(NASA-CR-169206) AUTOMATED SOLAR PANEL ASSEMBLY LINE Final Report (ARCO Solar, Inc., Chatsworth, Calif.) 101 p HC A06/MF A01 CSCL 10A

N82-29723

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AUTOMATED SOLAR PANEL ASSEMBLY LINE

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CHATSWORTH, CALIFORNIA 91311

FINAL REPORT - MAY 1981

PREPARED UNDER CONTRACT NO. 955278

FOR

JET PROPULSION LABORATORY

CALIFORNIA INSTITUTE OF TECHNOLOGY

PASADENA, CALIFORNIA 91103

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, under NASA Contract NAS7-100.

ACKNOWLEDGEMENTS

This report is the result of a two-year effort to develop automated module assembly equipment. The author gratefully acknowledges the following ARCO Solar employees for their contribution to this program.

PETER ASCHENBRENNER
JOHN DOUGHERTY
PAT GALLAGHER
BILL HAWLEY
GREG JONES
DICK KEENAN
DOMINIC SICOLI
DON WILKES
RAGNHIL WHITT

John W. Behm was the technical program monitor for JPL

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I. SUMMARY

This report contains the results of a two-year effort to design, develop and operate automated equipment for the interconnection of solar cells and lamination of cell circuits into modules. The overall objective was to effect near-term reduction of silicon solar cell array costs so as to achieve the 1986 goal of $0.70/W*.

The program consisted of four sections: 1) design of a module that lends itself to automated assembly, 2) design and development of prototype equipment for the interconnection and lamination of solar cells into a completed module, 3) the operation of a pilot production line using the equipment developed in this program, and 4) perform a cost analysis of the production run.

This program was originally proposed as a 12 month effort. However, because of the complexity of the soldering equipment task the program was extended to 27 months. In late 1979, a prototype element of the soldering machine was implemented into the module production operation. This section of the machine consisted of a roller transport mechanism integrated with an electromagnetic induction coil** for soldering continuous ribbon interconnects to the front of solar cells. In a fashion, it was the first step in the mechanization of soldering or "tabbing" solar cells, and this simple mechanism has reliably tabbed about 1.8 million solar cells to date.

In mid-1980, the lamination system began operation in ARCO Solar's automated solar panel facility in Camarillo, California. This

* All costs in this report are given in 1980 dollars.

** The automated soldering machine was subssequently redesigned to use an infrared heat source.

prototype system has produced PV modules representing in excess of one megawatt. The pilot production line operation integrating the completed soldering and lamination equipment was successfully conducted in April 1981.

The following achievements were made on this program:

- a lamination system capable of producing 20 modules/hour
- a soldering machine capable of interconnecting 900 cells/hour
- *a cost reduction of approximately 40% in module materials and labor

* Final SAMICS Format 'A's in this report have not been run. The

II. INTRODUCTION

The objective of this program was to effect near-term cost reduction in the assembly of solar cell arrays through development of automated module assembly equipment. The specific tasks were to: 1) design a solar cell module that facilitates automated fabrication, 2) design and develop automated solar cell soldering and laminating equipment, and 3) operate a pilot production line with the developed equipment and achieve the following:

- solder interconnects - 12 cells/minute
- laminate modules - 12 modules/hour
- reduce module assembly and material costs to \$0.67/W based on the following assumptions:

total estimated module cost -	\$2.24/W (ref.)
finished estimated solar cell cost -	\$1.57/W (ref.)
net module assembly/materials cost -	\$0.67/W (goal)*

The initial stage of the program was devoted to concept development and proof of approach through simple experimental verification. In this phase, laboratory bench models were built to demonstrate and verify concepts. Following this phase was machine design and integration of the various machine elements. The third phase was machine assembly and debugging. In this phase, the various elements were operated as a unit and modifications were made as required. The final stage of development was the demonstration of the equipment in a pilot production operation.

* Assembly cost goal includes realized yields and is based on assumed annual production rate of 1.0 megawatts.

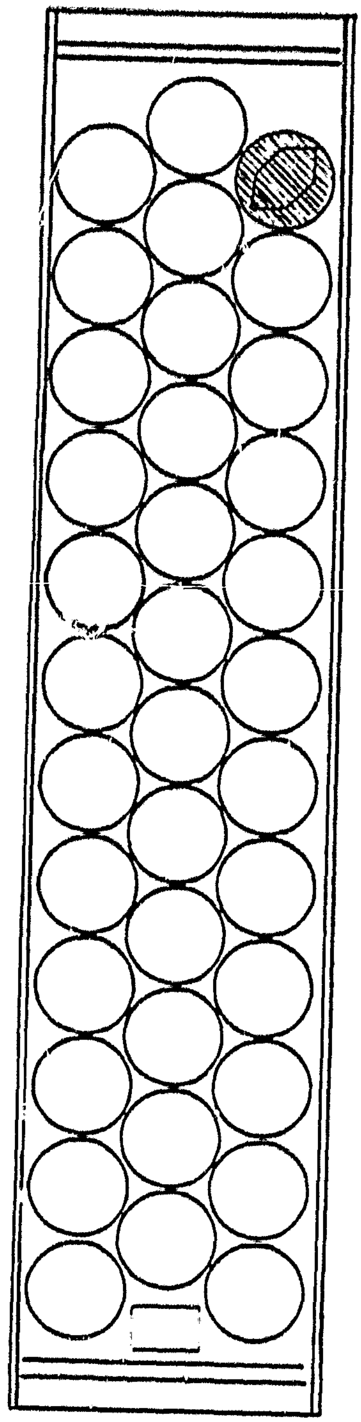
III. MODULE DESIGN

A. APPROACH TO AUTOMATED DESIGN

The origin of module size and configuration in the terrestrial photovoltaic market arose from battery charging requirements. In essence, charging 12 VDC batteries requires a PV module with 33-35 solar cells connected in series to produce 14-15 VDC. Modules typically used 75-100 mm (3-4 inch) diameter cells producing 1-2 ADC so that most modules had a single series string, or 3-4 strings side-by-side for purposes of providing a module of a manageable length and width.

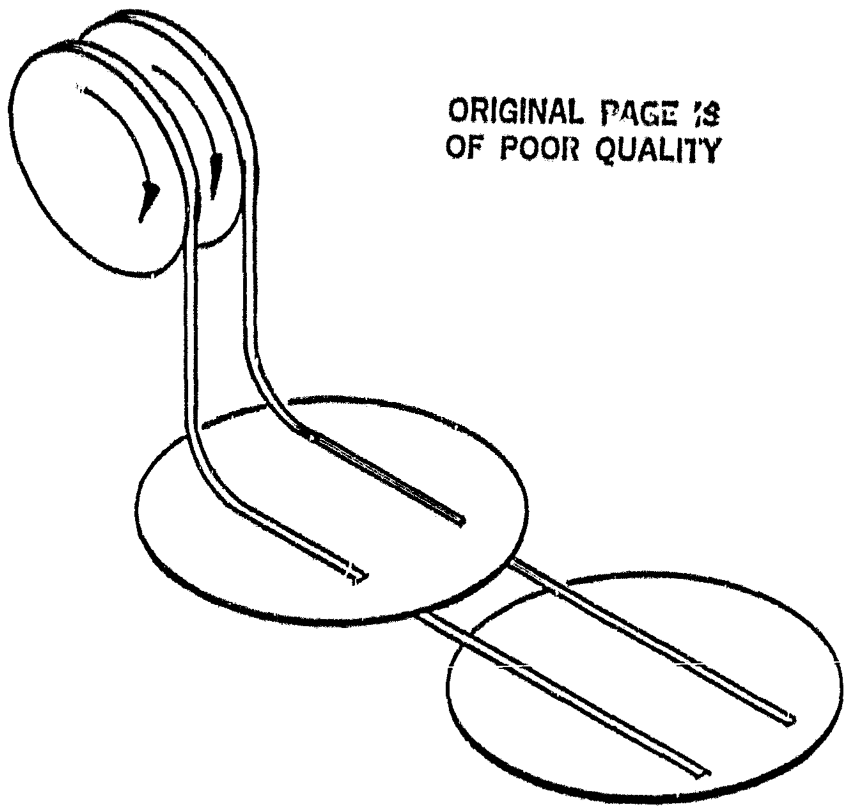
Early ARCO Solar designs used a rectangular shaped circuit of 3 strings (75 mm cells nested side-by-side for space efficiency) of series-connected solar cells as shown in Figure 1. This module was used in the LSA Block III procurement.

In early 1979, the LSA Block IV module design contracts were awarded and it was this design that was developed with automated assembly as its theme. Photovoltaic (PV) applications were still tied to battery charging at this time so ARCO Solar elected to develop automated interconnection of simple series strings. The two distinct advantages to this approach are: 1) the form of simple reels of ribbon interconnects available, and 2) the opportunity to provide redundancy and enhance reliability of the circuit. These features are illustrated in Figures 2 and 3. It was determined at this early stage that future circuit configurations requiring parallel and series combinations could be simply handled by taking multiple series strings



ARCO Solar BLOCK III MODULE·CONFIGURATION

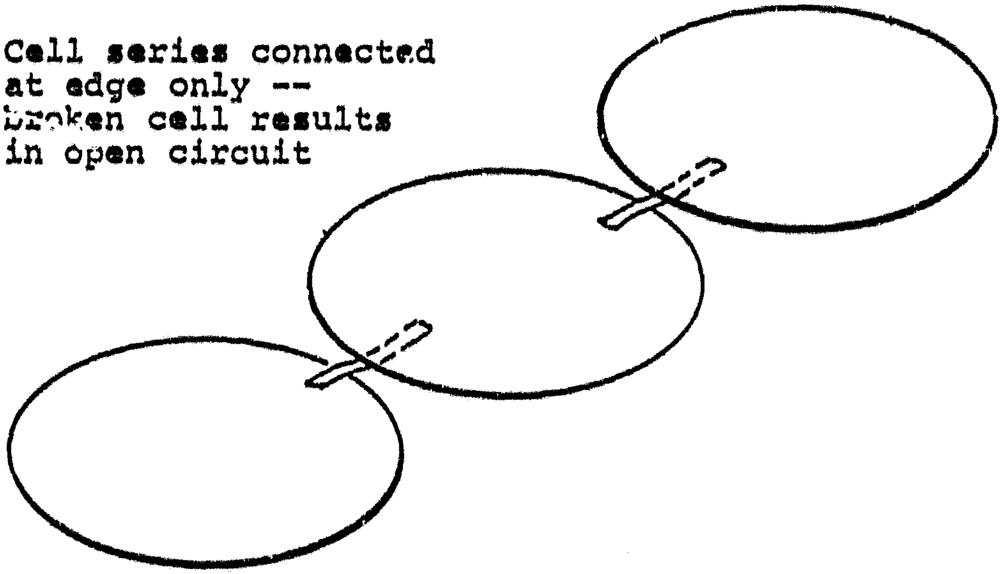
CELL INTERCONNECTION WITH RIBBON REELS

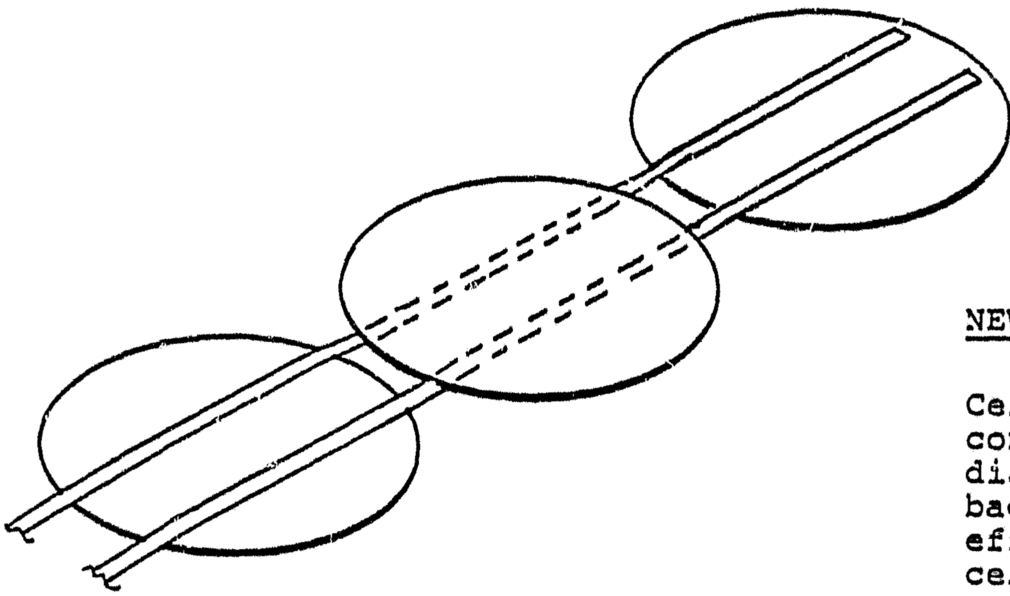


USING REELS OF CONVENTIONAL COPPER RIBBON (SOLDER PLATED) TO FORM SERIES STRING OF SOLAR CELLS --- FUTURE VARIATION IN CIRCUIT (MODULE) LENGTH IS SIMPLY HANDLED BY CUTTING BETWEEN INTERCONNECTED CELLS AS NEEDED.

OLD APPROACH

Cell series connected at edge only -- broken cell results in open circuit





NEW APPROACH

Cells have ribbons connected over full diameter (front & back)- minimizes effect of broken cell

IMPROVED INTERCONNECT RELIABILITY

of any desired length and end-connecting the correct polarities. This is depicted in Figure 4.

In designing the 16-2000 module the approach to cell interconnection and the use of 100 mm (4 inch) diameter solar cells represent the greatest departures from the Block III design. The basic superstrate design was retained and the module size was increased to accommodate the 100 mm solar cell. Figures 5 and 6 are drawings of the circuit and module respectively. Other changes included an extruded frame for sealing, mounting and providing structural rigidity for housing module terminations and a Korad/metal foil back cover for improved protection for the circuit and encapsulant.

B. MATERIALS OF CONSTRUCTION

The rationale in material selection for the 16-2000 module was to approach a 20 year life and implement cost reductions established by the Low-Cost Solar Array Project (LSA) goals.

Tempered glass* was retained as the module superstrate material because of its demonstrated long-life and its excellent optical, thermal and mechanical properties. Polyvinyl butyral** (PVB-SR11) was also retained from the former module design because of its proven performance and approach to automating the encapsulation (lamination) of cell circuits. The number of layers of PVB utilized is four.

An important design improvement in this new module was the

* ASG Industries
** Monsanto

replacement of the metal pan with an extruded aluminum molding. The advantages of this change were improved structural rigidity, better access to the module terminations, ease of array assembly and lower operating temperatures. The framing approach also facilitated mechanized assembly and the introduction of a low-cost sealant suitable for high volume applications. The aluminum was applied with an architectural finish that improves corrosion resistance in a terrestrial environment.

The edge sealant was changed from a vulcanized rubber sealant* to a butyl hot melt**. The reasons for this change were two-fold: 1) it was discovered in temperature/humidity testing that the catalyst (typically an inorganic oxide) was causing the PVB to crosslink and discolor at the perimeter of the module, and 2) this sealant was not suitable for the high volume assembly of modules.

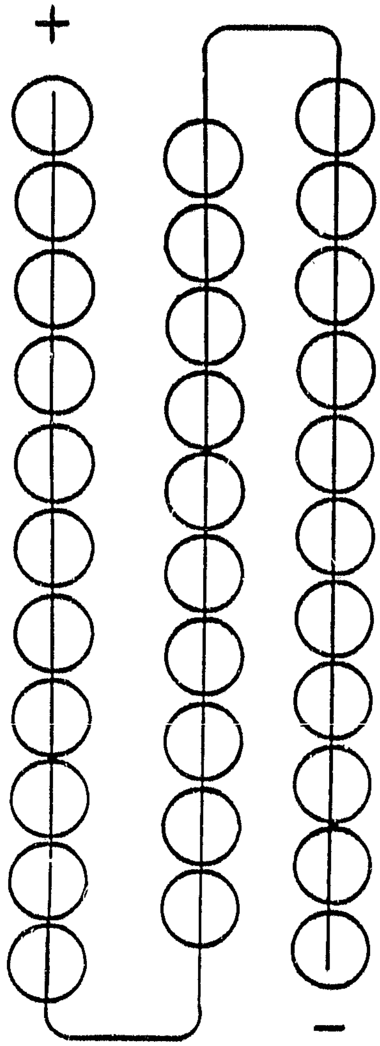
The final change to the module was the replacement of the Tedlar*** back cover material with a Korad-coated mild steel to improve its hermeticity to water vapor and other gaseous pollutants. The addition of this barrier virtually eliminated the passage of oxygen which, in the presence of ultraviolet light (UV), can cause degradation of the PVB.

