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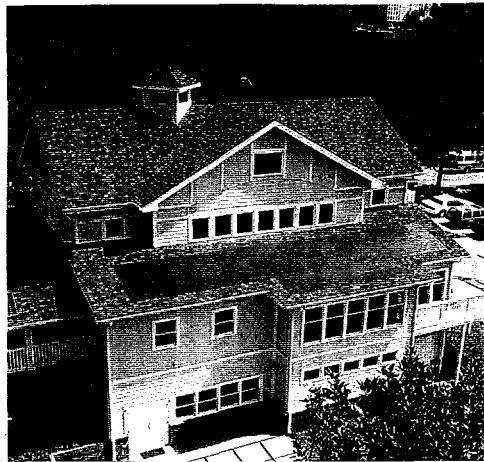
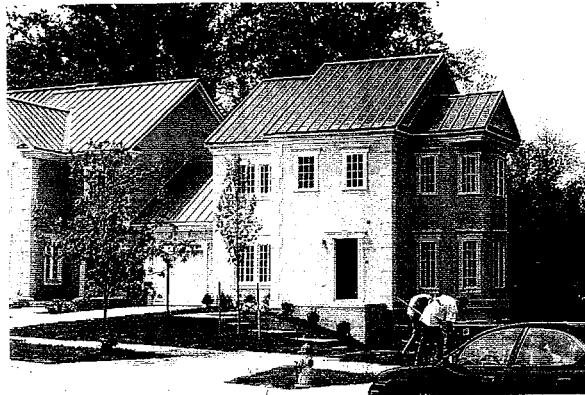
ROOFTOP PV SYSTEM

Final Technical Report
PV:BONUS Phase IIIB

DOE/CH/10571--T3

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Demonstration projects for ECD's PV:BONUS I Program. Top: ECD's PV metal roofing modules on the NAHB Research Center's 21st Century Townhouse Project in Bowie, Maryland; Bottom: United Solar's shingle modules on the Southface Environmental Resource Center in Atlanta, Georgia.

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TABLE OF CONTENTS

	PAGE
INTRODUCTION AND SUMMARY	4
Tasks (1-2): Completion and Monitoring of PV Shingle Array at the Energy Efficient House (1), and Standing Seam Metal Roofing Array on the NAHB House (2).....	5
Task 3: Introduction of the PV Shingles and Standing-Seam Metal Roofing Developed Under PV:BONUS into the United Solar Product Line.....	5
Task 4: Market Development and Business Planning	6
TASK 1. COMPLETION AND MONITORING OF PV SHINGLE ARRAY AT THE ENERGY EFFICIENT HOUSE, ATLANTA	7
A. Project Design	8
1. <i>Mechanical design and installation.....</i>	8
2. <i>Electrical design and installation.....</i>	10
B. Electrical System.....	11
1. <i>Data collection System.....</i>	11
2. <i>Electrical Installation/Design.....</i>	12
3. <i>Museum Display.....</i>	12
C. PV Shingle Installation on the Southface House.....	16
1. <i>PV Shingle Installation.....</i>	16
2. <i>Electrical Installation.....</i>	18
D. Southface Energy and Environmental Resource Center Array Monitoring.....	20
Task 2. Completion and Monitoring of Standing-Seam Metal Roofing Array on the NAHB House.....	24
A. Project Design.....	25
B. Electrical System.....	26
C. PV Metal Roofing Array Installation on the NAHB Research Center 21st Century Townhouse.....	30
D. Array Monitoring.....	34
Task 3. Introduction of the PV Shingles and Standing-Seam Metal Roofing Developed Under PV:BONUS into the United Solar Product Line.....	36
Shingle Module.....	36
1. <i>Introduction.....</i>	36
2. <i>Module Design.....</i>	37
3. <i>Roofing and Installation Considerations.....</i>	41
4. <i>Testing and Systems.....</i>	43
5. <i>Manufacturing.....</i>	46
Metal Roofing Modules.....	46
Task 4. Summary of Marketing Activities.....	48

LIST OF APPENDICES

Appendix I. NAHB Research Center Integrated PV Metal Roofing Project Summary

- Appendix 1.A NAHB 21st Century Townhouse Project Press Release
- Appendix 1.B Plots of PV Array Output vs. Temperature
- Appendix 1.C Normalized PV Output for 15-Month Period

Appendix II. United Solar BIPV Product Specifications

Appendix III. IEEE 1262 Testing Report Summary

Appendix IV. Shingle Module Owners Guide and Installation Guide

Appendix V. Shingle Module Installation Instructions

Appendix VI. Metal Roofing Owners Guide

Appendix VII. Metal Roofing Installation Instructions

Appendix VIII. Uni-Solar BIPV Sales Brochures

Introduction and Summary

During the past fifteen years, Energy Conversion Devices, Inc. (ECD) has made important progress in the development of materials, device designs and manufacturing processes required for the continued advancement and commercialization of photovoltaic technology. Among these accomplishments, ECD has pioneered and continues to develop two key proprietary technologies with significant potential for achieving the cost goals necessary for widespread growth of the photovoltaic market:

- (1) a low-cost, roll-to-roll continuous substrate thin-film solar cell manufacturing process; and
- (2) a high-efficiency, multiple-junction, spectrum-splitting thin-film amorphous silicon (a-Si) alloy device structure.

