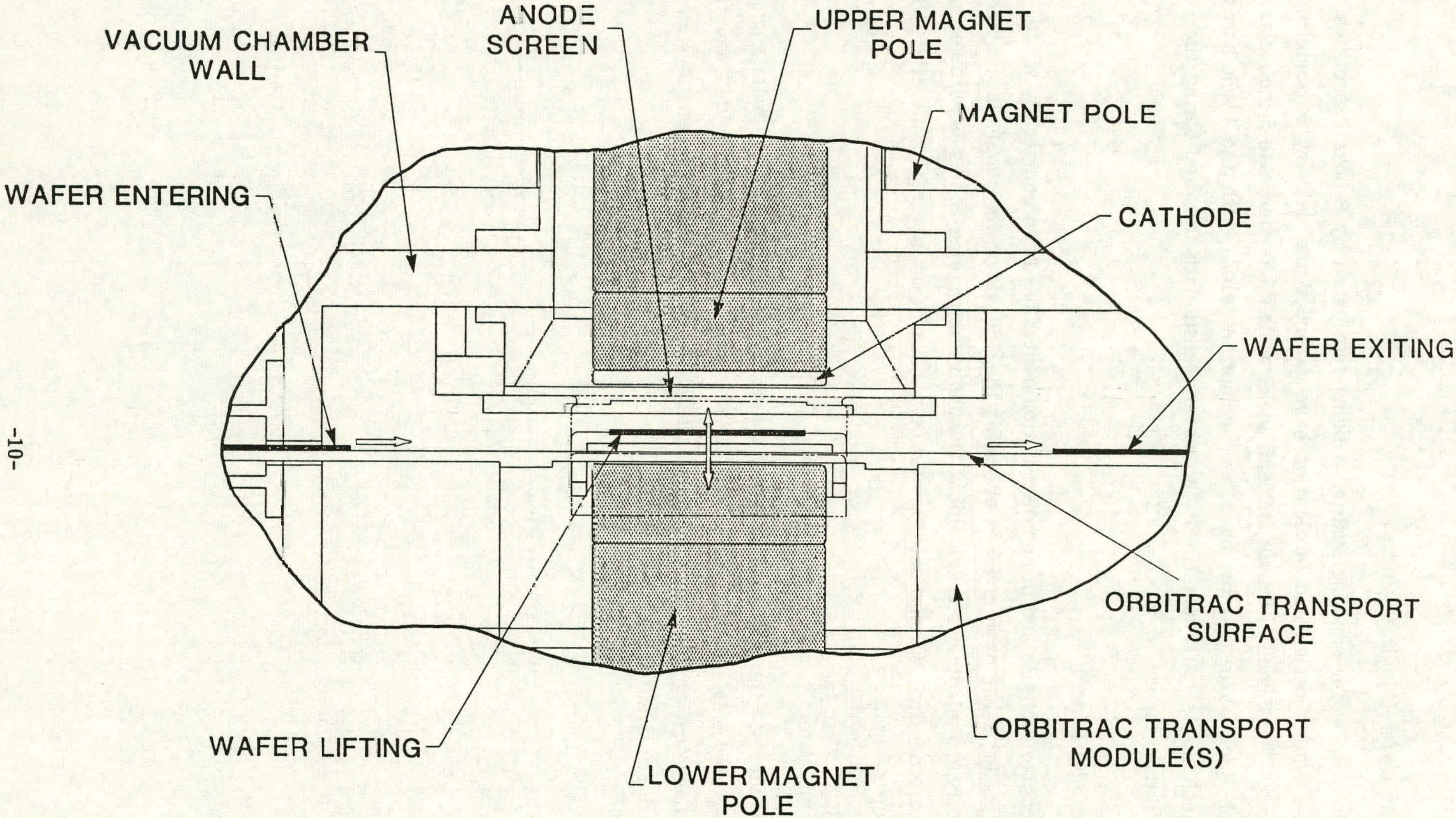

FIGURE 5. WAFER TRANSIT PATH DURING PEBA PROCESS

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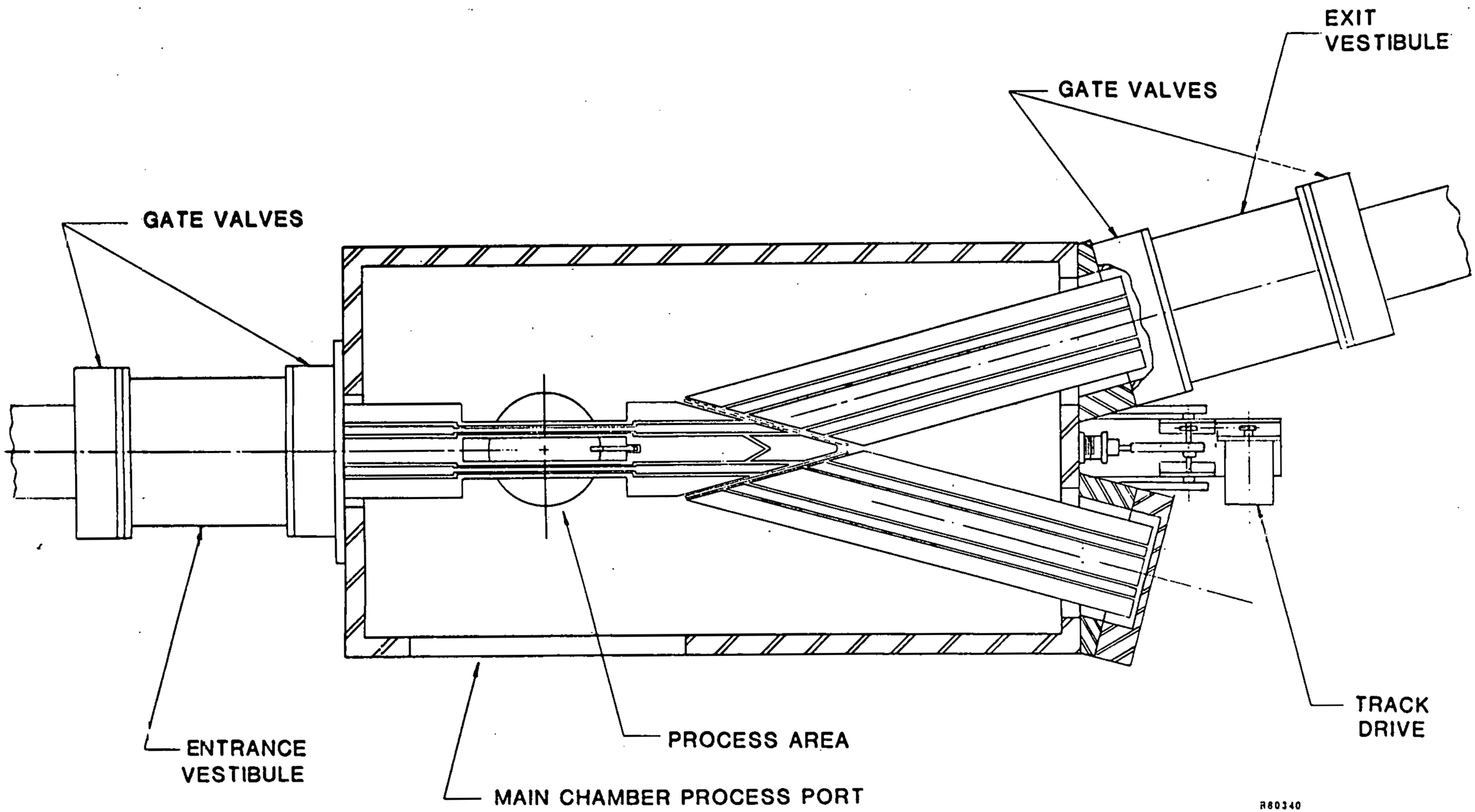

FIGURE 6. PROCESS CHAMBER OF SPI-PULSE 7000 — TOP VIEW

SECTION 4
PLANS

During the next reporting period the overall system assembly, including hardware integration and control electronics, should be accomplished.