C. ELECTRICAL AND THERMAL CHARACTERISTICS

The I-V characteristic of the 16-2000 module is shown in

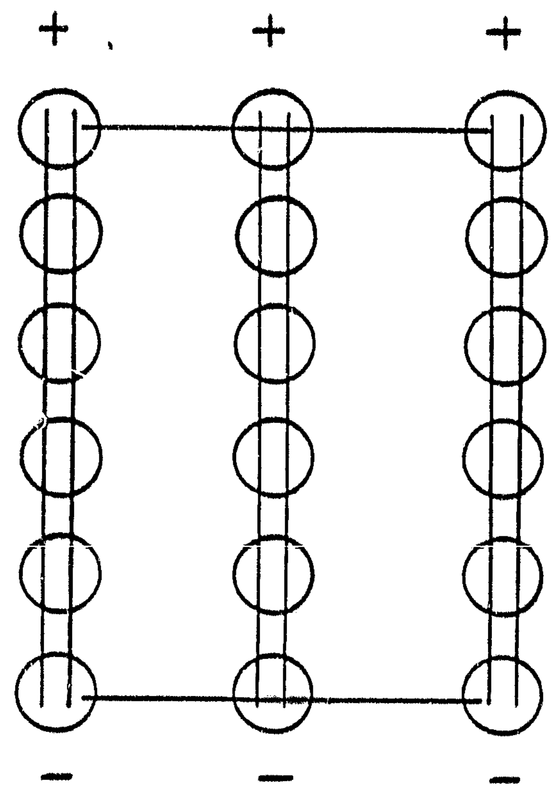
* MIL-S-8802D (9 Dec. 1974) sealing compound
** H.B. Fuller Co., Minneapolis, Minnesota
*** Borg-Warner Co.
**** Dupont Co., Wilmington, Delaware

CIRCUIT DESIGN SUITABILITY FOR PARALLEL/SERIES CONFIGURATION



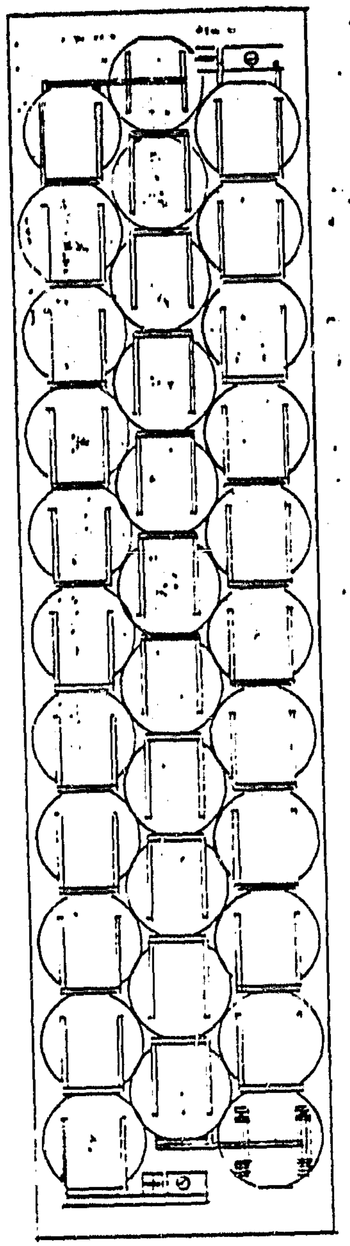
1P X 33S

OR



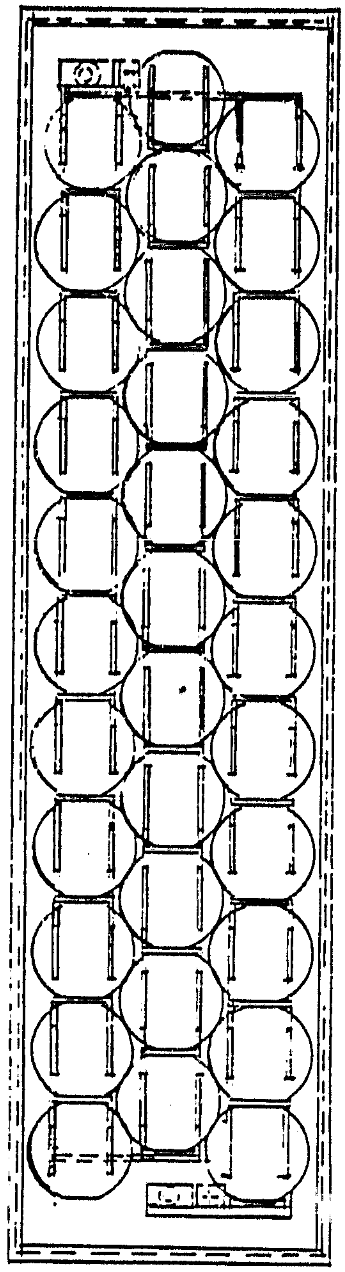
3P X 6S

CELLS WOULD BE MACHINE SOLDERED IN SERIES
AND CUT AT 6 CELLS INSTEAD OF 11 ---
STRINGS WOULD BE ARRANGED INTO CIRCUIT
AND END CONNECTED AS SHOWN.



16-2000 CIRCUIT

FIGURE 5



16-2000 MODULE

FIGURE 6

Figure 7 and reflects the power increase resulting from the larger 100 mm diameter solar cell and higher efficiency due to lower operating temperature.

An important change in operating characteristics is the lower Nominal Operating Cell Temperature (NOCT) of the ASI 16-2000 module. It has been determined to be 47°C as compared with 58°C of the Block III module. This is a direct result of changing the pan-type frame which was producing a "greenhouse" effect at the rear of the module.

D. PROOF OF DESIGN TESTING

In the development of the 16-2000 design, two types of rigorous tests were applied to module components (during in-house testing by ARCO Solar): thermal cycling to reveal undesirable material combinations in which thermal strains might be induced, and humidity cycling to expose areas of permeation to moisture and its consequences.

Thermal Cycling:

Conditions	No. Cycles	No. Modules
-40°C to +90°C	750	6

The temperature ramp was 100°C/hour maximum in accordance with JPL environmental test procedures. Electrical tests and visual examinations were conducted following each 100 cycles. No significant physical changes were observed after 750 cycles and all I-V measurements were within 1% of initial values.

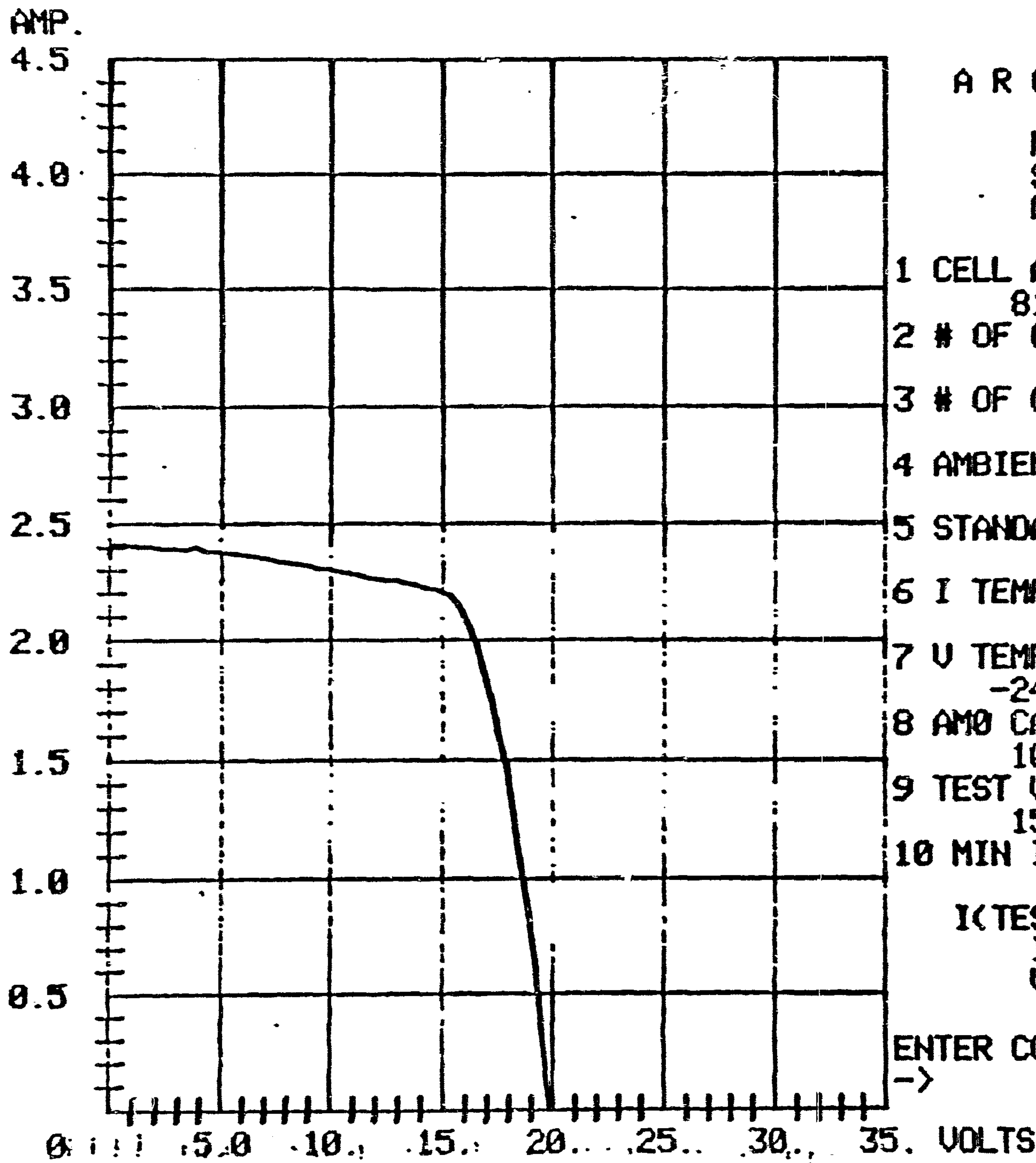
A R C O   S O L A R

MODEL #16-2000
SERIAL #277271
DATE 4-11-81

1 CELL AREA (SQ MM)
8129
2 # OF CELLS IN PARALLEL
1
3 # OF CELLS IN SERIES
33
4 AMBIENT TEMP (DEG C)
25
5 STANDARD TEMP (DEG C)
25
6 I TEMP COR(UA/SQ CM/DEG C)
15
7 V TEMP COR(UV/DEG C/CELL)
-2450
8 AM0 CAL CURRENT (0.1'S MA)
1002
9 TEST VOLTAGE (0.01'S V)
1550
10 MIN I(TEST) (0.01'S A)
10

I(TEST) = 2175000 UA
ISC = 2416000 UA
VOC = 19825000 UV

ENTER COMMAND LETTER
->



16-2000 MODULE I-V CHARACTERISTIC

Humidity Cycling:

Conditions	No. Cycles	No. Modules
23-75°C 95% RH	60 (one/day for 60 days)	12

The temperature ramp was done in accordance with MIL-STD-810C, Method 507.1 (2 hours from low to high, 16 hours dwell at high temperature). The one departure from this method was that the upper temperature was increased from 40.5°C to 75°C. Six of the twelve modules had a Tedlar* backing while the balance had a Korad-steel-Korad** backing. Within three days there was evidence of moisture penetration of the Tedlar and debonding in isolated areas of the PVB from the glass. The foil-backed modules exhibited no change in the laminate or evidence of moisture ingress.

* Dupont Trademark

IV. AUTOMATED EQUIPMENT DESIGN

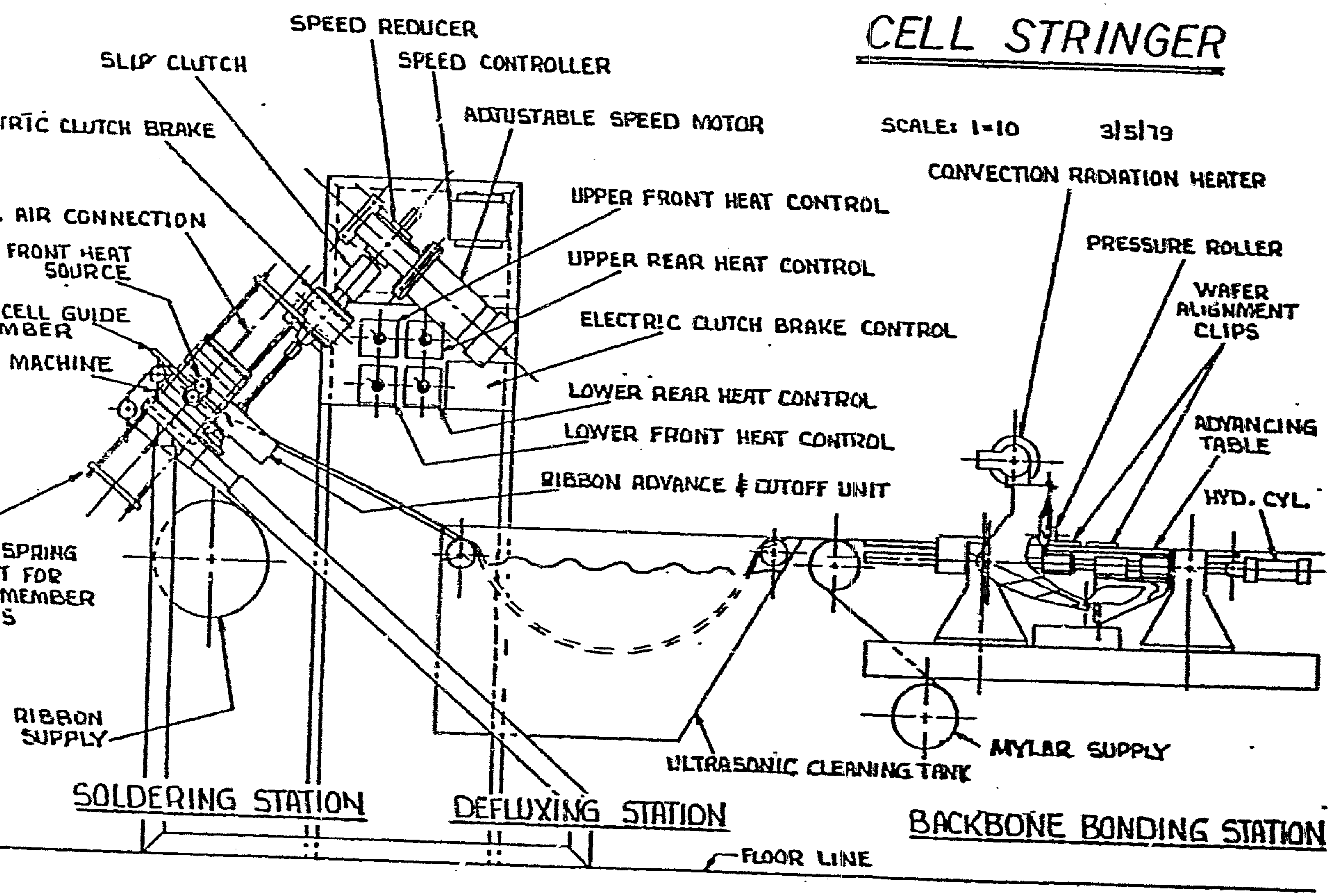
A. SOLAR CELL ASSEMBLY PROTOTYPE (SCAP)

The purpose of the Solar Cell Assembly Prototype (SCAP) is to interconnect solar cells into a continuous single series string. Figure 8 is a schematic of the first machine concept. This first machine consisted of five elements:

1. wafer unloading (not shown)
2. ribbon feed and deployment
3. soldering mechanism
4. solder flux removal
5. handling strip attachment station

Wafer handling or unloading is the process of removing completed solar cells from a plastic cassette into the machine, one at a time. The ribbon feed is two storage reels of solder plated copper ribbon, a roller feed mechanism and a shear for dispensing controlled lengths of dual interconnects to the solar cell.

The soldering mechanism is simply a transport/clamping/heating device that produces solder connections between the solar cell metallization and copper ribbon. Solder paste (a thick film product of solder particles, vehicle and flux) is pre-applied to the finished solar cells prior to entering the SCAP. Solder flux removal is the process of cleaning the residual flux in a fluorinated hydrocarbon/alcohol mixture in an ultrasonic tank. The handling strip attachment station is the application of a perforated plastic strip to the bottom of the completed solar cell string for purposes of handling.



SOLAR CELL ASSEMBLY PROTOTYPE

FIGURE 8

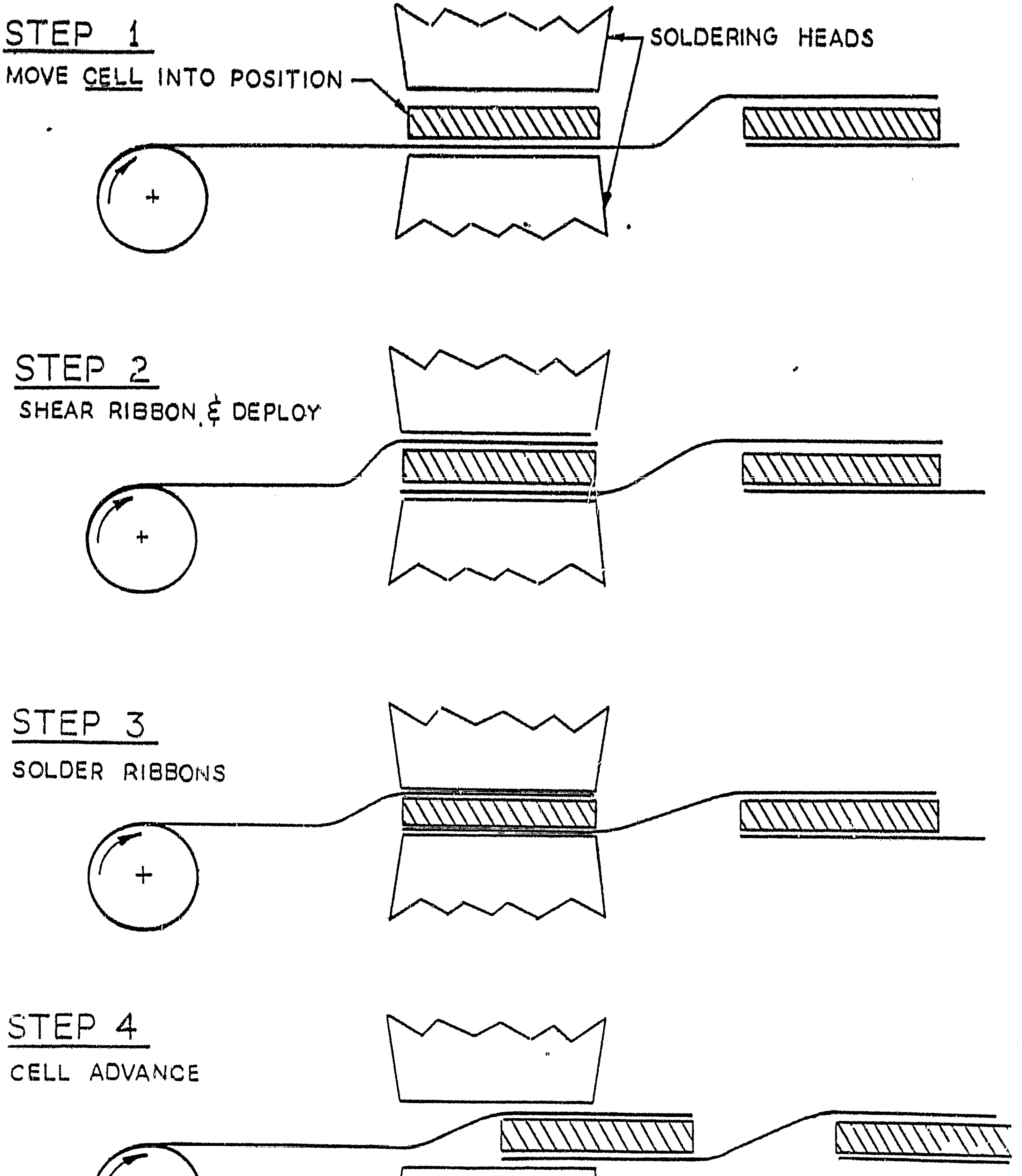
In this first machine concept, wafer transport and alignment from the cassette to the soldering head was to be achieved by using a gravity feed. This is evident in Figure 8 from the slope of this section of the machine.

The first soldering approach was a conductive method. This is depicted in Figure 9. In this design, two opposed, resistively heated copper heads were moved to the cell by a cam operation; soldering was achieved with attendant cooling; the heads were then moved away from the cell and it was advanced to the next position via gravity feed. A working model of the soldering mechanism was fabricated and bench tests of this approach were conducted. The following problems were encountered with this approach:

1. Lubrication of hot moving parts without contamination of the solar cells with lubricant.
2. Temperature control of heads and cooling of cells prior to transport.
3. Obtaining a non-stick heating surface.
4. Complexity of heating mechanism.
5. Cell breakage and alignment problems associated with gravity feed.