Commercial production of multiple-junction a-Si alloy modules has been underway at ECD and its American joint venture company, United Solar Systems Corp. (United Solar), for a number of years using ECD's proprietary roll-to-roll process and numerous advantages of this technology have been demonstrated. These include relatively low semiconductor material and process costs and a lightweight, rugged and flexible substrate that results in lowered installed costs of PV systems. In early 1997 United Solar began shipping product from its new 5 MW triple-junction facilities in Troy, MI that were designed and built by ECD.

Under the PV:BONUS Program, ECD and United Solar developed, demonstrated and commercialized two new lightweight, flexible BIPV modules specifically designed as replacements for conventional asphalt shingles and standing seam metal roofing. These modules can be economically and aesthetically integrated into new residential and commercial buildings, and can be used to address the even larger roofing-replacement market. An important design feature of these modules, which minimizes the installation and balance-of-system costs, is their ability to be installed by conventional roofing contractors without special training. The modules are fabricated from high-efficiency, triple-junction spectrum-splitting a-Si alloy solar cells developed by ECD and United Solar. These cells are produced on thin, flexible stainless steel substrates and encapsulated with polymer materials.

Under the Phase I Program, which ended in March 1994, we developed two different concept designs for the rooftop PV modules: (1) the United Solar 10 ft. long overlapping (asphalt replacement) shingle-type modules and (2) the ECD 20 ft. long metal roof-type modules. We also developed a plan for fabricating, testing and demonstrating these modules. Candidate demonstration sites for our rooftop PV modules were identified and preliminary engineering designs for these demonstrations were developed.

The major accomplishments of the Phase II Program, June 1994 - June 1995, were (1) the development, testing, and qualification the rooftop modules; (2) the development of mechanical and electrical engineering specifications for the

demonstration projects; and (3) the development of a marketing and commercialization plan.

The Phase III program began in August 1995. The principal tasks and goals of this program, which have all been successfully completed by ECD and United Solar, are summarized below and then described in more detail in the body and appendices of this report.

Tasks (1-2): Completion and Monitoring of PV Shingle Array at the Energy Efficient House, Atlanta (1) and Standing Seam Metal Roofing Array on the NAHB House (2).

ECD's metal roofing array was installed on the National Association of Home Builders Research Center 21st Century Townhouse in Bowie Maryland on Monday 06 May 1996. The modules were installed by the same roofing contractors that installed the original metal roof, after a 5 minute "training session/pep talk". The 18 modules were installed, with approximately 5 minutes required for the installation of each module. The roofers reported installation of these modules was nearly identical to the installation of conventional metal roofing, with the exception that the modules were easier to handle due to the increased stiffness from the PV lamination. This array was put on-line 09 May 1996 and has since operated continuously with no problems.

United Solar, employing two licensed roofing contractors from the Detroit area, installed a 2 kW shingle PV array on the Southface Energy Efficient House in Atlanta on 25 - 26 June 1996. The entire installation took about 16 hours and went almost entirely according to plan. One small deviation to the plan was the decision made on site to install only 110 of the planned 120 modules in order to leave a conventional shingle "walk-way" at the top of the array for workers to complete the construction of the unfinished wall. Even with this 8% reduction in modules, the array continues to operate with a normalized dc output power of over 2 kW.

Both these arrays have operated with no problems and continue to attract widespread attention in the media and to elicit a high degree of interest and excitement in the many visitors to these sites. In particular, the shingle module has received awards from Popular Science (The Best of What's New Grand Award) and Discovery magazines. The arrays are being continually monitored by on-site data-loggers.

Task 3: Introduction of the PV Shingles and Standing-Seam Metal Roofing Developed Under PV:BONUS into the United Solar Product Line.

