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AUTOMATED SOLAR PANEL ASSEMBLY LINE

LSA Task: Production Processes & Equipment

Quarterly Report No. 2

MASTER

By
H. Somberg

July 8, 1979

Work Performed Under Contract No: NAS-7-100-955278

ARCO Solar, Inc.
Chatsworth, California

U.S. Department of Energy

Solar Energy

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PREPARED BY: H. Somberg

REPORT DATE: July 8, 1979

The JPL Low-Cost Silicon Solar Array Project is sponsored by the U.S. Department of Energy and forms part of the Solar Photovoltaic Conversion Program to initiate a major effort toward the development of low-cost 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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ABSTRACT

The objective of this program is to design, fabricate and demonstrate an automated solar cell module production line with the ultimate goal of reducing module assembly costs.

During this reporting period a redesign of the SCAP soldering mechanism was effected due to temperature/friction problems encountered. The in-line cleaning system was designed and ordered and the Mylar* backbone attachment mechanism was assembled. The SPLP production prototype was fabricated and operated. Two hand-assembled versions of the automated module design completed 750 thermal cycles.

Albuquerque Laboratory, Ardev Inc., is under subcontract to develop the soldering equipment on this program. The lamination development is being done by ARCO Solar, Inc.

*Dupont Trademark

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1.0 SUMMARY

1.1 Introduction

The objective of this program is to design, fabricate and demonstrate an automated solar panel production line with the ultimate goal of reducing module assembly costs.

The principal tasks in this program are 1) the generation of a module design compatible with automated assembly methods, 2) the design and fabrication of automatic soldering equipment capable of interconnecting 12 solar cells/minute, 3) the design and construction of automatic laminating equipment capable of producing 12 modules/hour and 4) operation of an automated pilot line.

The approach used in the design of the solar cell module was to adapt a field-proven encapsulation system to a circuit design compatible with automated assembly.

The major differences between the conventional and automated module are larger cells (100mm vs. 75mm), module size increase to .3m x 1.2m (1 x 4 feet), halving of the encapsulant thickness to 2-.38cm (.015 inch) thick layers of PVB and extruded aluminum side and end channels instead of an enclosed box. The peak power of the module is 33 watts and its NOCT is 47°C.

The approach to solar cell interconnection was to design equipment capable of making series strings from individual cells. The design includes automatic cassette unloading and wafer alignment, ribbon feed and deployment, simultaneous soldering of top and bottom interconnects, in-line removal of soldering flux and attachment of a Mylar strip to each string for dimensional stability and handling.

ARCO Solar uses a superstrate module design to which the circuit is laminated using PVB. Lamination of PVB is accomplished using a "vacuum bag" approach which is integrated with infrared heating into a single system.

1.2 Solar Cell Assembly Prototype (SCAP)

The solar cell assembly prototype (SCAP) machine is designed to receive finished solar cells applied with solder paste and produce series interconnected strings. These strings can then be made into completed module circuits.

The SCAP consists of five elements:

- 1) cassette unloading and wafer alignment
- 2) ribbon feed and deployment
- 3) soldering mechanism
- 4) solder flux removal
- 5) handling strip attachment station

1.2.1

Cassette Unloading

Handling of 100mm diameter solar cell is accomplished through the use of plastic cassettes (25 wafers/cassette) familiar to the semiconductor industry. While multiple cassettes can be loaded or unloaded by a series of loaders, each handling one cassette at a time, this approach proved limiting to the 12 wafer/minute throughput goal of the SCAP. A cassette unloader was designed to handle four cassettes in series by simply stacking the cassettes in a rectangular tube and modifying the drive mechanism so that each cassette would drop out the lower end after its wafers were removed. In this way the cassettes could be easily returned to the solder paste printing and drying operation which is the last step prior to series string interconnection in the SCAP. Future wafer quantity increases in the unloader could be effected by simply extending the tube length for additional cassettes.

1.2.2

Soldering Mechanism

The soldering mechanism consists of two precisely machined and opposing heads that match the solar cell metallization pattern. The heads move vertically to and away from the cell during each machine cycle and heat input is through conduction. Between the relieved pads on each soldering head and holes that provide for adiabatic cooling of the solder connections. The soldering heads are mechanical copper so samples of both bright nickel and nickel sulfamate nickel plating on copper were made and treated to provide a surface that would remain unwetted by solder. The bright nickel plating was .025mm (.001 inches) thick while the nickel sulfamate plating was .051 - .076mm (.002 - .003 inches) thick. In the first test as-plated samples of each type were heated to 205°C (400°F) and a small quantity of solder paste (Sn62 + RMA flux) was applied to each nickel sample. In both cases the nickel readily wet with solder. In a second experiment the nickel samples were heated to 205°C for 16 hours in an air recirculating oven and the wetting test was repeated. In this test the bright nickel again readily wet with solder while the nickel sulfamate plating evidenced less wetting than in the first test. In all tests only a qualitative measure of wetting was determined by a sample spread test.

The continued wetting of the bright nickel is believed to be a result of the incorporated organic brighteners which prevent oxidation or passivation of the basis metal. A third conditioning test was made with nickel sulfamate at 427°C (800°F) for 16 hours and the wetting test was again repeated. In this test no wetting by the solder was observed even after repeated heating and application of solder paste. Additional samples of nickel sulfamate plating on copper were made and similarly conditioned. These samples were equally passive and did not evidence wetting by solder.