The most significant problem was the difficulty in obtaining a non-stick surface on the heating mechanism. A hard, chrome plate finish was first attempted with some success. However, after some use, the remaining rosin from the flux did not permit separation. A second approach was to use TFE Teflon* impregnated

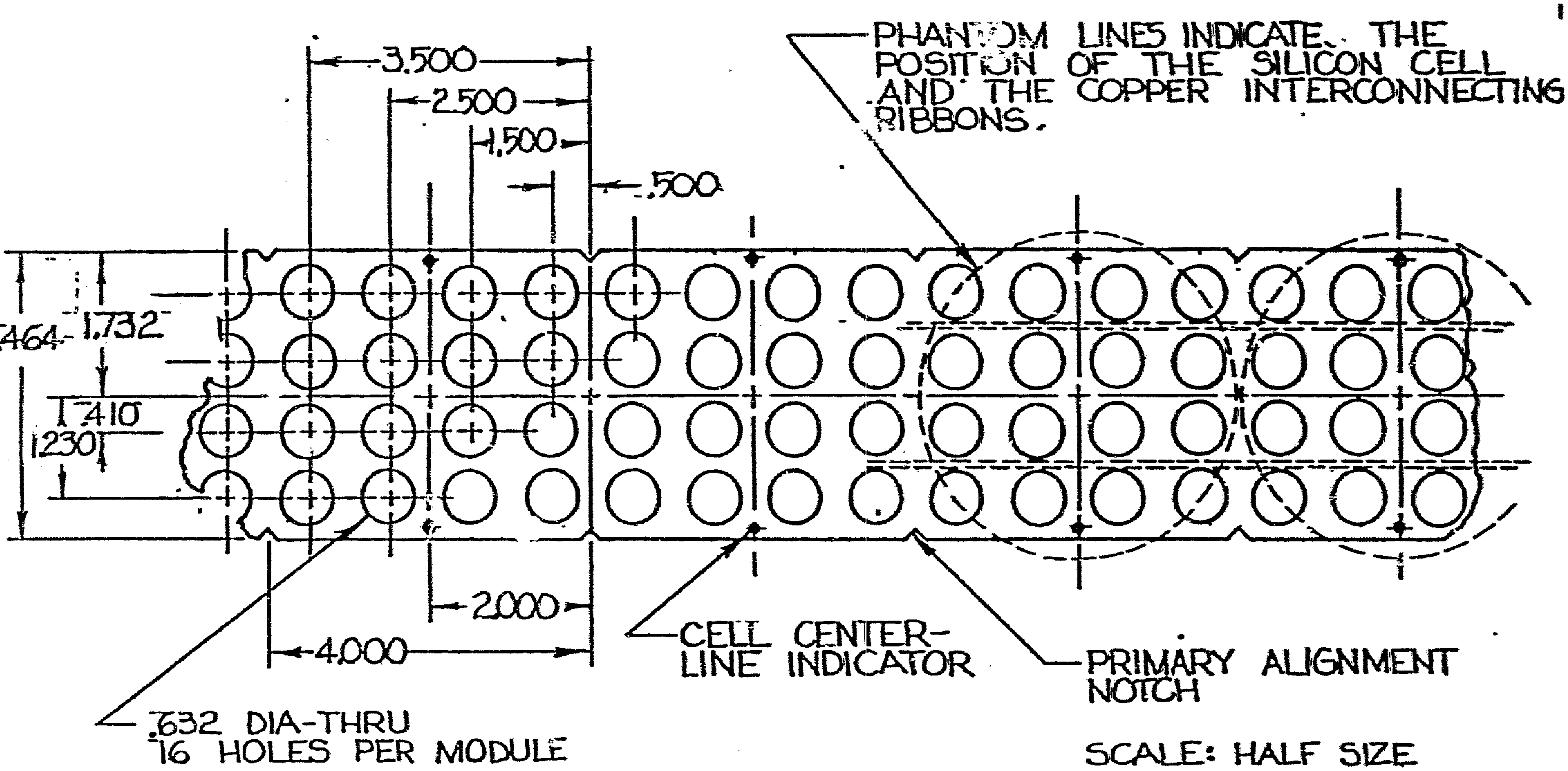
CONDUCTIVE SOLDERING



into the surface of the soldering head. This, too, presented problems with separation of the interconnects from the head after some use. Finally, an electroless nickel plating that was furnace-oxidized was used with greater success, however, it also had similar problems. Early in the program this approach to soldering was abandoned in favor of such non-contact approaches as electromagnetic induction and infrared heating.

A second element of the original machine that was designed, tested and abandoned was the handling strip attachment station. It was originally thought that the solar cell series string would require stiffening before it could be taken from the machine and handled. The addition of this feature would also allow a more precise spacing control between cells. This machine element was similar in operation to the ribbon feed and soldering mechanism; a roll of perforated, adhesive-backed Mylar* is fed beneath the emerging solar cell string, the cell and Mylar tape are heated, pressed together via transport rollers and the finished string proceeds to a cutoff area where strings are cut to appropriate length. The perforated Mylar is shown in Figure 10.

This machine element was similarly abandoned early in the program for two reasons: first, it was learned that a series of interconnected solar cell strings with dual redundant ribbons could be readily handled on large diameter (20-25 cm/8-10 inches) reels as it emerged from the soldering-defluxing operation; second, the cost of a module - compatible plastic film



NOTE: THESE DIMENSIONSIONS APPLY THROUGHOUT REPETITIVE PATTERN.

PERFORATED MYLAR HANDLING STRIP

FIGURE 10

for handling was about \$0.003/cm (\$0.10/foot). This amounted to \$0.90/module.

The concepts for wafer unloading, ribbon feed and solder flux removal remained essentially unchanged and will be discussed in succeeding sections.

1. SOLAR CELL HANDLING AND TRANSPORT

Preparation of solar cells for use in the SCAP required the application of a solder paste. The paste is applied by screen printing and handling of cells is done through the use of polypropylene cassettes familiar to the semiconductor industry*. Each cassette accommodates 25-100 mm cells and is compatible with automated loading equipment**.

Initial work centered around the use of this handling equipment, however, no equipment was available for handling multiple cassettes. The goal in soldering for this program was 12 cells/minute, and in order to best utilize the machine operator a cassette handler/unloader was built*** with expansion capability to accommodate 4-5 cassettes.

This equipment is shown in Figure 11. It consists of a vertical magazine of cassettes that are driven downward by sychronous motors, one wafer at a time. When the cassettes are loaded with cells, the pusher bar displaces a wafer out of the cassette into a wafer alignment/transport conveyor.

The pusher bar then retracts to its rest position and the

*Fluoroware, Co., Chaska Minnesota
**Silec, Sunnyvale, California
***Kinematics, Princeton, New Jersey

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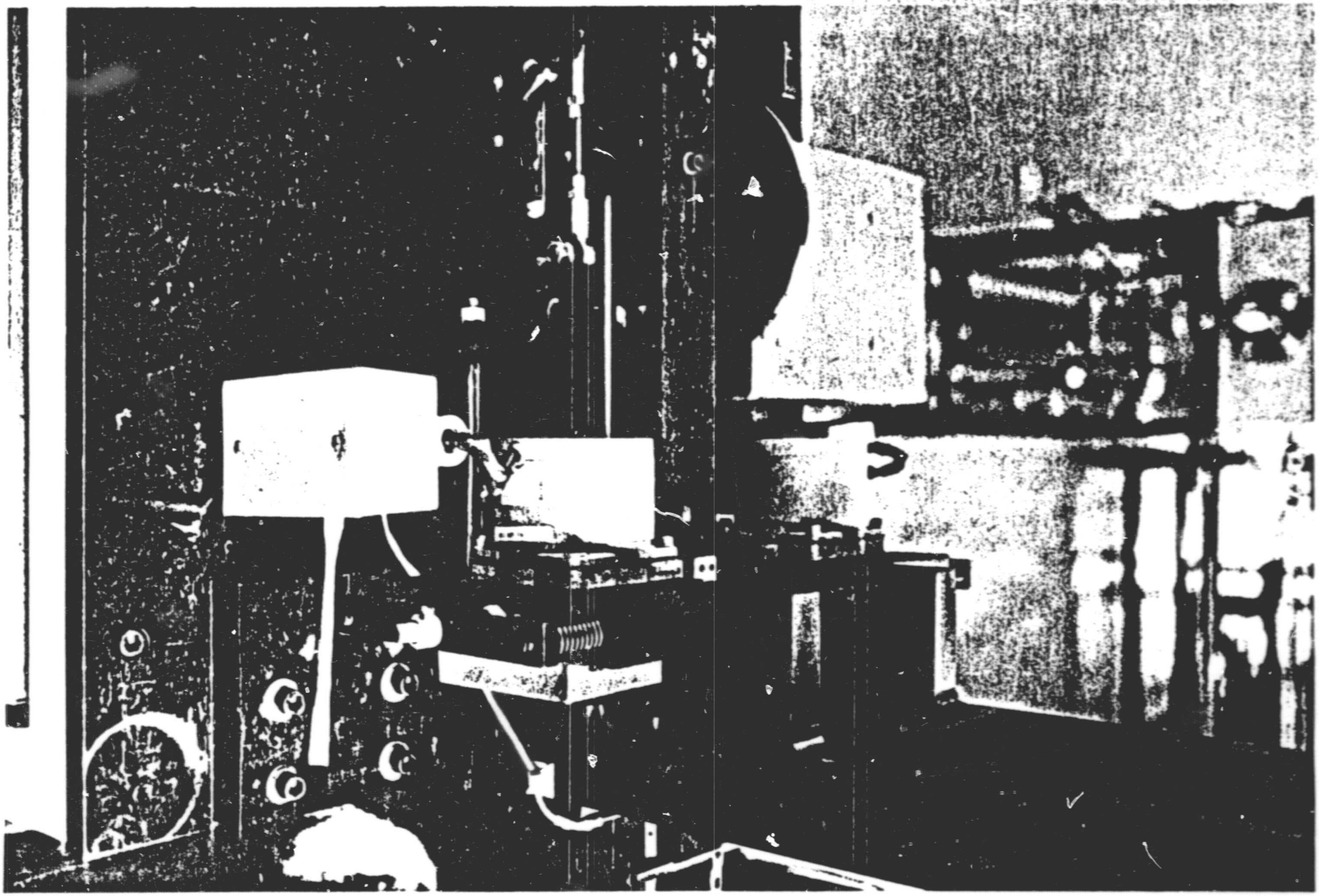
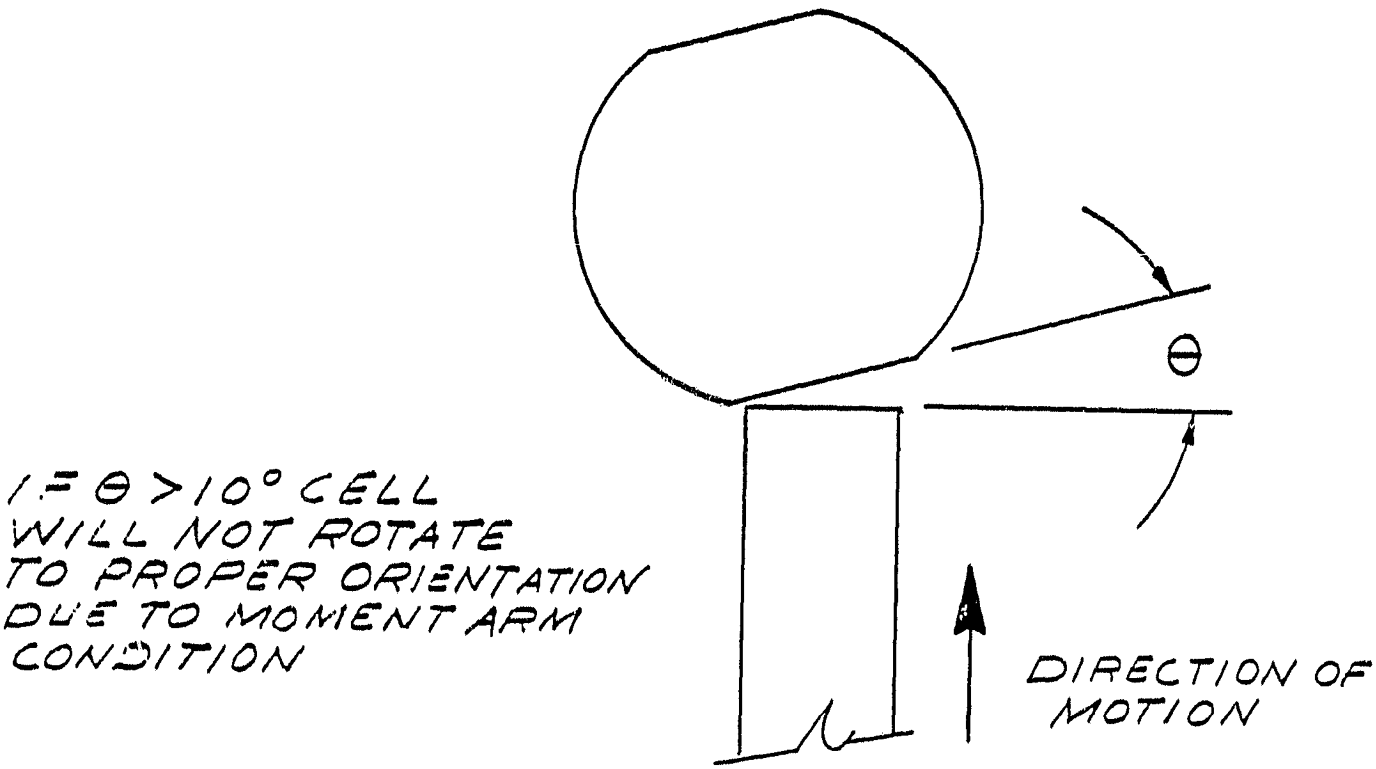


cassette stack moves down one wafer position. When a cassette is emptied, it drops out of the magazine into a chute and finally out of the machine into a basket of cassettes. The machine rate was designed for a range of 1-20 cells/minute so that the program goal of 12 cells/minute could be easily accommodated. The one important requirement of the loaded cassettes was the orientation angle of the flats of the solar cells relative to the pusher bar.

This is illustrated in Figure 12. In order to insure proper orientation all cassettes were placed on a flat-finder prior to loading of the magazine.

From the cassette unloader cells are moved onto a set of rails where the alignment and transport occur. As the cell moves onto the rails, a second pusher bar transports the cell into the alignment grips of the conveyor. This is shown in Figure 13, Using the principal of a flat and two points (the flat being the second pusher bar while the points are the forward grips of a station on the conveyor), alignment is effected simultaneously with forward motion of the cell into the ribbon application area. The conveyor is shown in Figure 14.

The conveyor consists of two gear-synchronized tracks with 13 alignment/transport stations. Like the cassette unloader the rate is variable between 1-20 cells/minute.



CRITICAL ANGLE OF CELL FLAT

FIGURE 12

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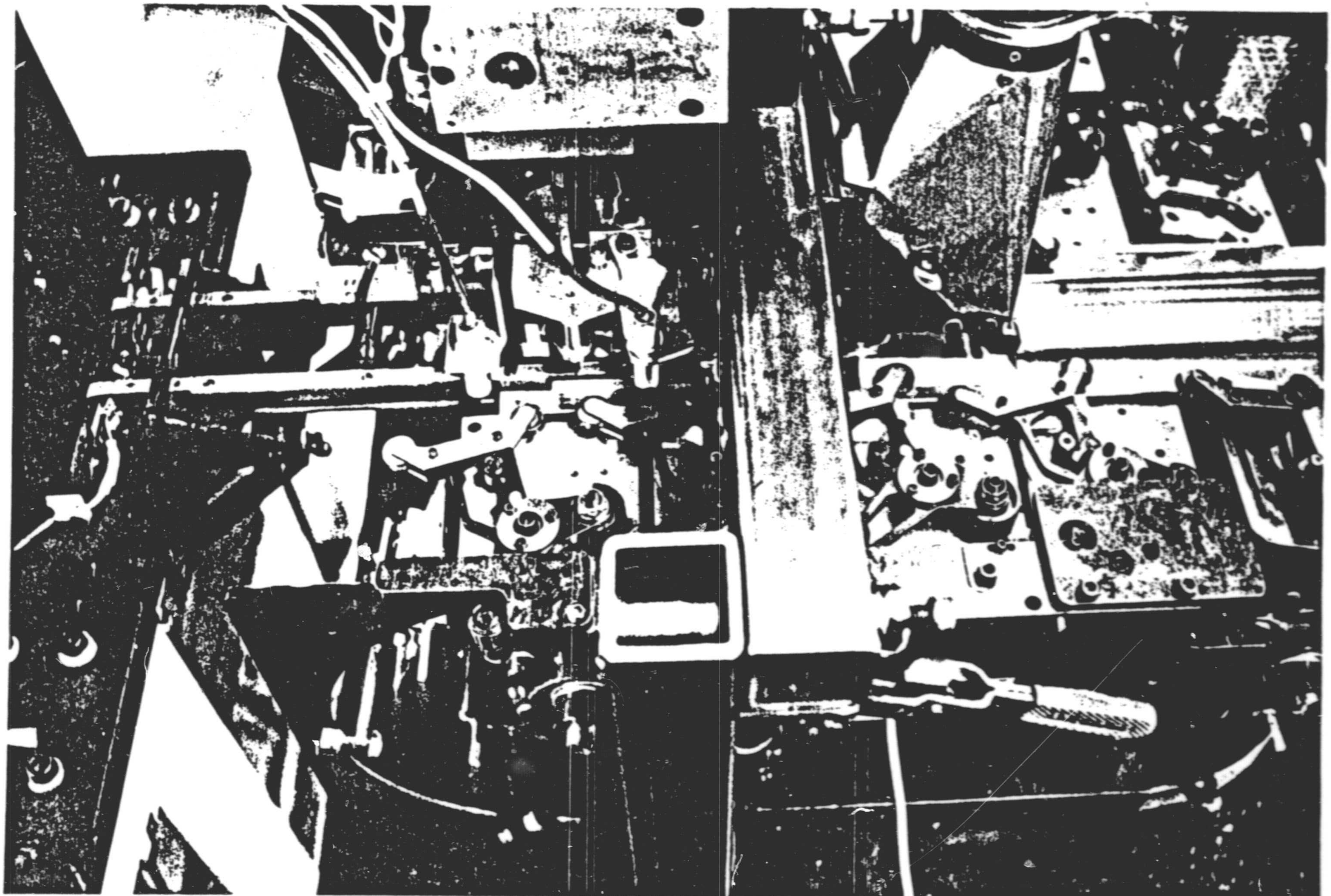