These new BIPV modules have now been successfully introduced into United Solar's production line. There are now 5 standard products: the shingle module (SHR-17) that emulates standard asphalt/fiberglass shingles and a family of standing seam metal roofing laminates that can be integrated with either architectural or structural metal pans and are available in two different lengths, approximately 9 and 18 feet (ASR-64, ASR-128, SSR-64, SSR-128). The module

specifications are summarized in Appendix II of this report. A number of smaller milestones were met in achieving this goal:

- The Southface demonstration array used United Solar double-junction PV cells and the NAHB array used ECD prototype triple-junction PV cells. During the Phase IIIB portion of this program the module designs have been adapted to the new triple-junction spectrum-splitting PV cell now being manufactured at the new United Solar 5 MW manufacturing facility in Troy MI designed and built by ECD.
- The module encapsulation design has been improved, incorporating new types of Tefzel, EVA, and non-woven glass fiber to improve the module performance and reliability and to reduce the module cost.
- The modules have undergone full accelerated testing according to the IEEE 1262 standard. These tests are summarized in Appendix III. The modules have also been formally submitted to the Underwriters Laboratory (UL) for approval of the UL label under UL1703; certification is expected in January-February, 1998. Both the standing seam and shingle modules have passed developmental tests for a Class C fire rating. The shingle module has passed wind test of 120 mph, and the standing seam modules will be rated at UL90 based on an already approved standing-seam design.
- The installation techniques for these modules, designed to be installed by conventional roofing contractors with little or no additional training, have been revised and optimized to minimize the time and cost of installation. This has been an iterative process with changes in installation method affecting details of the module design, and vice versa. The installation procedures for the shingle and metal roofing guides are contained in Appendices V and VII.
- Jigs and fixtures have been designed, tested and implemented in the production lines. Detailed work standards and documentation have been prepared for manufacturing and marketing the products.
- The modules have been incorporated into United Solar's manufacturing line and are now offered as standard products with a 10 year warranty.

Task 4: Market Development and Business Planning

United Solar, at its own expense, has been carrying out extensive marketing and business planning activities to commercialize these new BIPV products. These activities are aimed to achieve United Solar's goal of dominating the emerging BIPV market worldwide. Sales literature has been prepared for these modules. Information is also being prepared for inclusion in the next edition of Sweet's, the standard architectural and building reference guide. The new modules have been installed on a number of additional demonstration (and other) sites. Solar Utilities Company, Inc. is marketing these products in the U.S.

In the following report we summarize the work on each of the principle tasks listed above.

TASK 1: COMPLETION AND MONITORING OF PV SHINGLE ARRAY AT THE ENERGY EFFICIENT HOUSE, ATLANTA



A. Project Design

1. Mechanical design and installation

The PV array consists of 110 shingle modules installed on an 800 sq. ft. roof deck over the main floor of the Southface Ecology House in Atlanta. The shingle modules cover an approximate 500 sq. ft. portion of this deck. The modules are arranged in five columns (up and down the roof deck), making for an array width of 50 ft. Due to the geometry of the roof, two columns of shingle modules contain 30 rows and the other three columns 20 rows, as shown in Fig. 1.A.1. The modules are positioned sufficiently in from the perimeter of the roof deck to ensure that all wires fed through the deck lie inside of the outside walls. This enabled all wiring to take place inside the house. In the borders (sides, top and bottom) of the shingle array conventional asphalt or fiberglass shingles were installed. The color of these shingles was chosen to best match the PV shingle color. The PV shingles take on a primarily brownish tint.