SECTION 5
SCHEDULE

Figure 7 shows the projected schedule for Task 1, "Pulsed Electron Beam Subsystem Development".

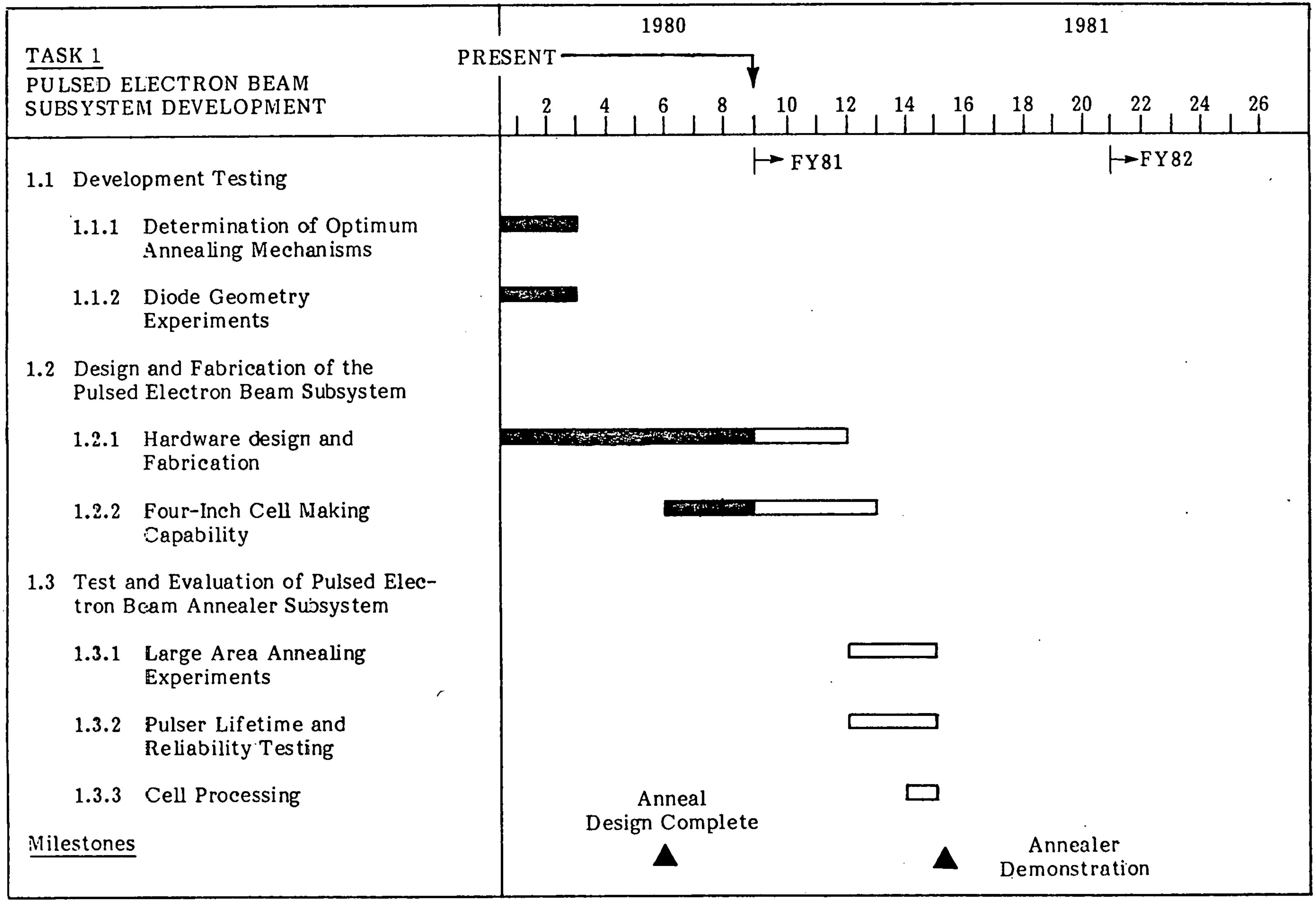

FIGURE 7. TASK 1 SCHEDULE

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