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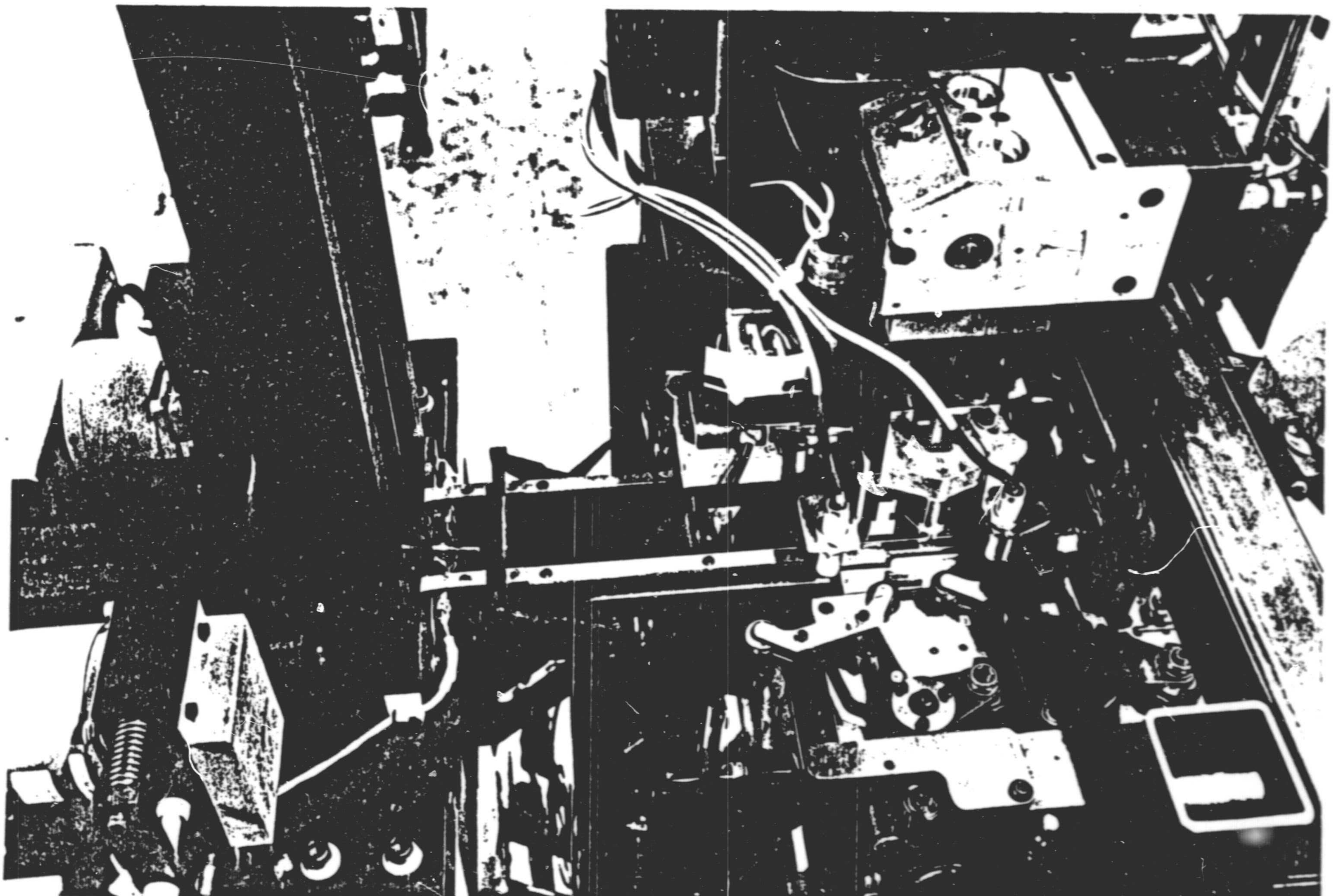


2. RIBBON FEED AND DEPLOYMENT

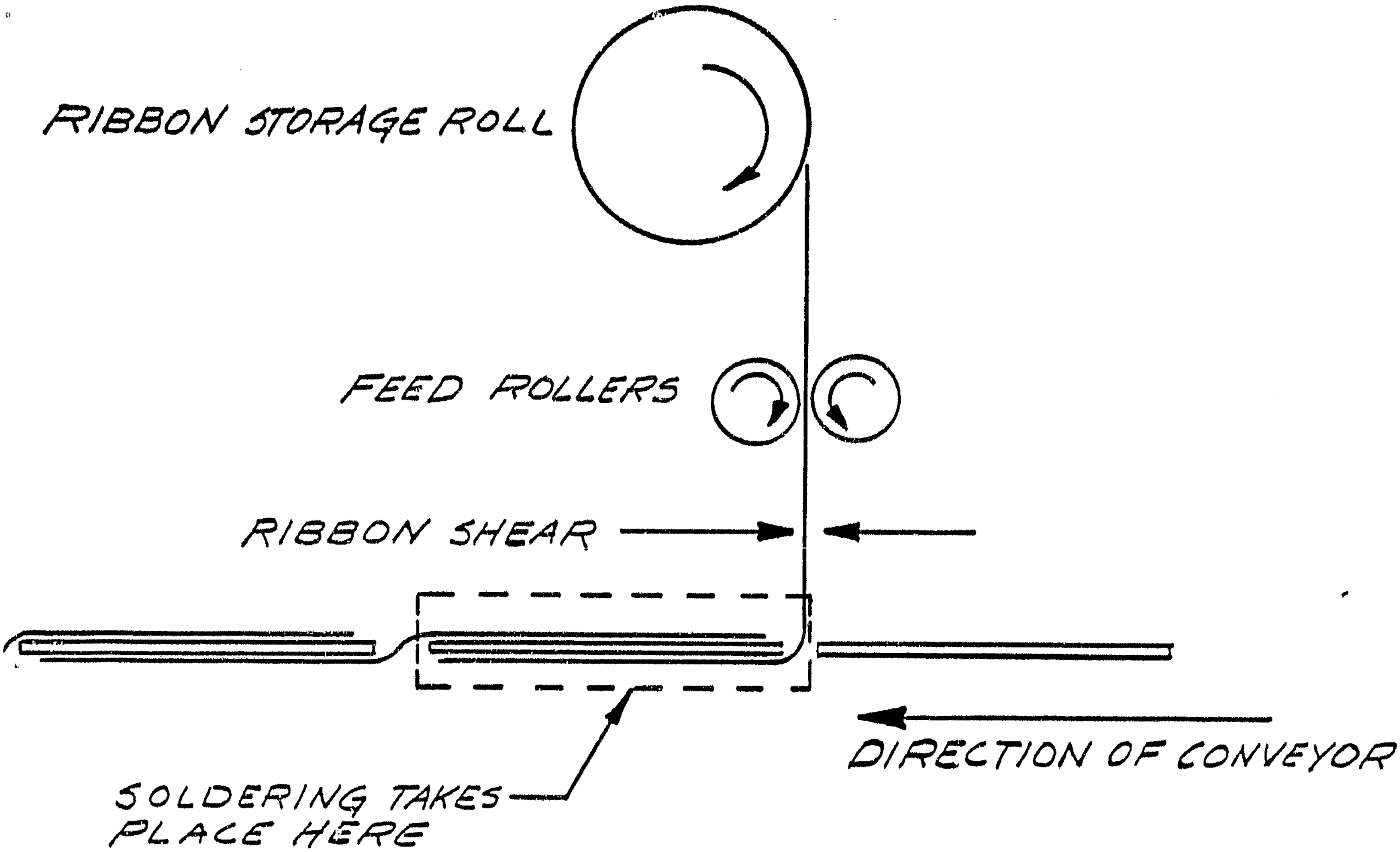
The first concept for ribbon feed and deployment was to push the ribbon from reels into guide tubes and onto or below the cell. This idea is shown in Figure 15. Typically the ribbon materials are "pulled" from one end for deployment since their stiffness precludes "pushing" due to buckling. Preliminary tests on .05 mm (.002 inch) thick copper ribbon by 2.6 mm (.1 inch) wide indicated that it could, in fact, be "pushed" through properly designed guides onto or beneath the cell with horizontal alignment of $\pm$ .38 mm (.015 inch) over a length of 10.2 cm (4 inches), the length of a 100 mm solar cell. A bench model of this concept was fabricated and tested successfully to demonstrate proof of approach.

A search was then made of industries using and/or manufacturing ribbon or rod feeding equipment. A company* that builds equipment for feeding welding rod was found and contracted to build a modified rod feeder to handle ribbon. A shear was designed in-house and integrated with the ribbon/feeder.

3. SOLDERING METHOD

As mentioned in Section IV A., the first approach to soldering interconnect was conduction and this was abandoned in favor of non-contact approaches such as electromagnetic induction and infrared heating, the former being the primary choice with infrared as a backup. Historically, solar cells

* [illegible] Corp., Daytona Beach, Florida



RIBBON FEED AND DEPLOYMENT

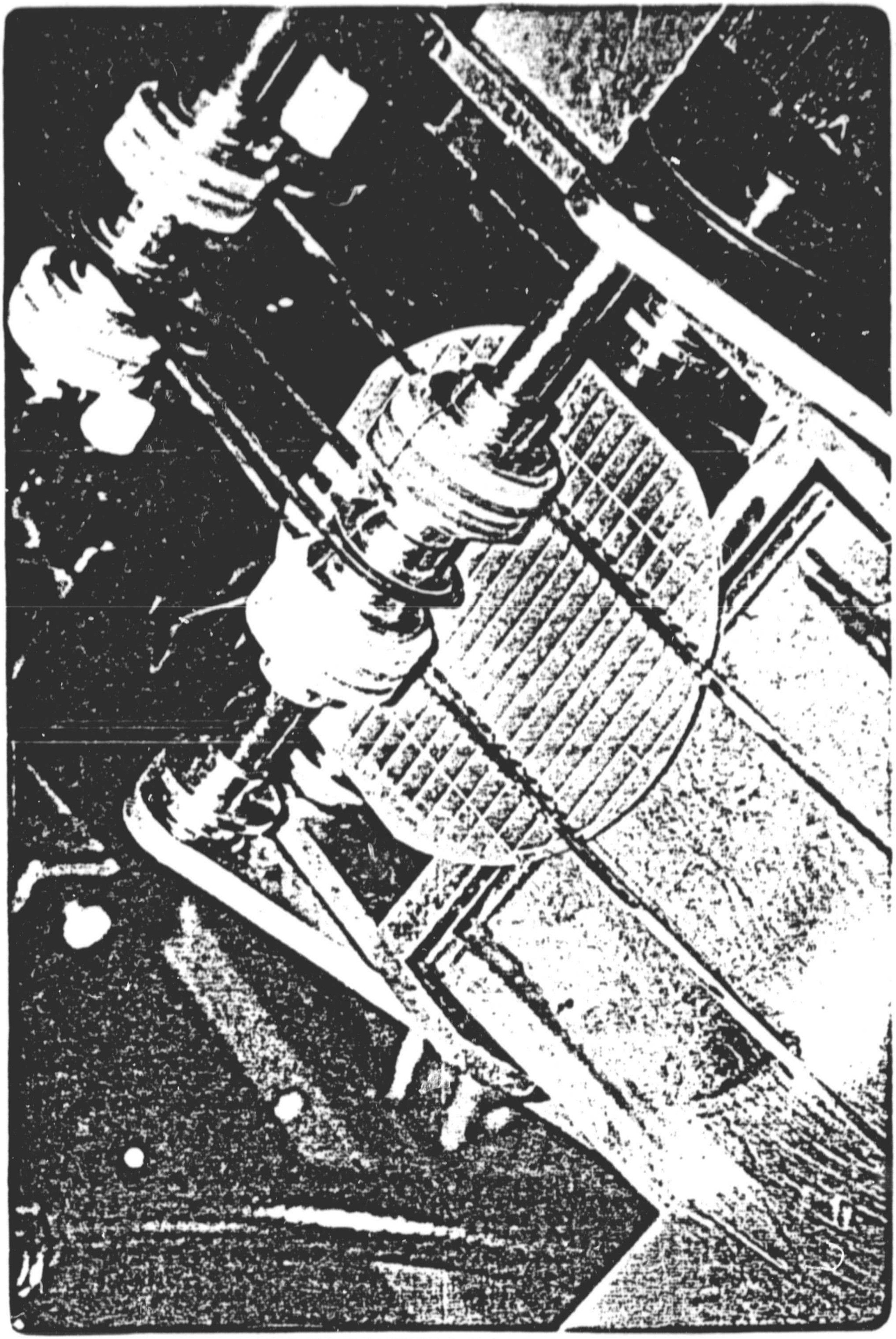
FIGURE 15

have been applied with short ribbon tabs while the cell is in a fixed position and soldered while being clamped together. The application of dual full-length ribbons to the cell while it was in motion appeared feasible, particularly if rollers could clamp the ribbon and cell together long enough for solder joint formation to occur. It was experimentally determined, in the prior section, that long ribbons could be reliably fed above or below the solar cell. The next step was to examine the use of RF induction as a heat source to complement this approach to soldering solar cells.

Following some preliminary screening of RF power supplies and successful attempts to solder full length ribbons to solar cells in a fixed position, a 3 kW RF induction power supply was purchased*. A bench top roller mechanism was designed and integrated with the RF power supply and work coil. This is shown in Figure 16. In early tests two reels of solderplated copper ribbon (not shown) were fed through two sets of rollers and cells were located beneath the ribbons and similarly sent through the rollers as the RF power was activated. The cells were pre-applied with Sn62 solder paste (Sn62/Pb36/Ag2) having a moderately active rosin flux (RMA).

The RF work coil, located between the two sets of rollers and below the cell, was a double hairpin designed to induce

* Cycle-Dyne, Jamaica, New York



RF INDUCTION SOLDERING

current flow in the solar cell grid lines and subsequent heating of the silicon. A piece of Kapton* polymide film was attached to the work coil so as to prevent flux residue from dripping onto the coil. In Table 1, results of early cell interconnection are given. Figure 17 is a photograph of the contact pull test set-up used for measuring solder connection strength.

Using optical methods, measurements of temperature uniformity were made as the solar cell tranversed the RF coil. In these tests it was found that the side of the cell closest to the power supply operated at slightly higher temperatures than the side farther from the power supply. Also, the temperature of the leading edge of the cell was found to be lower than the trailing edge. This probably results from wafer heating at the leading edge with subsequent conduction to the trailing edge in addition to the effects of normal induction heating. Figure 18 is the outline of a cell with the observed temperature gradients.

Further refinements of the work coil, roller clamping and drive mechanism gave rise to a useful mechanism that could be used for applying dual ribbon interconnects to the front of individual solar cells (in a so-called "tubbing" operation) and resulted in lower labor content. In August 1979, this simple SCAP machine element was integrated into ARCO Solar's regular module production facility and has reliably soldered about 2,000,000 - 100 mm solar cells.