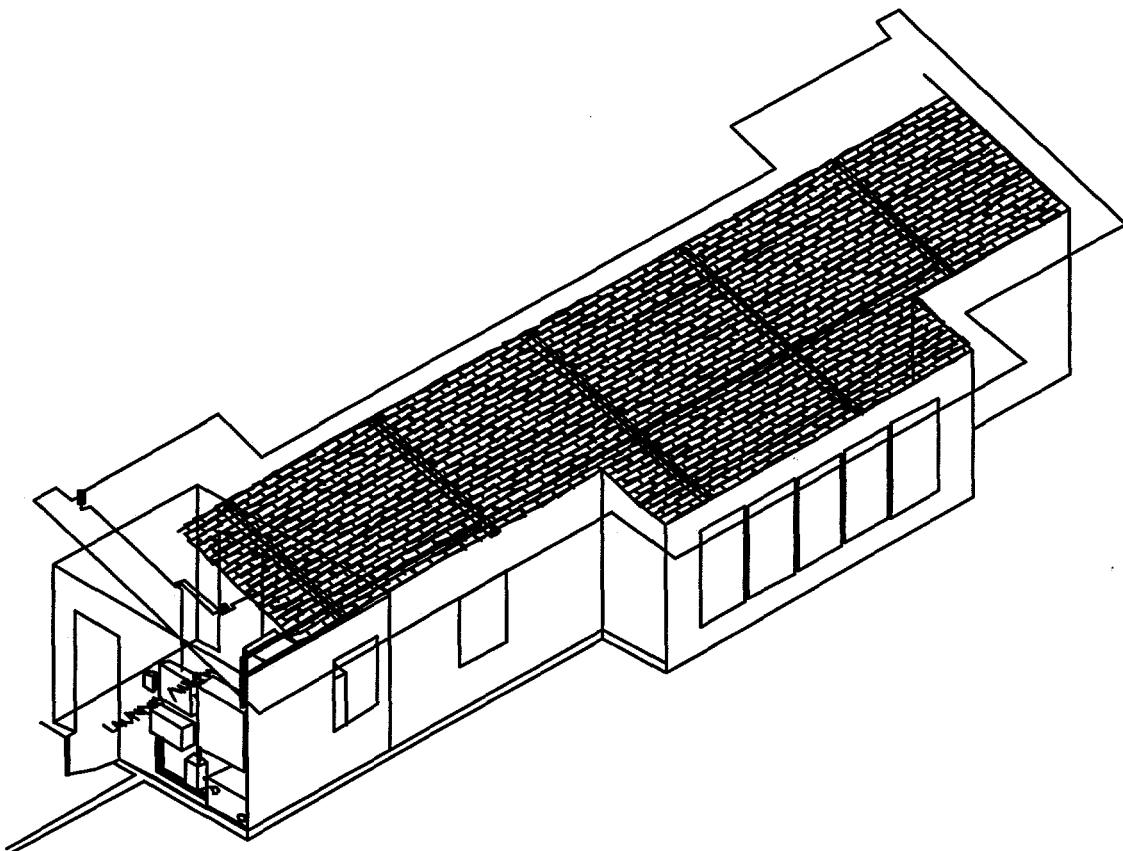


Figure 1.A.1. Skeletal view of PV shingle installation on ecological house, Atlanta.

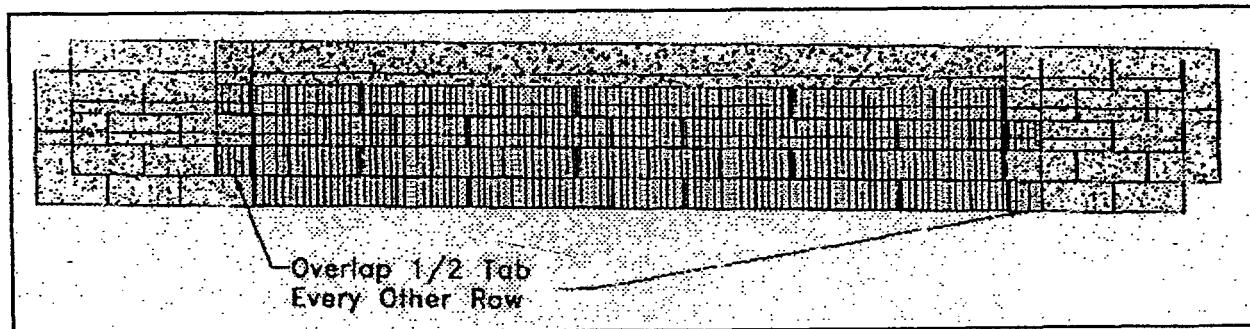


Figure 1.A.2. Layout of PV and convention shingle edge integration.

The integration on the sides of the shingle module array is accomplished by overlapping the conventional shingle on top of the PV shingle, as shown in Fig. 1.A.2. In this figure, the 6" portion of the PV shingle on every other course is overlapped by a conventional shingle. The submodule containing the 6" portion (12" submodule) is inactive. Thus, every other course of PV shingle ends with a shingle module with an inactive submodule on the end.

A key feature of the PV shingle design is that the installation may be accomplished with existing roofing contractor personnel. United Solar contracted two professional roofers to perform the installation of the PV shingle as well as the conventional shingle. United Solar provided these roofers with a four-hour training session to explain details of the design and installation procedures.