As was mentioned earlier, the soldering heads move vertically to and away from wafer during each soldering cycle. A sequencer rotates against each head which provides both heat input and air for cooling. The major difficulty with the rotating mechanism is that of friction generated at the relatively high operating temperature (about 200-220°C). It was determined early that dry lubrication was inadequate and that active (liquid) lubrication would be necessary to minimize wear of the sequencer surface.

The one problem with liquid lubrication is that it could run into the air-chilling ports of the soldering head and onto the solar cell. No satisfactory solution was found without a major modification of the routing of the air ports. While an alternative frictionless design was possible, it was decided to pursue the alternate approach using RF induction heating. Both the wafer alignment and ribbon deployment elements were still in a conceptual design phase so that the transition to induction heating provided some alternative approaches to these mechanisms as well.

1.2.3 Ultrasonic Cleaning

A heated ultrasonic tank 122cm (48 inches) long with a solvent recovery unit was ordered from Deltasonics, Long Beach, California.

1.2.4 Mylar Attachment Mechanism

The handling strip attachment station will apply a thin .076mm (.033 inch) strip of Mylar to the back of each cell in order to provide a dimensionally stable and manageable circuit string. This mechanism will also count and shear each series string at the appropriate length. The Mylar has a thin .025-.05mm (.001 - .002 inch) layer of thermoplastic polyester adhesive which is heat-applied to the back of each cell. Sample hole patterns were made in the Mylar strip to determine the extent of lamination fill around the ribbon and to provide exposed cell areas for direct lamination of PVB to the solar cells. Hole sizes varying from 1.5 - 3.2 mm (.060 - .128 inches) in diameter were made in the Mylar strip which was placed against series strings of 100mm solar cells and laminated. Included in the laminate were solid strips of Mylar. All strips were 2.54cm (1 inch) wide and .076mm (.003 inches) thick. Following lamination each different set of holes was examined and found to have complete filling by the encapsulant. The Mylar bonding mechanism was assembled and the hydraulics connected and tested. The mechanics of operation were tested and adjustments made. A schematic of the bonding station is shown in Figure 1.

BACKBONE BONDING STATION

FIGURE 1

1.3 Solar Panel Lamination Prototype (SPLP)

1.3.1 Production Prototype Lamination System

During this period the production prototype lamination chamber was fabricated, tested and used for production laminations. An end view assembly drawing of the lamination chamber is shown in Figure 2. Two G.E. QH5M-T3 tungsten filament lamps 53 13/16" long are used for heating the laminate. The lamp configuration and uniformity filters are shown in Figure 3. Due to asymmetry in the radiation pattern, strips of aluminum were strategically placed to improve the heating uniformity pattern. The temperatures shown in Figure 3 represent the uniformity achieved and the location of thermocouples used for measurement. The lamps are rated 5KW at 960V, and it was determined that operation at 480V provided rapid heat up to lamination temperature (5-6 minutes to 150°C). According to the manufacturer operation at this lower voltage also results in extended bulb life.

Peel adhesion tests of PVB to glass were made at various points around the perimeter of the laminate as well as in the center. In all areas on 10 different laminates made during a one-week period, peel adhesion values were greater than 14Kg/in width (31 pli).

1.3.2 Carousel Design

Facilities Systems Engineering Corp. (FSEC) was retained under subcontract by ARCO Solar to design a rotating carousel on which nine lamination chambers would be placed. The idea behind a series of rotating chambers was to service all laminating operations from a single service area. A schematic of the carousel is shown in Figure 4. Not shown in the schematic is a small vacuum pump for holding the chambers under vacuum after pumpdown by the larger roughing pump, and a compressor which would provide air for the air cylinders to be used for raising and lowering the top of the lamination chamber.

The carousel rotates about 2 RPH based on a lamination cycle of 30 minutes. The valving and temperature controller for each chamber operates on its own timer so that the chambers are operational independantly of the carousel rotation. A preliminary cost estimate of the carousel was made by FSEC at \$56,000 excluding chamber costs which amounted to \$20,000. In going out for bid to qualified fabricators the estimate to build the carousel rose to \$93,000 and about \$20,000 of this figure was associated with add-on electrical equipment such as over-temperature visual and audio alarms. It was then decided to eliminate the carousel approach in deference to the LSA goals since the costs for building the carousel could not be justified in automation. The alternative is to place lamination chambers on stationary tables in a circular fashion and move part of the production area associated with lamination into this circular area to minimize traffic.

FIGURE 2

1- 149°C 5- 145°C
 2- 152°C 6- 151°C
 3- 145°C 7- 154°C
 4- 152°C

FIGURE 3

Lamp Arrangement
and Uniformity

FIGURE 4

1.4

Module Testing

Two hand assembled versions of the 16-2000 automated module design completed 750 thermal cycles from -40°C to $+90^{\circ}\text{C}$ without any significant physical changes. A 1-1.5% decrease in power was measured for the two modules.

2.0

Results and Discussion

During this quarter a redesign of the soldering mechanism was effected to incorporate induction heating. The ultrasonic cleaning system was ordered and Mylar backbone bonding station was assembled. The first production lamination chamber was assembled and operated successfully. Two hand-assembled versions of the automated module design successfully completed 750 thermal cycles.

3.0

Future Plans

During the next quarter breadboard testing of the soldering mechanism, wafer alignment and ribbon deployment will be conducted. A stationary design for the lamination system will be made and chambers ordered. Lamination of production modules will be performed and environmental testing will continue.

PLANNING SCHEDULE

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