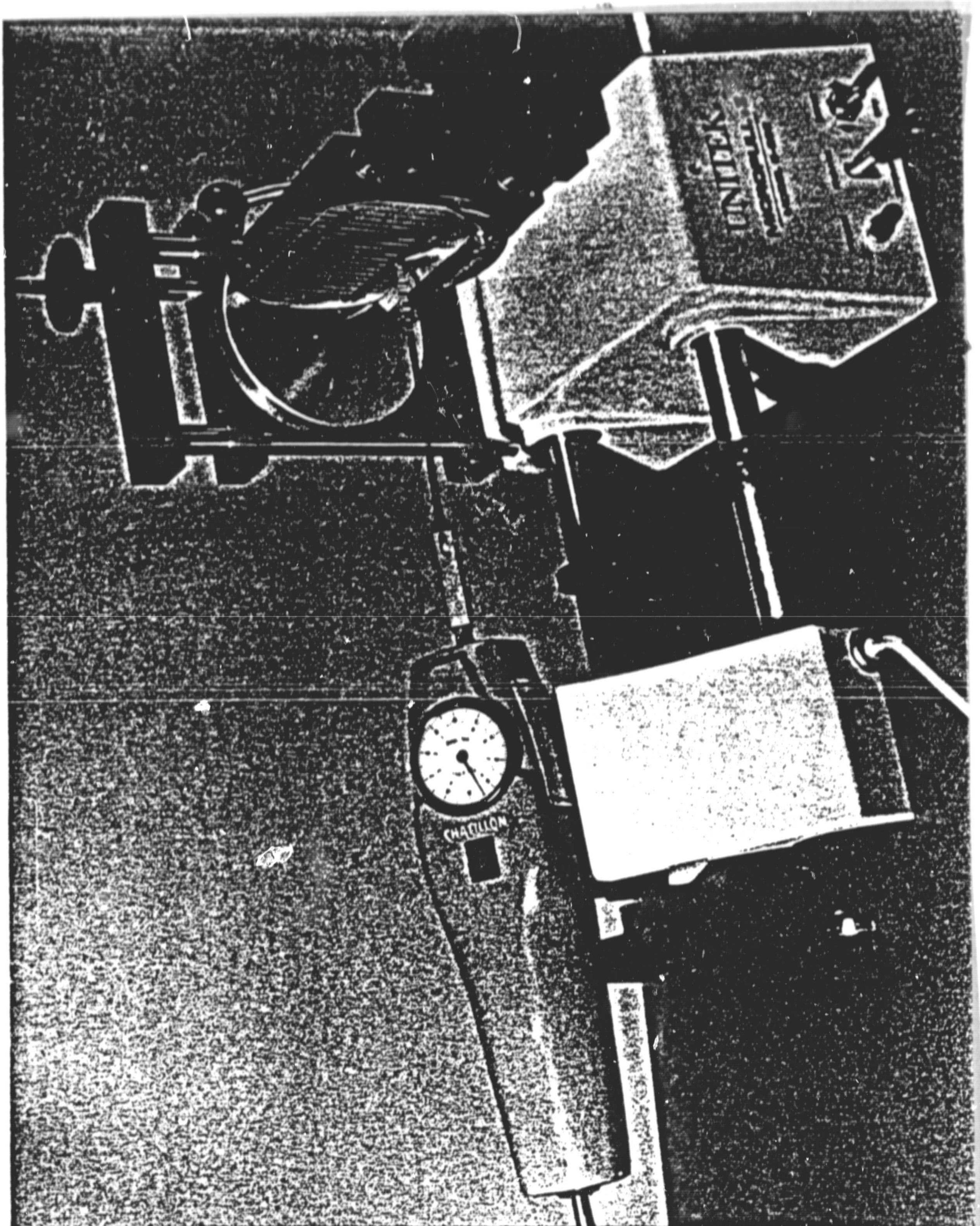
* Dupont Trademark

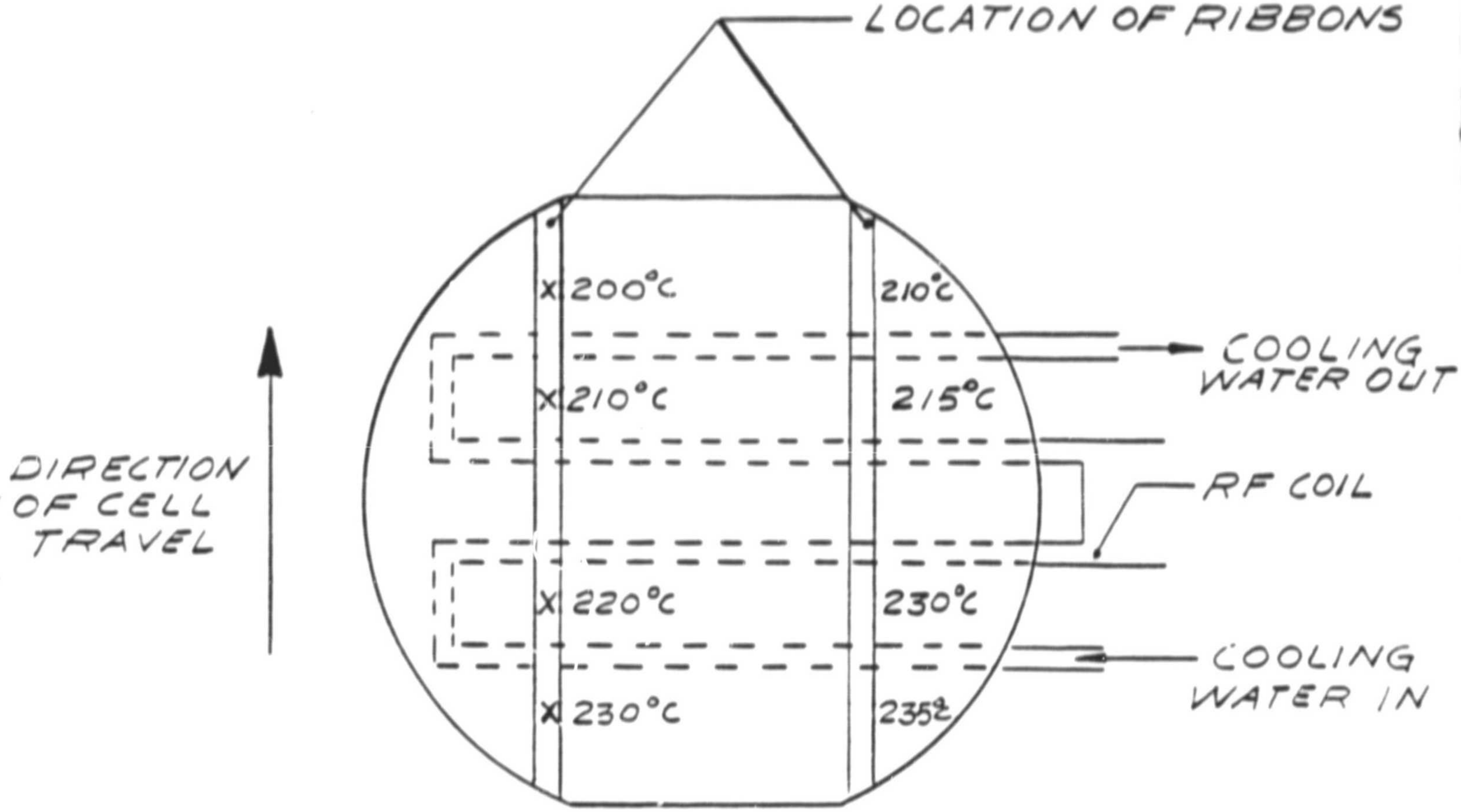
TABLE 1

INDUCTION SOLDERING OF SOLAR CELLS

TRANSPORT FEED (CM/SEC)	RF POWER SETTING (%)	CONTACT* PULL TEST (GMS)	NO. SAMPLE
2.5	60	350 - 600	50

* 90° PULL TEST OF COPPER RIBBONS FROM SOLAR CELL USING UNITEK MICROPULL #6-092


CHATILLON



EFFECTS OF INDUCTION HEATING ON SOLAR CELL TEMPERATURE

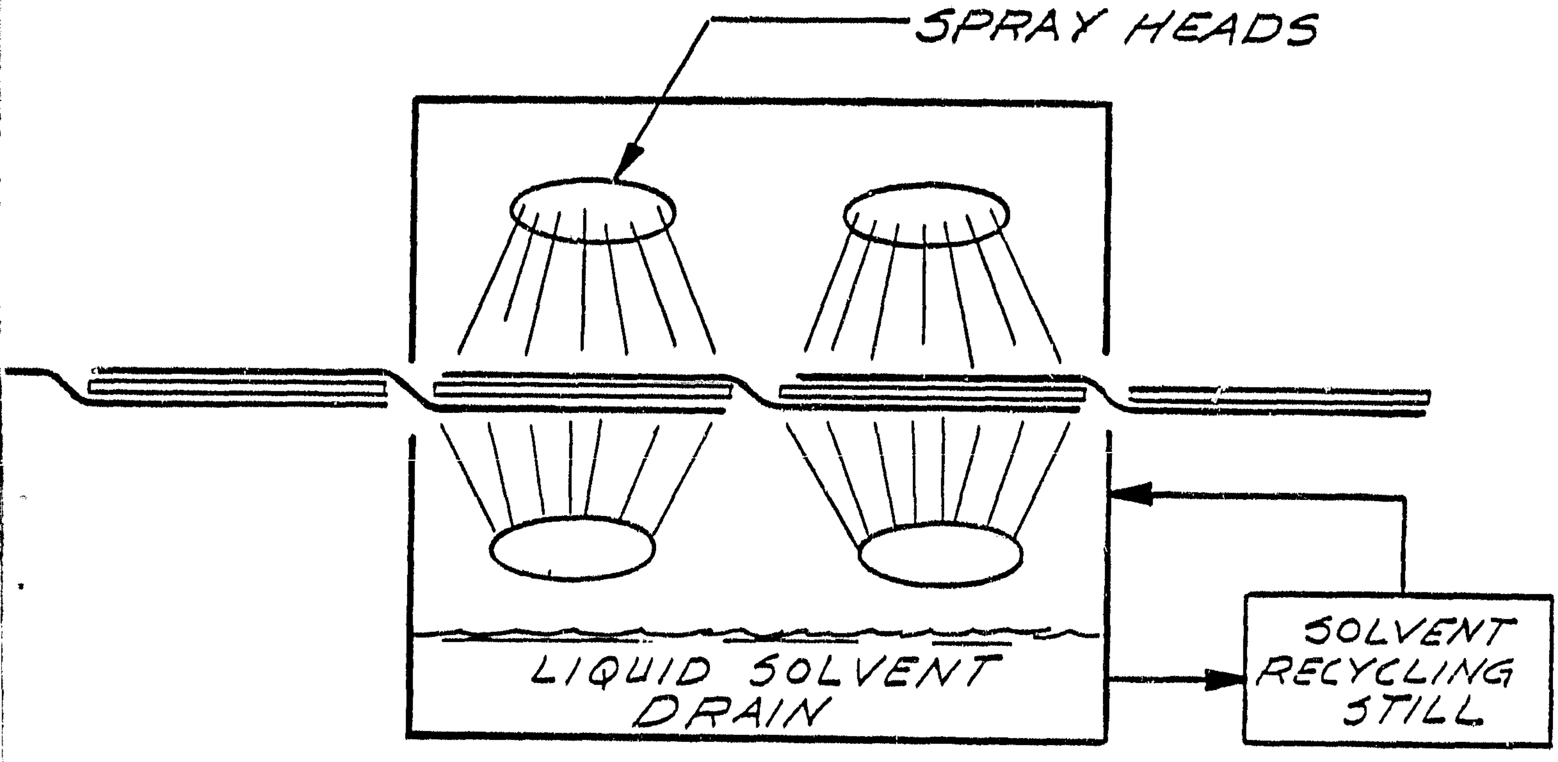
FIGURE 18

4. SOLDER FLUX REMOVAL

The first attempts at solder flux removal was to develop an in-line solvent spray system. This approach is depicted in Figure 19. Based on rates of 2.5 cm/sec. travel through the SCAP, it was not possible to remove flux residue with a spray system using chlorinated solvents such as 1-1-1 trichloroethane, methylene chloride as well as solvent blends using Freon*-alcohol azetropic mixtures. Evidence of rosin presence was determined both visually and colorimetrically**.

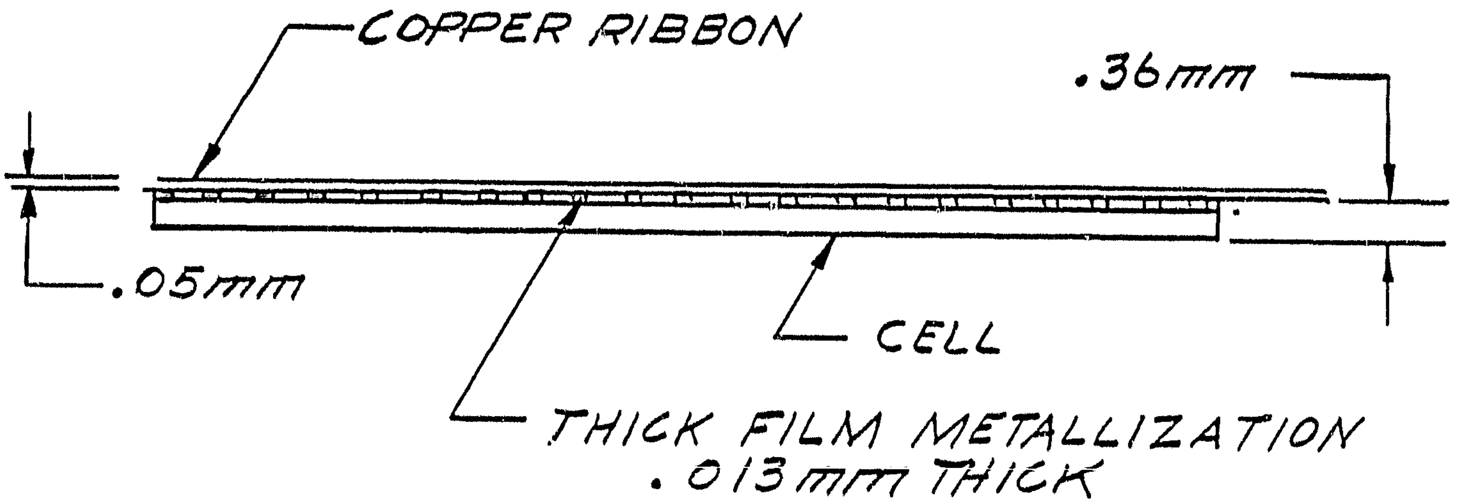
Insufficient removal of flux residue is believed to be a direct result of the interconnect/cell metallization configuration. This is shown in Figure 20. The second approach was to use a warm ultrasonic solution of the aforementioned solutions, determine the dwell time required for residual flux removal, and design a tank that renders sufficient residence time for flux removal. It was determined that 40 seconds dwell in Freon TMS Plus* (90% Freon, 5% ethanol and 5% methanol with a stabilizer) was effective in removal. Figure 21 is the resulting tank designed to provide this required residence time and be integrated as an in-line component***. The tank was equipped with refrigeration coils to minimize solvent loss as well as a solvent recirculating system with a remote still, so that used solvent could be recycled as required.

* Dupont Trademark
** Appendix A



SOLVENT SPRAY FLUX REMOVAL

FIGURE 19



CELL INTERCONNECT/MATALLIZATION PATTERN

FIGURE 20

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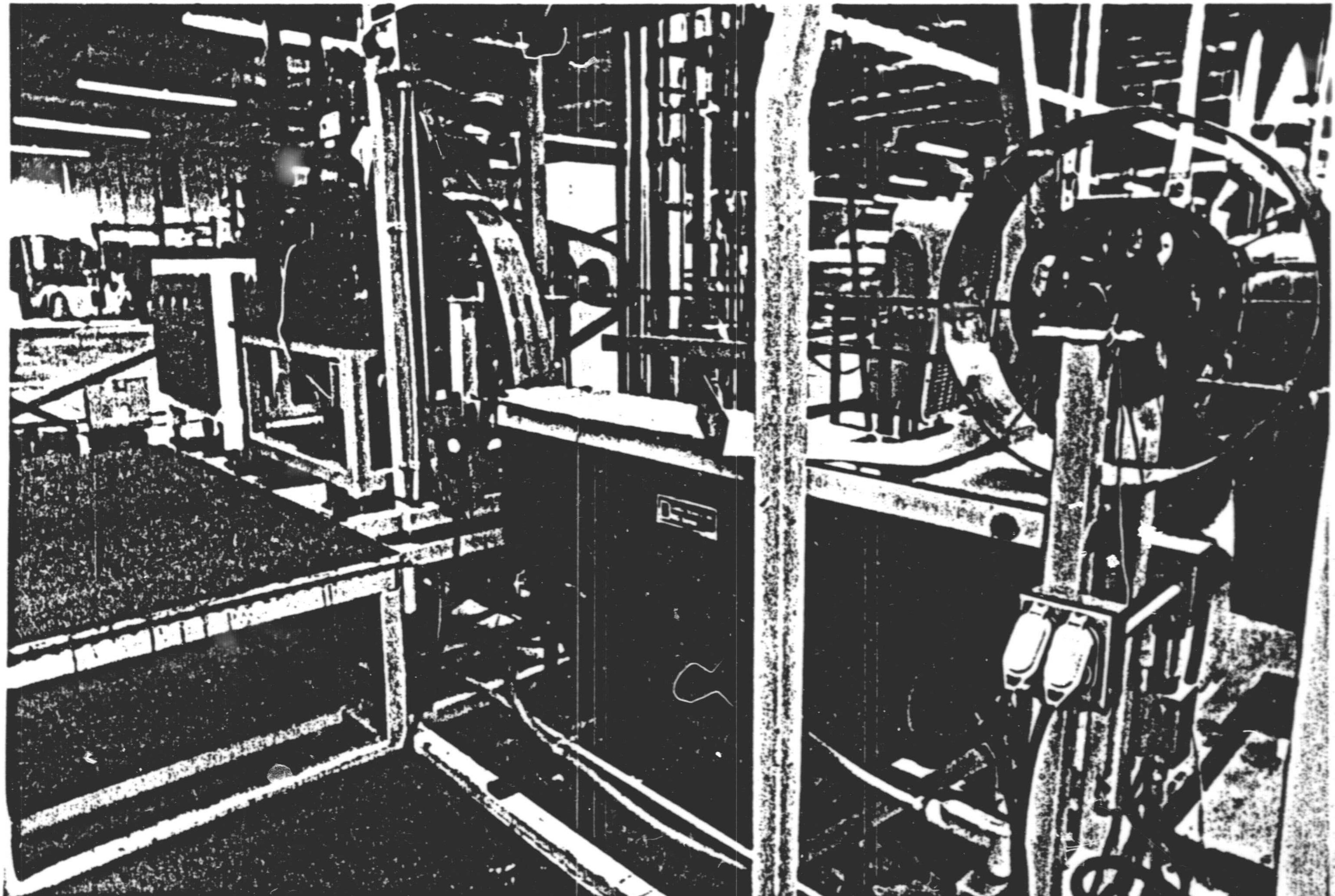


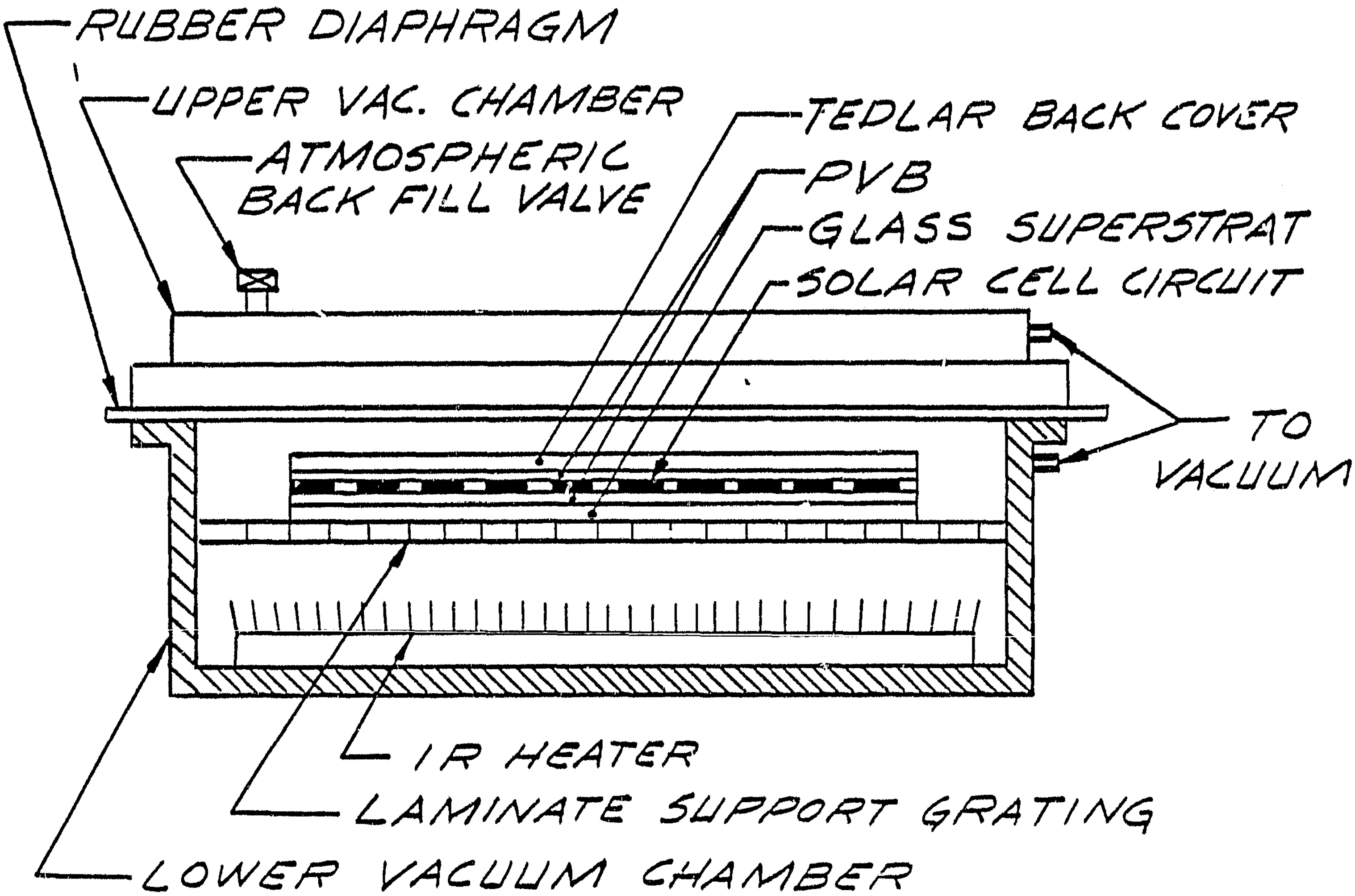
B. SOLAR PANEL LAMINATION PROTOTYPE (SPLP)

The purpose of the Solar Panel Lamination Prototype (SPLP) is to encapsulate or laminate the solar cell circuit using polyvinyl butyral (PVB-SR-11)* or similar hot-melt encapsulant to a glass superstrate. In early studies two lamination approaches applicable to photovoltaic modules were examined; both use evacuation followed by pressure application. In the first, atmospheric pressure levels are used while in the second pressures up to about 13 atmospheres are present. Sample laminations produced by both processes resulted in comparable adhesion of the PVB to glass (1.1-1.4 Kg/cm and .9-1.6 Kg/cm respective 90° peel adhesion strengths).