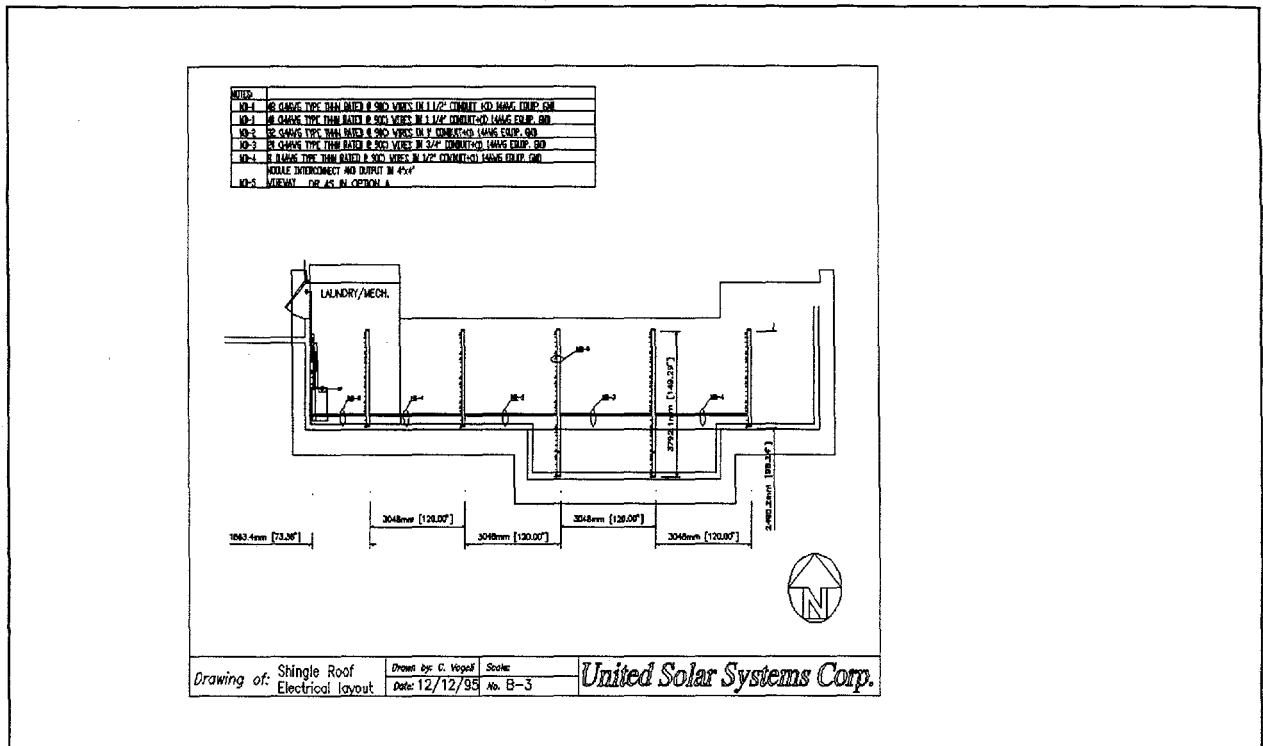


Figure 1.A.3. Layout of electrical wiring under PV shingle roof deck.

2. Electrical design and installation

The electrical design is shown in Figures 1.A.3. and 1.A.4. Figure 1.A.3. shows the ceiling under the PV shingle roof deck. The wire pairs are fed through the roof deck from the modules and into an electrical wireway running the full length of each column of PV shingles.

The individual wires from five modules are connected in series (plus to minus) using solder grips to produce a 48-volt string. The terminals to this 48-volt (5-module) string will be connected to 14 AWG wire, also by means of a solder grip, and then run along in the wireway to a conduit to the laundry/mechanical room in the southwest corner of the building.

Once in the laundry/mechanical room, these wires are fed into a combining box. In the combining box, the positive lead of each string will be connected to an overcurrent/disconnect breaker and then into a blocking diode and finally paralleled together. A lightning arrester is installed to ground at this point. The output charges four batteries housed in a vented box. The Trace inverter converts the DC power to AC for use in the house's electrical circuits. The data logger records operating current and voltage of the array, AC power output, irradiance, ambient temperature and roof deck temperature (under a PV shingle).