In a low pressure process PVB tends to block or adhere to itself even though the film is ribbed to aid in the evacuation of air. One approach that can be used to minimize blocking and accelerate the evacuation process is a double vacuum. This is illustrated in Figure 22. In this arrangement the module is evacuated while a second vacuum is applied to the rear of the module. The vacuum level is typically 1-5 TORR in both chambers. The prototype chamber used to develop the lamination process is shown in Figure 23. The design of this chamber is such that different sealing approaches can be examined, additional heat sources can be added, if required, and cooling can be implemented if necessary.

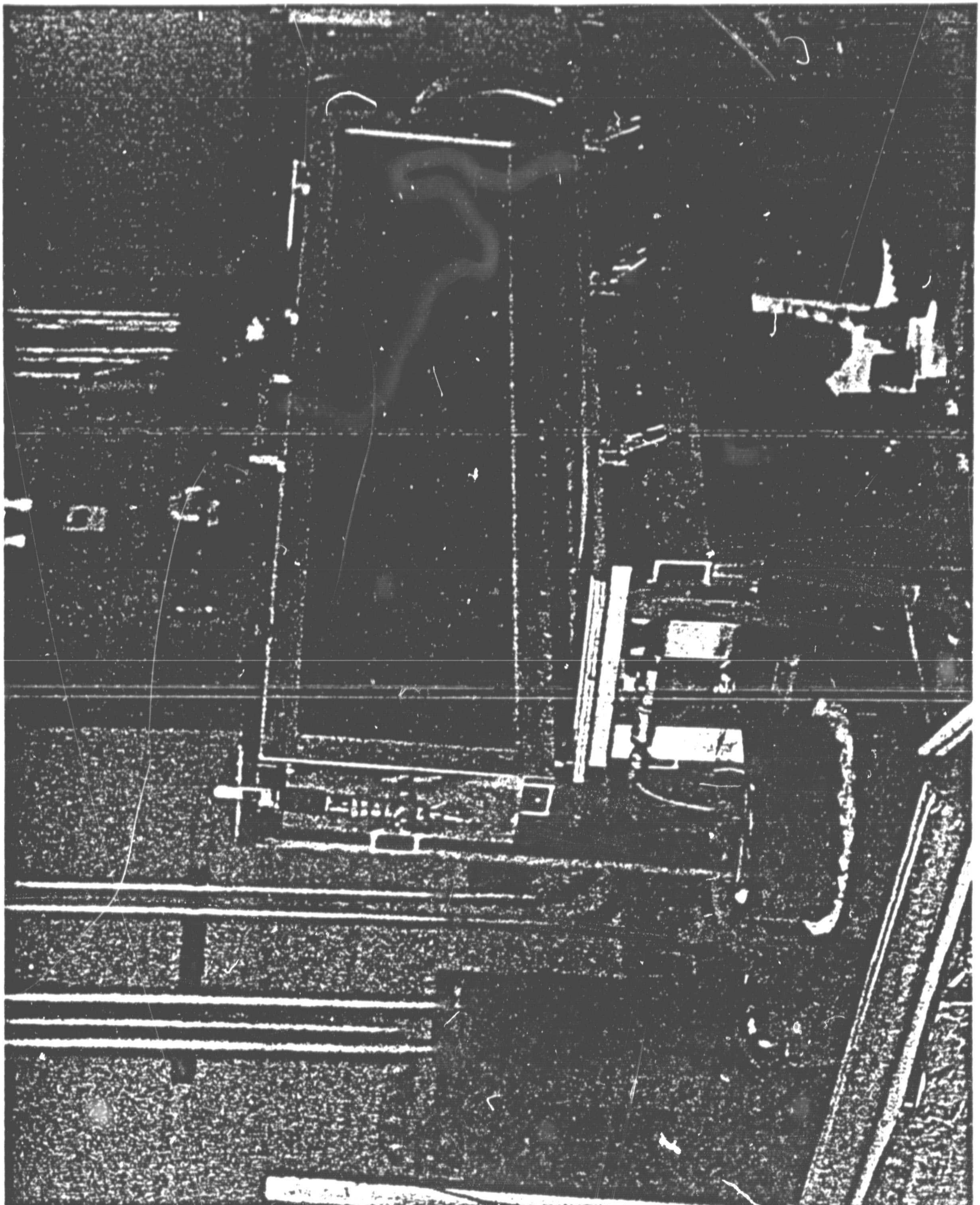
1. LAMINATION VESSEL DESIGN

In work with the prototype chamber, two approaches to



DOUBLE VACUUM LAMINATION

FIGURE 22



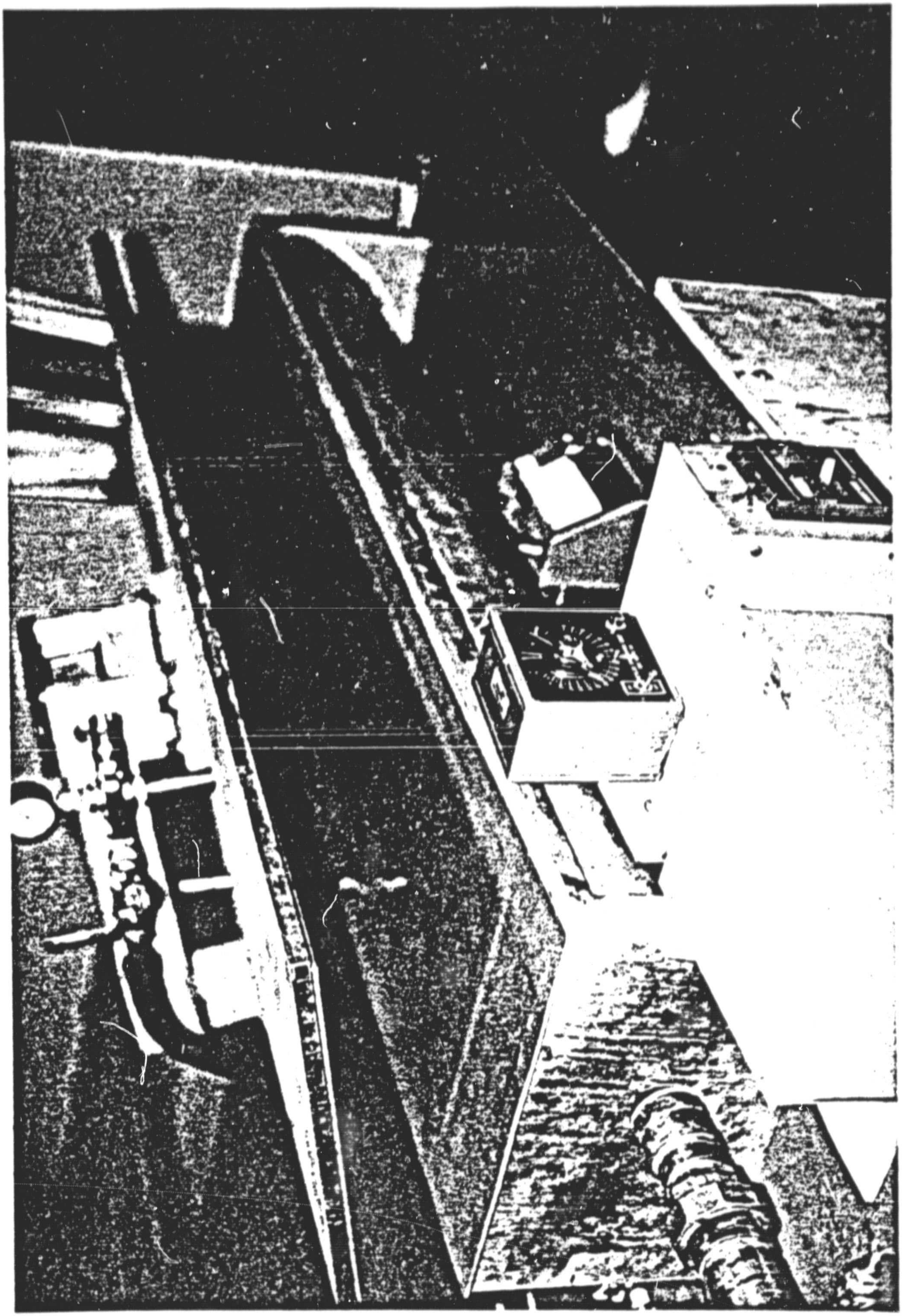
ORIGINAL PAGE
PROTOTYPE LAMINATION CHAMBER BLACK AND WHITE PHOTOGRAPH

chamber sealing were examined. In the first, a gasket was placed in the chamber flange and the Tedlar rear module cover was cut oversize so that it could be used as a diaphragm between the two chambers as well as the back cover for the module. The problems with this approach were poor chamber sealing and wrinkling of the Tedlar. The second approach was to use a large sheet of silicone rubber 3.2 mm (.125 inch) thick as both a chamber seal and bladder between the two chambers. This approach worked well and eliminated the O-ring requirement in the flange. The problem of the bladder sticking to the Tedlar was resolved by the addition of a Teflon-coated glass fabric beneath the bladder. This was later changed to a perforated cloth fabric for cost reasons.

In related experiments, it was determined that forced cooling was unnecessary and that heat-up could be accomplished from the lower chamber using a 2.5-3 kW infrared heating unit. These results led to simpler chamber design. Figure 24 illustrates the production chamber design.

2. PROCESS OPTIMIZATION

Figure 25 shows the evolution of the lamination process from work in the prototype chamber to the first production unit. Due to non-uniform lamp temperatures in the prototype unit, the 4 lamp configuration was changed to a 2 lamp arrangement in the bottom of the semi-cylindrical chamber. Polished aluminum lighting sheet (83% reflective) was cut



PRODUCTION LAMINATION CHAMBER

LAMINATION PROCESS OPTIMIZATION

PROTOTYPE OPERATION (50 MINUTES)

1. EVACUATE LOWER CHAMBER
2. EVACUATE UPPER CHAMBER
3. MAINTAIN UPPER AND LOWER VACUUM FOR 15 MINUTES
4. BACKFILL TOP CHAMBER TO ATMOSPHERIC PRESSURE
5. HEAT TO 150°C (302°F) AND HOLD FOR 15 MINUTES
6. COOL TO 65°C (150°F)
7. BACKFILL LOWER CHAMBER TO ATMOSPHERIC PRESSURE
8. REMOVE FINISHED LAMINATE

PRODUCTION OPERATION (32 MINUTES)

1. EVACUATE LOWER CHAMBER
2. EVACUATE UPPER CHAMBER
3. START HEATUP
4. BACKFILL TOP CHAMBER TO ATMOSPHERE WHEN TEMPERATURE IS 100°C (212°F)
5. HOLD AT 150°C FOR 8 MINUTES
6. BACKFILL LOWER CHAMBER TO ATMOSPHERE
7. REMOVE FINISHED LAMINATE

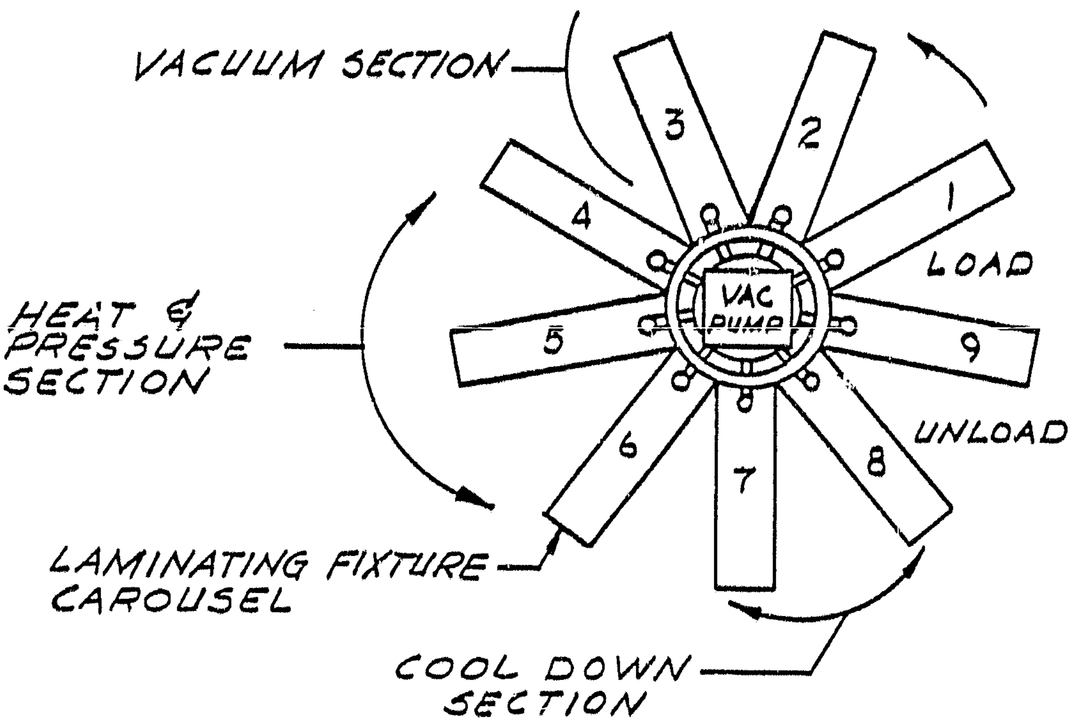
to fit the curvature of the chamber. The lamps (quartz-halogen), which were each rated at 5 kW @ 960 V, were operated at 480 VDC in an on/off mode as dictated by the need for heat from the controller. At this voltage the lamps were each rated at about 1.6 kW, and both lamp life and uniformity were good. High temperature areas in the center of the lamps were moderated by the addition of pieces of aluminum lighting strips over the lamps. In this way it was possible to maintain a temperature of ± 10°C over the .37 m^2 (4 ft^2) area of the glass superstrate.

Early laminations were allowed to cool under vacuum to 65°C (150°F) since it was thought that edge blow-in of air would occur while the PVB was soft. Investigation of this aspect revealed that removal of the laminate at 150°C did not result in edge blow-in and this step was subsequently eliminated.

3. PRODUCTION OPERATION

In August 1979, two prototype production units were integrated into ARCO Solar's module production facility and were operated at yields of 97-98%. These units were operated on a 35-40 minute cycle such that 3 modules/hour could be fabricated. Later in 1979, two additional units were added to double this capacity.

All units had manual valving and temperature control was maintained by the thermocouple feedback to a temperature controller. The controller operated a high voltage on/off



LAMINATION CAROUSEL

FIGURE 26

V. PILOT OPERATION AND SAMIS ANALYSIS

A. PILOT PRODUCTION VERIFICATION

The purpose of this pilot operation was to demonstrate equipment operation by producing 288 module assemblies and prepare a manufacturing cost analysis. This cost information was then used as a data base for SAMIS* preparation and determination of program cost achievements. The production line verification run was conducted April 8 and 9, 1981. Table 2 is the production run history of the auto-soldering equipment indicating downtime and reasons. The lamination equipment was operated continuously during each day shift and a total of 350 modules were manufactured. No downtime was experienced with the lamination equipment.

In Table 3 are the resulting yields from the pilot operation. Below a comparison is made between program goals and achievements from the pilot verification run.

	PROGRAM GOALS	PILOT PRODUCTION
SOLDERING RATE	12 cells/minute	16 cells/minute**
LAMINATION RATE	12 modules/hour	20 modules/hour***

* SAMIS-Standard Assembly-line Manufacturing Industry Simulation. A computer program developed by JPL for DOE to project photovoltaic module fabrication costs.

** Single automated soldering machine.

TABLE 2
AUTO-SOLDERING PRODUCTION RUN HISTORY

	CLOCK	RUN TIME	DOWN TIME	MAINTENANCE	NOTES
START	9:32:00				
		12:00			
STOP	9:44				
			2:00		Broken Cell
START	9:46				
		6:00			
STOP	9:52				
START	9:58			6:00	Change Ribbon
		5:00			
STOP	10:03				
			20:00		Ribbon Jam(stop for break)
START	10:23				
STOP	10:46	23:00			
			14:00		Ribbon Jam
START	11:00				
		42:00			
STOP	11:42				
				13:00	Clean Equipment
START	11:55				
		57:00			
STOP	12:52				
			30:00		Lunch Break
START	12:57				
		8:00			
STOP	1:05				
			5:00		Ribbon Jam
START	1:10				
		8:00			
STOP	1:18				
			82:00		Clean Equipment and make adjust.
START	2:40				
		12:00			
STOP	2:52				
START	3:04			12:00	Change Ribbon
		83:00			
STOP	4:27				
			3:00		Ribbon Jam
START	4:30				
		22:00			
STOP	4:52				
			2:00		Ribbon Jam

TABLE 2 (continued)
AUTO-SOLDERING PRODUCTION RUN HISTORY

	CLOCK	RUN TIME	DOWN TIME	MAINTENANCE	NOTES
START	4:54				
		14:00			
STOP	5:08				
			2:00		Ribbon Jam
START	5:10				
		16:00			
STOP	5:26				
			3:00		Ribbon Stopped
START	5:29				
		15:00			
END OF RUN	5:44				
TOTAL		338:00	138:00	31:00	
START	8:53				
		47:00			
STOP	9:40				
				7:00	Change Ribbon
START	9:47				
		37:00			
STOP	10:24				
			4:00		Boat Jam
START	10:28				
		97:00			
STOP	12:05				
			----	----	Out of Cells
START	2:05				
		72:00			
STOP	3:17				
				5:00	Change Ribbon
START	3:22				
		143:00			
END OF RUN	5:45				
TOTAL		396:00	4:00	12:00	
GRAND TOTAL		719:00	[illegible]:00	43:00	

TABLE 3
PILOT PRODUCTION YIELD

SOLDERING	TOTAL	NOT REWORKED	REWORKED
CRACKED CELLS	53	53	--
MISALIGNED CELLS	361	--	361
NO RIBBON	55		55
CRACKED CELLS	56	56	--
USE CLEANER	17	17	--
CELL SPACING	39	--	39
CASSETTE JAM	11	11	--
OTHER	--	--	--
TOTAL	592	137	455

TOTAL NUMBER OF CELLS SOLDERED: 11,504

INITIAL SOLDERING YIELD: 94.85%

YIELD AFTER REWORK: 98.81%

LAMINATION

NUMBER OF MODULES LAMINATED: 350

YIELD: 99.8%*

* This percentage based upon limited runs. The yield value is not conclusive.

B. COST ANALYSIS

Appendix A contains the Format A forms for the module assembly manufacturing process, including the two automated equipment/process sequences developed under this program. SAMIS analysis reveals that the module assembly cost is approximately $1.61/pW** based on an assumed yearly production rate of 2 MW/yr. Table 4 summarizes the program cost goals and actual projected costs. As can be seen, the cost goals were not totally met; however, the use of the automated equipment has resulted in a significant cost reduction in actual fact.

At the time this program was proposed as part of the Near Term Cost Reduction Program* to the LSA Project, production modules were primarily fabricated and assembled using hand labor. In-house analysis by ARCO Solar at that time indicated that module assembly costs (labor, materials and all other applicable costs excluding cells) were typically $2.43/pW (1978 dollars). If this same mode of fabrication were performed during the time of the automated equipment demonstration (April 1981) the assembly cost would have increased to approximately $3.15/pW based on an assumed SAMIS average inflation rate of 9% per year. Therefore, the development and use of this equipment has reduced the module assembly cost from $3.15/pW to $1.61/pW. This represents a very significatn cost reduction of approximately $1.54/pW (a 49% cost reduction.

* The Near Term Cost Reduction Program was funded as part of a special funding amendment sponsored by Congressman Tsongas.

** Based on preliminary data.

VI. CONCLUSIONS

The conclusions of importance to JPL and LSA program are that a signficant reduction in solar cell module manufacturing cost was achieved, and the state-of-the-art of module assembly manufacuring equipment was sufficiently automated to permit large scale low-cost module assembly.

APPENDIX A

COLORIMETRIC DETECTION OF ROSIN

TYPE OF TEST:	Rosin insolation and qualitative identification using sucrose/sulfuric acid test.
DESCRIPTION OF TEST:	Extract rosin from assembly using methylene chloride (dichloromethane) or toluene. Concentrate extract by forced evaporation. Shake extract with small amount of concentrated sucrose solution. After addition of 2-3 drops of concentrated sulfuric acid, a scarlet red color will develop if rosin is present.
INTERPRETATION:	Detection limit of rosin is 1.0mg/liter using this test.

SAMICS

FORMAT "A," "B," and "C" FORMS

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California Institute of Technology
4800 Oak Grove Dr / Pasadena, Calif 91103

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT C – INDUSTRY DESCRIPTION

C-1 Industry Referent: ARCOMOD

C-2 Descriptive Name of Industry: ARCO MODULE COMPANY

C-3 INDUSTRY OBJECTIVE: Produce peak-watt power

C-4 Units: Peak-watts/year

DESCRIPTION OF THE FINAL PRODUCT OF THE INDUSTRY

C-5 Reference: PAKMOD Name: Packed modules in carton

C-6 Production is Measured in: Carton

C-7 Hardware Performance: 132 Peak-watts/carton (Units are C-4 per C-6)

C-8 Product Design Description: Four 16-2000 Modules in one carton

MAKERS OF THE FINAL PRODUCT OF THE INDUSTRY

C-9 Company Reference: MODULECO Market Share: 100%

Company Reference: Market Share:

Company Reference: Market Share:

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT B – COMPANY DESCRIPTION

Company Referent: MODULECO

DESCRIPTIVE NAME: SOLAR MODULAR ASSEMBLY

15	0. (b)	(Final) Product(s) Produced	PAKMOD	
	(a)	(Final) Process(es)	PACKG	
	(c)	Ideal Ratio(s) with units		.25 Cartons/Module
14	1. (b)	Intermediate Product(s)	MODTEST	
	(a)	Process(es)	FINTEST	
	(c)	Ideal Ratio(s) with units		1 Module/Module
13	2. (b)	Intermediate Product(s)	CLNMOD	
	(a)	Process(es)	CLEANMOD	
	(c)	Ideal Ratio(s) with units		1 Module/Module
12	3. (b)	Intermediate Product(s)	FRAMMOD	
	(a)	Process(es)	FRAME	
	(c)	Ideal Ratio(s) with units		1 Module/Module
11	4. (b)	Intermediate Product(s)	DSPBUTYL	
	(a)	Process(es)	AFIXBTYL	
	(c)	Ideal Ratio(s) with units		1 Module/Module
10	5. (b)	Intermediate Product(s)	HIPOTTEST	
	(a)	Process(es)	HIPOT	
	(c)	Ideal Ratio(s) with units		1 Module/Module
9	6. (b)	Intermediate Product(s)	SODTRLUG	
	(a)	Process(es)	TERMSOD	
	(c)	Ideal Ratio(s) with units		1 Module/Module
8	7. (b)	Intermediate Product(s)	TRMLAM	
	(a)	Process(es)	EDGTRM	
	(c)	Ideal Ratio(s) with units	POSLAMCT	1 Module/Module
7	8. (b)	Intermediate Product(s)	POSLMCKT	
	(a)	Process(es)	POSLAMCT	
	(c)	Ideal Ratio(s) with units		1 Module/Module
6	9. (b)	Intermediate Product(s)	LAMCKT	
	(a)	Process(es)	LAMMOD	
	(c)	Ideal Ratio(s) with units		
		Purchased Product(s)		
		Supplier and Percentage		
		Supplier and Percentage		

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Format B: Company Description (Continued) — Financial Parameters

Page ____ Of ____

Note: In the LSA SAMICS context, leave this page blank; use default values of all company financial parameters.

Company Referent (From Front Side) ____________________

LSA SAMICS defaults and appropriate units are shown preprinted.

B-1 Percent of Capacity 100%	B-20 Startup Production Fraction 0.635 units/unit
B-2 (Financial) Leverage 1.2 $/$	B-21 Cash Balance Operation Time 0.06 yrs.
B-3 Debt Interest Rate 9.25%/yr.	B-22 Between Process Inventory Time 0 yrs.
B-4 Other Tax Rate 2%/yr.	B-23 Fiscal Hours Per Shift 8 hrs./shift
B-5 Insurance Rate 4%/yr.	B-24 Fiscal Minutes Per Fiscal Hour 60 min./hr.
B-6 Facility Life 40 yrs.	B-25 Fiscal Days Per Fiscal Week 7 days/wk.
B-7 Rate Of Return On Equity 20%/yr.	B-26 Fiscal Weeks Per Fiscal Year 52.1429 wks./yr.
B-8 Misc. Expense (as) Percentage Of Revenue 3%	B-27 Closed Weekdays Per Fiscal Year 20 days/yr.
B-9 Misc. Expense (as) Percentage Of Operating Expense 4%	B-28 Working Hours Per Person Per Shift 8 hrs./person/shift
B-10 Misc. Expense (as) Percentage Of Book Value 0%/yr.	B-29 Working Days Per Working Week 5 days/wk.
B-11 Facilities Tax Depreciation Method DDB	B-30 Paid Holidays Per Fiscal Year 8 days/yr.
B-12 Facilities Book Depreciation Method SL	B-31 Paid Vacation Days Per Fiscal Year 13.5 days/yr.
B-13 Facilities Inflation Rate Table 1975 8.0 • (yr. %/yr.)	B-32 Working Weeks Per Fiscal Year 52.1429 wks./yr.
	B-33 Average Paid Absenteeism Days Per Fiscal Year 17.5 days/yr.
B-14 Raw Materials Inventory Time 0.04 yrs.	B-34 Second Shift Wage Factor 1.15 ($/hr.)/($/hr.)
B-15 Processing Time Multiplier 1.0 min./min.	B-35 Third Shift Wage Factor 1.20 ($/hr.)/($/hr.)
B-16 Finished Goods Inventory Time 0.04 yrs.	B-36 Fourth Shift Wage Factor 1.20 ($/hr.)/($/hr.)
B-17 Accounts Receivable Turnover Time 0.10 yrs.	B-37 Number Of Shifts Per Day 3 shifts/day
B-18 Accounts Payable Turnover Time 0.09 yrs.	B-38 Facilities (Construction) Contingency Percentage 15%
B-19 Startup Direct Commodity Usage Fraction 1.25 units/unit	B-39 Equipment Contingency Percentage 15%

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT B — COMPANY DESCRIPTION

Company Referent

DESCRIPTIVE NAME

	0.	(b)	(Final) Product(s) Produced	
		(a)	(Final) Process(es)	
		(c)	Ideal Ratio(s) with units	1 Module/Module
5.5	1.	(b)	Intermediate Product(s)	ASMMOD
		(a)	Process(es)	ASLMMOD
		(c)	Ideal Ratio(s) with units	1 Module/Module
5	2.	(b)	Intermediate Product(s)	CLGLASS
		(a)	Process(es)	GLWASH
		(c)	Ideal Ratio(s) with units	1 Module/Module
4	3.	(b)	Intermediate Product(s)	PRELMCKT
		(a)	Process(es)	PRLAMCT
		(c)	Ideal Ratio(s) with units	1 Module/Module
3	4.	(b)	Intermediate Product(s)	SODMODCK
		(a)	Process(es)	TASOD
		(c)	Ideal Ratio(s) with units	1 Module/Module
2.5	5.	(b)	Intermediate Product(s)	CKTSUBTA
		(a)	Process(es)	TACKTSUB
		(c)	Ideal Ratio(s) with units	.03.03.03CELLCK/CELL
2	6.	(b)	Intermediate Product(s)	SCIS
		(a)	Process(es)	CELSTSOD
		(c)	Ideal Ratio(s) with units	1 Cell/Cell
1	7.	(b)	Intermediate Product(s)	SODPACELL
		(a)	Process(es)	SPSP
		(c)	Ideal Ratio(s) with units	
	8.	(b)	Intermediate Product(s)	
		(a)	Process(es)	
		(c)	Ideal Ratio(s) with units	
	9.	(b)	Intermediate Product(s)	
		(a)	Process(es)	
		(c)	Ideal Ratio(s) with units	
			Purchased Product(s)	
			Supplier and Percentage	
			Supplier and Percentage	

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Format B: Company Description (Continued) — Financial Parameters

Note: In the LSA SAMICS context, leave this page blank; use default values of all company financial parameters.

Company Referent (From Front Side) ______________________

LSA SAMICS defaults and appropriate units are shown preprinted.

B-1 Percent of Capacity 100%	B-20 Startup Production Fraction 0.635 units/unit
B-2 (Financial) Leverage 1.2 $/$	B-21 Cash Balance Operation Time 0.05 yrs.
B-3 Debt Interest Rate 9.25%/yr.	B-22 Between Process Inventory Time 0 yrs.
B-4 Other Tax Rate 2%/yr.	B-23 Fiscal Hours Per Shift 8 hrs./shift
B-5 Insurance Rate 4%/yr.	B-24 Fiscal Minutes Per Fiscal Hour 60 min./hr.
B-6 Facility Life 40 yrs.	B-25 Fiscal Days Per Fiscal Week 7 days/wk.
B-7 Rate Of Return On Equity 20%/yr.	B-26 Fiscal Weeks Per Fiscal Year 52.1429 wks./yr.
B-8 Misc. Expense (as) Percentage Of Revenue 3%	B-27 Closed Weekdays Per Fiscal Year 20 days/yr.
B-9 Misc. Expense (as) Percentage Of Operating Expense 4%	B-28 Working Hours Per Person Per Shift 8 hrs./person/shift
B-10 Misc. Expense (as) Percentage Of Book Value 0%/yr.	B-29 Working Days Per Working Week 5 days/wk.
B-11 Facilities Tax Depreciation Method DDB	B-30 Paid Holidays Per Fiscal Year 8 days/yr.
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B-13 Facilities Inflation Rate Table 1975 8.0 • (yr. %/yr.)	B-32 Working Weeks Per Fiscal Year 52.1429 wks./yr.
	B-33 Average Paid Absenteeism Days Per Fiscal Year 17.5 days/yr.
B-14 Raw Materials Inventory Time 0.04 yrs.	B-34 Second Shift Wage Factor 1.15 ($/hr.)/($/hr.)
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B-17 Accounts Receivable Turnover Time 0.10 yrs.	B-37 Number Of Shifts Per Day 3 shifts/day
B-18 Accounts Payable Turnover Time 0.09 yrs.	B-38 Facilities (Construction) Contingency Percentage 15%
B-19 Startup Direct Commodity Usage Fraction 1.25 units/unit	B-39 Equipment Contingency Percentage 15%

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process (Referent)
SPSP

Note: Names given in brackets ( ) are the names of process attributes requested by the SAMIS computer program.

A-2 (Descriptive. Name) of Process: Screen print solder paste

PART 1 — PRODUCT DESCRIPTION

A-3 (Product. Referent): SODPACELL

A-4 Descriptive Name (Product. Name): Solder paste printed cell

A-5 Unit Of Measure (Product. Units): Cell

PART 2 — PROCESS CHARACTERISTICS

A-6 (Output. Rate) (Not Thruput): 22.790425 (.5%) Units (given on line A-5) Per Operating Minute

A-7 (Inprocess. Inventory. Time): 6.0549548 Calendar Minutes (Used only to compute in-process inventory)

A-8 (Duty. Cycle): .85238095 Operating Minutes Per Minute

A-8a (Number. Of. Shifts. Per. Day): 3 Shifts

A-8b (Personnel. Integerization. Override. Switch): Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component (Referent)	PAPRINTER	CSTACKER	CFURNACE
A-9a Component (Descriptive. Name)	Printer	Stacker	Furnace
A-10 Base Year For Equipment Prices (Price. Year)	1979	1979	1979
A-11 (Purchase. Cost. Vs. Quantity. Bought. Table) (Number Of and $ Per Component)	125000	20000	31000
A-12 Anticipated (Useful. Life) (Years)	7	7	7
A-13 (Salvage. Value) ($ Per Component)	Ø	Ø	Ø
A-14 (Removal. And. Installation. Cost) ($/Component)	1500	200	2500

Note: The SAMIS computer program also prompts for the (Payment. Float. Interval), the (Inflation. Rate. Table), the (Equipment. Tax. Depreciation. Method), and the (Equipment. Book. Depreciation. Method). In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) SPSP

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	350	SqFt	Manufacturing Space
B3752D	1.0	Person/Shift	Operator, Prod-Machine

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	1.11111	kWh/min	Electricity
C2032D	10	CFM	Compressed air
E1065D	3.5714285	GR/min	Solder Paste Cream
E1141D	21.873298		Cell (Dummy) Photo-voltaic

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield) * (%)	A-26 (Ideal, Ratio) ** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
				SODPACELL

PREPARED BY	DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#2

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent]: CELSTSOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process: Cell String Soldering

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent]: SCIS

A-4 Descriptive Name [Product. Name]: Solder Cell Into String

A-5 Unit Of Measure [Product. Units]: Cell CK

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput): 14.66324 — 1.5 loss — Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time]: 6.5986108 — Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle]: .875 — Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day]: 3 — Shifts

A-8b [Personnel. Integerization. Override. Switch]: Off — (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	STRGSOD		
A-9a Component [Descriptive. Name]	String Solder		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	≃250,000		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	Ø		
A-14 [Removal. And. Installation. Cost] ($/Component)	≃10,000		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) CELSTSOD

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	168.33333	SqFt	Manufacturing Space
B3752D	2.5	Persons/Shift	Operator Prod-Machine

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.1242833	kWh/min	Electricity
C2032D	5	CFM	Compressed Air
EP15D	38.255	GR/min	Interconnecting Ribbon .100 X .002

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
SODPACELL	.988	1/33	CELLCK/CELL	SCIS

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#2.5

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent] TACKTSUB

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process Turn Around CKT Sub-Assembly

PART 1 — PRODUCT DESCRIPTION

A-3 [Product. Referent] CKTSUBTA

A-4 Descriptive Name [Product. Name] CKT sub turn around

A-5 Unit Of Measure [Product. Units] SUBCKT

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput) 10 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time] .1 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	TAMACH		
A-9a Component [Descriptive. Name]	CKT TA Machine		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	20000		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	Ø		
A-14 [Removal. And. Installation. Cost] ($/Component)	500		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) TACKTSUB

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	27.5	SqFt	Manufacturing Space
B3752D	1	Persons/Shift	Operator Prod-Machine

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.1	kWh/min	Electricity
E1835D	.00714285711	PR/min	Gloves cotton
EP16D	.008	LB/min	200 X .005 Ribbon

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
*	100	1	SUBCKT	CKTSUBTA

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or C.../Wafer.