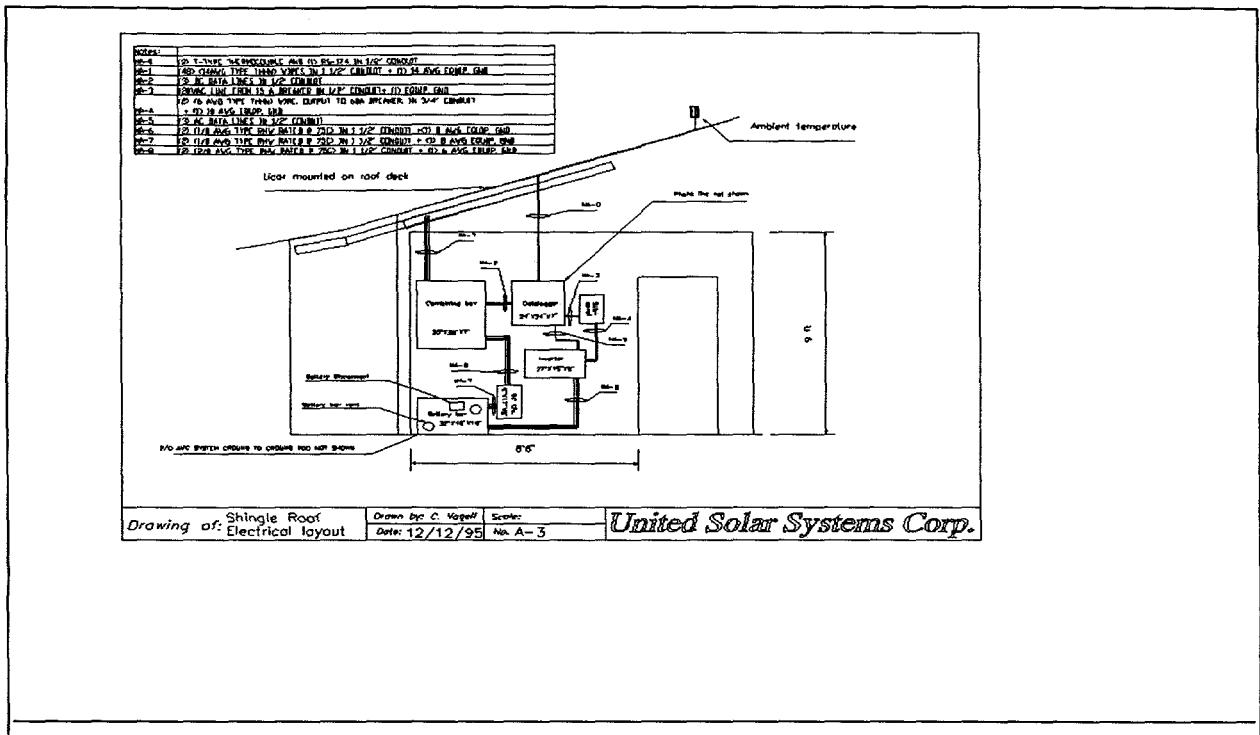


Figure 1.A.4. Layout of electrical wiring and boxes in laundry/mechanical room.

B. Electrical System

1. Data Collection System

The heart of the collection system is the Angus VGR4 video graphic recorder which monitors six inputs from the array and outdoor conditions. The inputs are: array voltage and current into the battery, ambient and module temperature, power delivered from the inverter and from solar insolation. Table 1.B.1 describes each measurement device.

Table 1.B.1. Description of system measurement devices.

Measurement	Part	Range/Output
Inputs	VGR4	-24 to +24 VDC -30 to +30 m VDC
Array voltage	Resistor divider	10V / 75 VDC
Array current	OSI CTA-101	5V / 50 ADC
Power delivered	OSI PC8	5V / 3kWAC
Temperature	T-type thermocouple	Linear
Insolation	Li-Cor Radiation sensor	10mV / 1000 W/M ²

The VGR4 is a powerful recorder and display unit. The VGR4 software flow is shown in Fig. 1.B.1. Data is collected, converted and displayed every 1 min., 15 secs. This data is displayed on one of twelve pages available on the VGR4. Examples of the pages available are given in Fig. 1.B.2. These data are averaged over 30 mins. and displayed on the VGR4 screen and stored on a 3.5" floppy disc. Then the data are stored in a circular file that contains approximately 300 days of data. The data is available through an on-board modem operating at a maximum of 14.4K baud.