#3

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

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A-1 Process [Referent] TASOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process Turn around soldering

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent] SODMODCK

A-4 Descriptive Name [Product. Name] Solder several strings together

A-5 Unit Of Measure [Product. Units] Module

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput) 1.155 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time] 103.5 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] .9375 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	TABECH		
A-9a Component [Descriptive. Name]	Bench		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	3000		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	Ø		
A-14 [Removal. And. Installation. Cost] ($/Component)	500		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) TASOD

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	35.5	SqFt	Manufacturing space
B3032D	1.0	Person/Shift	Assembler Electronics

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 ~~Catalog Number~~ (Expense Item Referent)	A-22 ~~Amount Required~~ Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.002	kWh/min	Electricity
E1835D	.0077777	Glove	Gloves cotton

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
SCIS	100	1/1	MODULE/CELLCK	SODMODCK
CKTSUBTA	100	1	MOD/SUBCKT	

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#4

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent]
PRLAMCT

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process Prelamination CKT test

PART 1 — PRODUCT DESCRIPTION

A-3 [Product, Referent] PRELMCKT

A-4 Descriptive Name [Product, Name] Test ckt for being fully operable

A-5 Unit Of Measure [Product, Units] Module

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput) 1.33333 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess, Inventory, Time] 17.25 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle] .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day] 3 Shifts

A-8b [Personnel, Integerization, Override, Switch] Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	XENON	Gauge	
A-9a Component [Descriptive, Name]	Generator		
A-10 Base Year For Equipment Prices [Price, Year]	1979	1979	
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	4500	29061	
A-12 Anticipated [Useful, Life] (Years)	7	7	
A-13 [Salvage, Value] ($ Per Component)	1000	500	
A-14 [Removal, And, Installation, Cost] ($/Component)	500	250	

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) PRLAMCT

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	38	SqFt	Manufacturing Space
B3752D	1	Persons/Shift	Operator Prod-Mach

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.166666	kWh/min	Electricity

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
SODMODCK	.995	1/1	MODULE/MODULE	PRELMCKT

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DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#5

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

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A-1 Process [Referent]: GLSWASH

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process: Glass washing

PART 1 — PRODUCT DESCRIPTION

A-3 [Product. Referent] CLGLASS

A-4 Descriptive Name [Product. Name] Wash 1'X4' Pane of glass

A-5 Unit Of Measure [Product. Units] Glass

PART 2 — PROCESS CHARACTERISTICS .1% Loss not considered in output

A-6 [Output. Rate] (Not Thruput) 0.5 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time] 160 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] 0.83174603 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	GLASWASH		
A-9a Component [Descriptive. Name]	Glass washing		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	17000		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	Ø		
A-14 [Removal. And. Installation. Cost] ($/Component)	500		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) GLSWASH

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	336	SqFt	Manufacturing Space
B3752D	2.0	Persons/Shift	Operator, Prod-Machine

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.10564055	kWh/min	Electricity 8.5 HP
C1016B	.016729589	CuFt	Water domestic
E1815D	2.0	2pcs/min	Glass, Sunadex
ECD11D	.00069986838	LB	Detrex Soap #531700869-00 $740/550#

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#5.5

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent]: ASLMMOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process: Assemble lamination module

PART 1 — PRODUCT DESCRIPTION

A-3 [Product, Referent]: ASMMOD

A-4 Descriptive Name [Product, Name]: Assembled module

A-5 Unit Of Measure [Product, Units]: Module

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput): .33333 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess, Inventory, Time]: ______ ______ Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle]: .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day]: 3 Shifts

A-8b [Personnel, Integerization, Override, Switch]: Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	ATOMCHAM		
A-9a Component [Descriptive, Name]	Ball Chamber		
A-10 Base Year For Equipment Prices [Price, Year]	1980		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	150000		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	Ø		
A-14 [Removal, And, Installation, Cost] ($/Component)	1000		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) ASLMMOD

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	851.35937	SqFt	Manufacturing Space
B3080D	2.0	Persons/Shift	Assembler Module

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.18331742	kWh/min	Electricity
EG22D	5.333333	SqFt	PVB
EM1010D	1.333333	SqFt	CORAD
E1815D	1.333333	SqFt	

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Or Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
CLGLASS	1.0	1/1	MODULE/GLASS	ASMMOD
PRELMCKT	1.0	1/1	MODULE/MODULE	

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#6

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

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A 1 Process [Referent]: LAMMOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process: Glass & circuit lamination

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent]: LAMCKT

A-4 Descriptive Name [Product. Name]: Lamination of cell circuit to glass super strate

A-5 Unit Of Measure [Product. Units]: Module

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput): .2886813188 Units (given on line A-5) Per Operating Minute — .5% Loss

A-7 [Inprocess. Inventory. Time]: 189.58333 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle]: .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day]: 3 Shifts

A-8b [Personnel. Integerization. Override. Switch]: Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	LACHAMB		
A-9a Component [Descriptive. Name]	Lam chamber		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	200000		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	Ø		
A-14 [Removal. And. Installation. Cost] ($/Component)	2500		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

A-15 Process Referent (From Front Side Line A-1) LAMMOD

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	647.22222	SqFt	Manufacturing Space
B3048D	2.0	Persons/Shift	Assembler encapsulator

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.29	kWh/min	Electricity
C2032D	1.0	CFM	Compressed air
E1835D	.0071428571	Pairs	Gloves
E1569D	.0021978021	Sheet	Rubber sheets

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield) * (%)	A-26 (Ideal, Ratio) ** Of Units Out/Units In	A-27 Units Of A-28***	A-25 Just Name
ASMMOD	1.0	1/1	MODULE/MODULE	LAMCKT

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DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#7

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent]: POSLAMCT

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process: Post lamination circuit test

PART 1 — PRODUCT DESCRIPTION

A-3 [Product, Referent]: POSLMCKT

A-4 Descriptive Name [Product, Name]: Test circuit for being fully operable

A-5 Unit Of Measure [Product, Units]: Module

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput): 1.33333 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess, Inventory, Time]: 17.25 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle]: .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day]: 3 Shifts

A-8b [Personnel, Integerization, Override, Switch]: Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	XENON		
A-9a Component [Descriptive, Name]	Generator		
A-10 Base Year For Equipment Prices [Price, Year]	1979		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	4500		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	1000		
A-14 [Removal, And, Installation, Cost] ($/Component)	500		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) POSLMCT

PART 4 -- DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	38	SqFt	Manufacturing space
B3752D	1	Persons/Shift	Operator Prod-Mach

PART 5 -- DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.16666	KWh/min	Electricity

PART 6 -- INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
LAMCKT	.995	1/1	MODULE/MODULE	POSLMCKT

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent] EDGTRM

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process: Lamination edge trim

PART 1 – PRODUCT DESCRIPTION

A-3 [Product, Referent]: TRMLAM

A-4 Descriptive Name [Product, Name]: Trim excess lam from edge of module

A-5 Unit Of Measure [Product, Units]: Module

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput): .83333 Units (given on line A-5) Per Operating Minute .1%

A-7 [Inprocess, Inventory, Time]: 2.25 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle]: .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day]: 3 Shifts

A-8b [Personnel, Integerization, Override, Switch]: Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	ETRIM		
A-9a Component [Descriptive, Name]	Edge trim		
A-10 Base Year For Equipment Prices [Price, Year]	1980		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	≈1000		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	50		
A-14 [Removal, And, Installation, Cost] ($/Component)	10		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) EDGTRM

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	27.5	SqFt	Manufacturing Space
B3080D	1	Persons/Shift	Assemble module

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
EG1036D	.47619047	Blades/min	Razor blades
E1835D	.0071428571	Pair	Gloves cotton
E1370D	.33333	Each	Label SN
E1372D	.33333	Each	Label Grounding
E1371D	.33333	Each	Label Warning

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
POSLMCKT	1.0	1/1	MODULE/MODULE	TRMLAM

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

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A-1 Process [Referent]: TERMSOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process: Terminal soldering

PART 1 — PRODUCT DESCRIPTION

A-3 [Product, Referent]: SODTRLUG

A-4 Descriptive Name [Product, Name]: Solder terminal lug to module

A-5 Unit Of Measure [Product, Units]: Module

PART 2 — PROCESS CHARACTERISTICS

Ø Loss

A-6 [Output, Rate] (Not Thruput): .75 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess, Inventory, Time]: 1.33333 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle]: .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day]: 3 Shifts

A-8b [Personnel, Integerization, Override, Switch]: Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	INDHTR		
A-9a Component [Descriptive, Name]	Induction Heater		
A-10 Base Year For Equipment Prices [Price, Year]	1979		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	10000		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	1000		
A-14 [Removal, And, Installation, Cost] ($/Component)	1000		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) TERMSOD

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	104	SqFt	Manufacturing Space
B3032D	1.0	Persons/Shift	Assembler, Electronics

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.3125	kWh/min	Electricity
C2032D	.1	CFM	Compressed Air
E1065D	.39682538	GR.	Solder paste
E1900D	1.5	Each	2 Terminal lugs
E1915D	1.5	"	2 Screw 10-32
E1910D	1.5	"	2 Flat Washer
E1905D	1.5	"	2 Lock Washer

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield) * (%)	A-26 (Ideal, Ratio) ** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
TRMLAM	1.0	1/1	MODULE/MODULE	SOLTRLUG

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

Page 1 of 2

FORMAT A — PROCESS DESCRIPTION

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A-1 Process [Referent]
HIPOT

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process Hi voltage pot test

PART 1 — PRODUCT DESCRIPTION

A-3 [Product, Referent] HIPOTTEST

A-4 Descriptive Name [Product, Name] Hi voltage pot test

A-5 Unit Of Measure [Product, Units] Module

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput) 1.3333 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess, Inventory, Time] 17.25 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle] .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day] 3 Shifts

A-8b [Personnel, Integerization, Override, Switch] Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	HIPOTTES		
A-9a Component [Descriptive, Name]	Hi pot test		
A-10 Base Year For Equipment Prices [Price, Year]	1980		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	1200		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	500		
A-14 [Removal, And, Installation, Cost] ($/Component)	300		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) HIPOT

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	27.5	SqFt	Manufacturing Space
B3704D	1	Persons/Shift	Electronics technician

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.1	KWh/min	Electricity

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
SODTRLUG	.995	1/1	MODULE/MODULE	HIPOTTEST

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DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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FORMAT A — PROCESS DESCRIPTION

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A-1 Process [Referent]
FRAME

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process Framing the module

PART 1 — PRODUCT DESCRIPTION

A-3 [Product. Referent] FRAMMOD

A-4 Descriptive Name [Product. Name] Framing the module

A-5 Unit Of Measure [Product. Units] Module

PART 2 — PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput) .33333 Units (given on line A-5) Per Operating Minute — Ø Loss

A-7 [Inprocess. Inventory. Time] 69.0 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 — EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	FIXTURE	HEATER	
A-9a Component [Descriptive. Name]	Wood Fixture	Flat Heater	
A-10 Base Year For Equipment Prices [Price. Year]	1980	1980	
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	2000	300	
A-12 Anticipated [Useful. Life] (Years)	7	7	
A-13 [Salvage. Value] ($ Per Component)	100	100	
A-14 [Removal. And. Installation. Cost] ($/Component)	100	100	

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) FRAME

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
[Facility, Or, Personnel Requirement]

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) [Amount, Per, Machine]	A-19 Units	A-17 Requirement Description or Name
A2096D	94.66666	SqFt	Manufacturing Space
B3080D	1	Persons/Shift	Assembly Module

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
[Byproduct] and [Utility, Or, Commodity Requirement]

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute [Amount, Per, Cycle]	A-23 Units	A-21 Requirement Description or Name
C1032B	.2892	kWh/min	Electricity
E1920D	2.2857142	Screw/min	Screw #320700416-01

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 [Required, Product] [Reference]	A-28 [Yield] * (%)	A-26 [Ideal, Ratio] ** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
DSPBUTYL	1.0	1/1	MODULE/MODRAIL	FRAMMOD
HIPOTTEST				

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*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process (Referent): AFIXBTYL

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process: Affix butyl to module frames

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent] DSPBUTYL

A-4 Descriptive Name [Product. Name] Dispense butyl onto module frames

A-5 Unit Of Measure [Product. Units] MODRAIL

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput) 1.25 Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time] 130 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	APPLICATOR	DISPENSER	DISPENSER
A-9a Component [Descriptive. Name]			Dispenser
A-10 Base Year For Equipment Prices [Price. Year]			1979
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)			35000
A-12 Anticipated [Useful. Life] (Years)			7
A-13 [Salvage. Value] ($ Per Component)			Ø
A-14 [Removal. And. Installation. Cost] ($/Component)			800

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) AFIXBTYL

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	252	SqFt	Manufacturing Space
B3752D	2	Persons/Shift	

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.0621415	kWh/min	Electricity
C2032D	.1	CFM	Compressed Air
E1232D	.02028566	GR	Edge Seal
E1835D	.0071428571	Pair	Gloves

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name

PREPARED BY	DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent] CLEANMOD

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process: Clean entire module

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent]: CLNMOD

A-4 Descriptive Name [Product. Name]: Clean module

A-5 Unit Of Measure [Product. Units]: Module

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput): .11904761 Units (given on line A-5) Per Operating Minute — Ø Loss

A-7 [Inprocess. Inventory. Time]: 193.2 Calendar Minutes (Used only to compute inprocess inventory)

A-8 [Duty. Cycle]: .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day]: 3 Shifts

A-8b [Personnel. Integerization. Override. Switch]: Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	CLEANMOD		
A-9a Component [Descriptive. Name]	Clean module		
A-10 Base Year For Equipment Prices [Price. Year]	1980		
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	200		
A-12 Anticipated [Useful. Life] (Years)	7		
A-13 [Salvage. Value] ($ Per Component)	50		
A-14 [Removal. And. Installation. Cost] ($/Component)	10		

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) CLEANMOD

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	44	SqFt	Manufacturing Space
B3080D	1	Persons/Shift	Assemble module

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
EG1036D	.11904761	Blades/min	Razor blades
E1353D	.0095238095	Gal/min	Propanell
EG23D	.0095238095	Gal/min	Solvant
E1836D	.0023809523	Pair	Gloves Pletex
E1837D	.059523809	Each	Gloves Rubber thin
EG60D	.23809523	Each	Terminal support

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
FRAMMOD	1.0	1/1	MOD/MOD	CLNMOD

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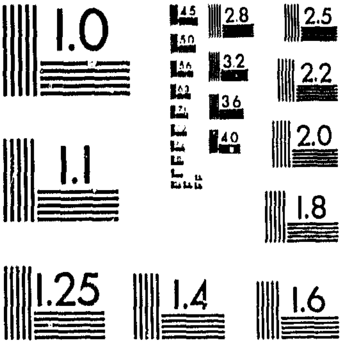
*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

#14

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SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent] FINTEST

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive, Name] of Process Final module electrical test

PART 1 – PRODUCT DESCRIPTION

A-3 [Product, Referent] MODTEST

A-4 Descriptive Name [Product, Name] Test module for rating

A-5 Unit Of Measure [Product, Units] Module

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output, Rate] (Not Thruput) .85714285 Units (given on line A-5) Per Operating Minute .41493775 Loss .5/120.5

A-7 [Inprocess, Inventory, Time] 26.833335 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty, Cycle] .875 Operating Minutes Per Minute

A-8a [Number, Of, Shifts, Per, Day] 3 Shifts

A-8b [Personnel, Integerization, Override, Switch] Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	FINTESTER		
A-9a Component [Descriptive, Name]			
A-10 Base Year For Equipment Prices [Price, Year]	1980		
A-11 [Purchase, Cost, Vs, Quantity, Bought, Table] (Number Of and $ Per Component)	150000		
A-12 Anticipated [Useful, Life] (Years)	7		
A-13 [Salvage, Value] ($ Per Component)	40000		
A-14 [Removal, And, Installation, Cost] ($/Component)	1000		

Note: The SAMIS computer program also prompts for the [Payment, Float, Interval], the [Inflation, Rate, Table], the [Equipment, Tax, Depreciation, Method], and the [Equipment, Book, Depreciation, Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) FINTEST

PART 4 – DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
(Facility, Or, Personnel Requirement)

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) (Amount, Per, Machine)	A-19 Units	A-17 Requirement Description or Name
A2096D	204	SqFt	Manufacturing Space
B20801	1	Persons/Shift	Digital Comp Operator

PART 5 – DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
(Byproduct) and (Utility, Or, Commodity Requirement)

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute (Amount, Per, Cycle)	A-23 Units	A-21 Requirement Description or Name
C1032B	.048	KWh/min	Electricity
E1835D	.0071428571	Pair/Min	Gloves cotton
E1375D	.23809523	Label/Min	Label, color

PART 6 – INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 (Required, Product) (Reference)	A-28 (Yield)* (%)	A-26 (Ideal, Ratio)** Of Units Out/Units In	A-27 Units Of A-28***	A-25 Product Name
CLNMOD	.996	1/1	MODULE/MODULE	MODTEST

PREPARED BY	DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.

#15

JET PROPULSION LABORATORY
California Institute of Technology
4800 Oak Grove Dr / Pasadena, Calif 91103

SOLAR ARRAY MANUFACTURING INDUSTRY COSTING STANDARDS

FORMAT A — PROCESS DESCRIPTION

A-1 Process [Referent] PACKG

Note: Names given in brackets [ ] are the names of process attributes requested by the SAMIS computer program.

A-2 [Descriptive. Name] of Process Packaging modules in carton

PART 1 – PRODUCT DESCRIPTION

A-3 [Product. Referent] PAKMOD

A-4 Descriptive Name [Product. Name] Pack modules in carton

A-5 Unit Of Measure [Product. Units] Carton

PART 2 – PROCESS CHARACTERISTICS

A-6 [Output. Rate] (Not Thruput) .25 — 9.67742% Loss — Units (given on line A-5) Per Operating Minute

A-7 [Inprocess. Inventory. Time] 90.785714 Calendar Minutes (Used only to compute in-process inventory)

A-8 [Duty. Cycle] .875 Operating Minutes Per Minute

A-8a [Number. Of. Shifts. Per. Day] 3 Shifts

A-8b [Personnel. Integerization. Override. Switch] Off (Off or On)

PART 3 – EQUIPMENT COST FACTORS (Machine Description)

A-9 Component [Referent]	STAPLER	Bander	
A-9a Component [Descriptive. Name]	STAPLER	Bander	
A-10 Base Year For Equipment Prices [Price. Year]	1980	1980	
A-11 [Purchase. Cost. Vs. Quantity. Bought. Table] (Number Of and $ Per Component)	500	180	
A-12 Anticipated [Useful. Life] (Years)	7	7	
A-13 [Salvage. Value] ($ Per Component)	400	20	
A-14 [Removal. And. Installation. Cost] ($/Component)	Ø	0	

Note: The SAMIS computer program also prompts for the [Payment. Float. Interval], the [Inflation. Rate. Table], the [Equipment. Tax. Depreciation. Method], and the [Equipment. Book. Depreciation. Method]. In the LSA SAMICS context, use 0.0, (1975 6.0 *), DDB, and SL. (The asterisk is a signal to the computer, not a reference to a footnote.)

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Format A: Process Description (Continued)

A-15 Process Referent (From Front Side Line A-1) PACKG

PART 4 — DIRECT REQUIREMENTS PER MACHINE (Facilities) OR PER MACHINE PER SHIFT (Personnel)
[Facility. Or. Personnel Requirement]

A-16 Catalog Number (Expense Item Referent)	A-18 Amount Required Per Machine (Per Shift) [Amount. Per. Machine]	A-19 Units	A-17 Requirement Description or Name
A2096D	594	SqFt	Manufacturing Space
B3720D	1	Persons/Shift	Inspector system

PART 5 — DIRECT REQUIREMENTS PER MACHINE PER MINUTE (SAMIS will ask first for Byproducts)
[Byproduct] and [Utility. Or. Commodity Requirement]

A-20 Catalog Number (Expense Item Referent)	A-22 Amount Required Per Machine Per Minute [Amount. Per. Cycle]	A-23 Units	A-21 Requirement Description or Name
C1032B	.0041427666	kWh/min	Electricity
C2032D	3	CFM	Compressed air
E1930D	18.0	Staple	Staples
EG42D	.22580645	Sets	Box sets
	2.0	Bands	

PART 6 — INTRA-INDUSTRY PRODUCT(S) REQUIRED

A-24 [Required. Product] [Reference]	A-28 [Yield]* (%)	A-26 [Ideal. Ratio]** Of Units Out/Units In	A-27 Units Of A-26***	A-25 Product Name
MODTEST	1.0	1/4	CARTON/MODULE	PAKMOD

PREPARED BY | DATE

*100% minus percentage of required product lost in this process.
**Assume 100% yield here.
***Examples: Modules/Cell or Cells/Wafer.