2. *Electrical Installation/Design*

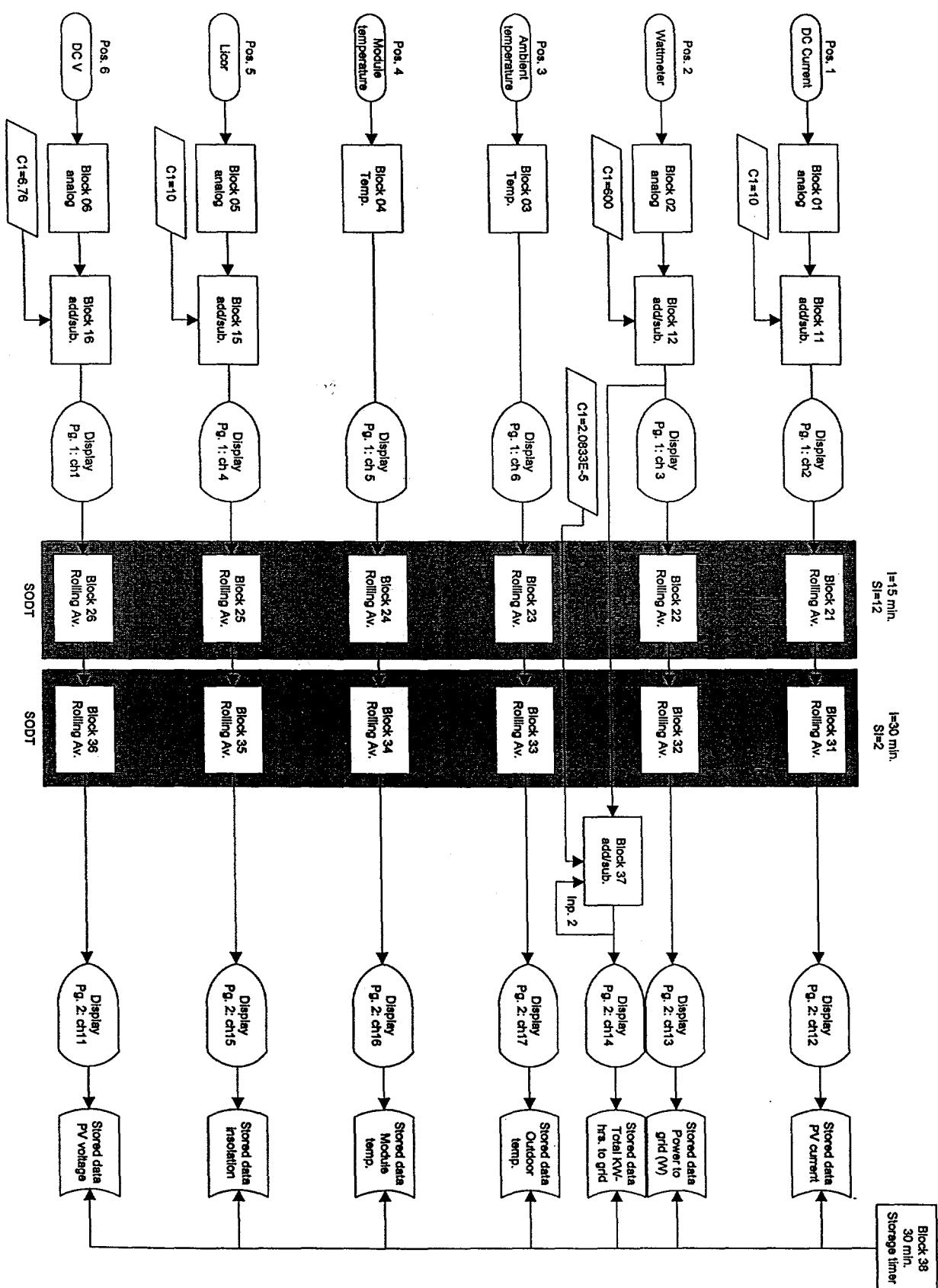
The combining box is shown in Fig. 1.B.3a., and the data logger, shown in Figures 1.B.3b. and 1.B.3c. The battery box for the batteries used in the Southface House shingle array was purchased from Zantron Corporation. The box holds four deep-cycle batteries (12V, 100A-Hr) and is vented to the outside air. The battery box is a sealed unit with a 12-volt blower attached to a vent. The box measures 19 in x 19 in x 36 in.

3. *Museum Display*

The computer system for the museum display consists of a 486 tower computer with a 14.4K modem and a 21 in. NEC monitor. The software for this system has been written by United Solar. The language chosen was Visual Basic, to work in a Windows '95 environment. The software calls the VGR4 (described above) every 30 mins. on the half hour, collects the current data and displays the result. Figures 1.B.4. through 1.B.9 are sample display pages. The software stores important data such as the VGR's phone number, communication port, modem initialization strings, time between pages, communication port settings and the last 24 hours of data. This will allow the unit to start from power up with no user input.

Data collection flowchart for VGR4 recorder

Fig. 1.B.1. Data collection flowchart for VGR4 recorder



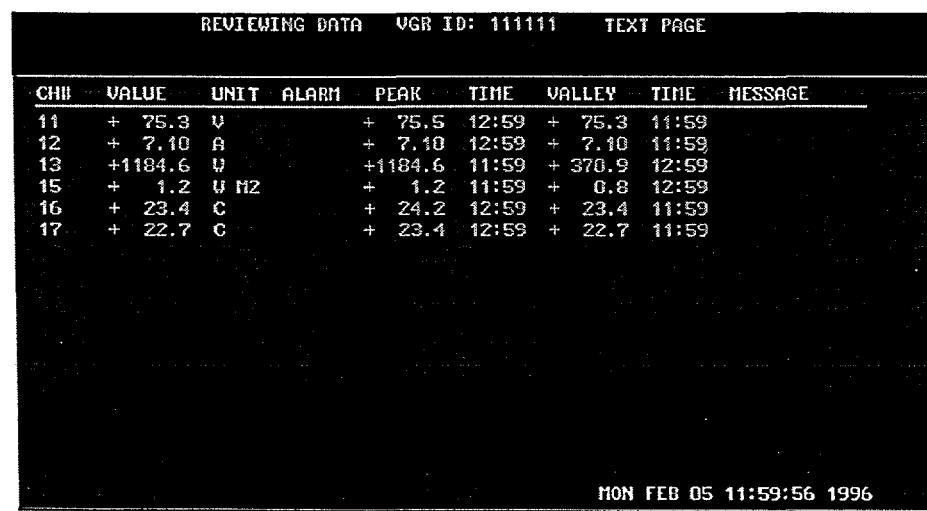
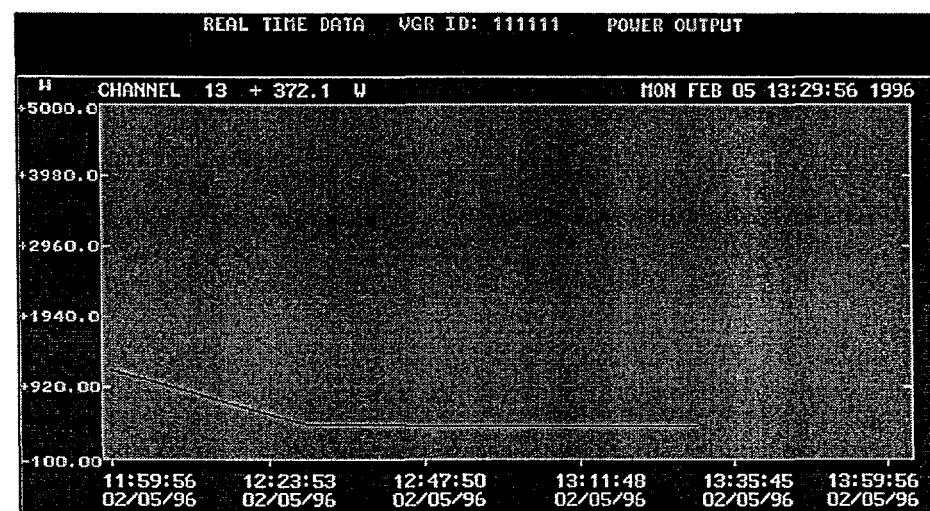
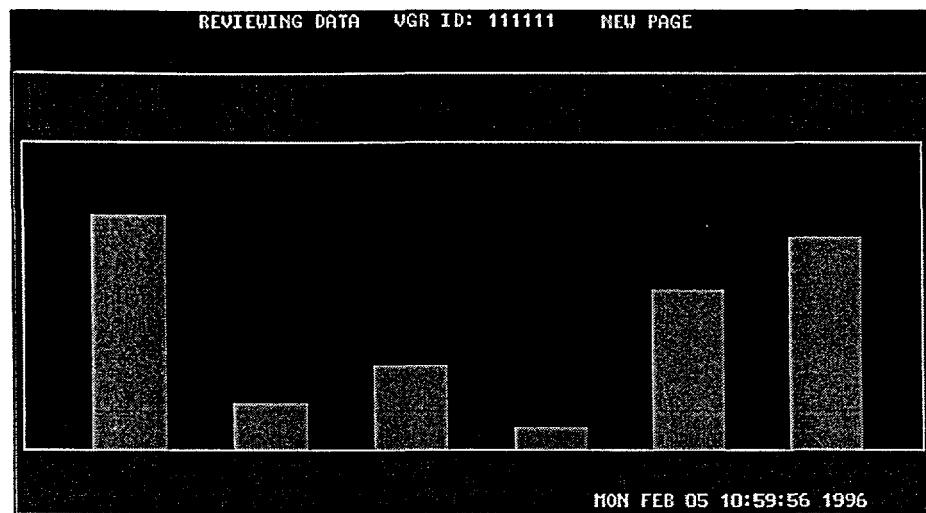


Fig. 1.B.2. Examples of data displayed on the VGR4 unit.

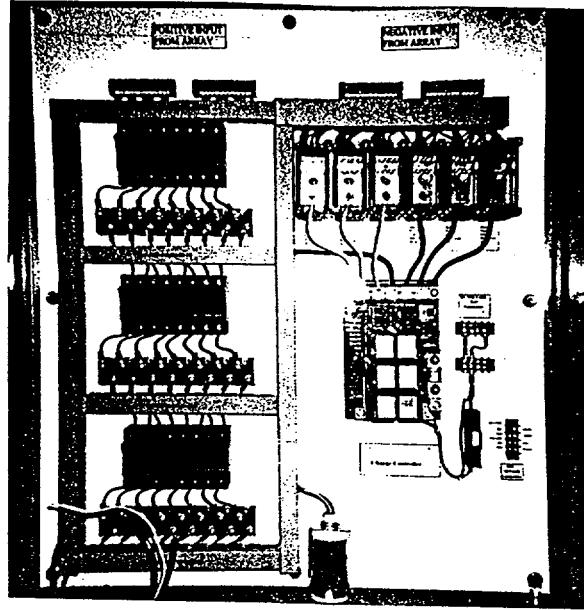


Fig. 1.B.3a. Combiner Box for the Southface House in Atlanta.

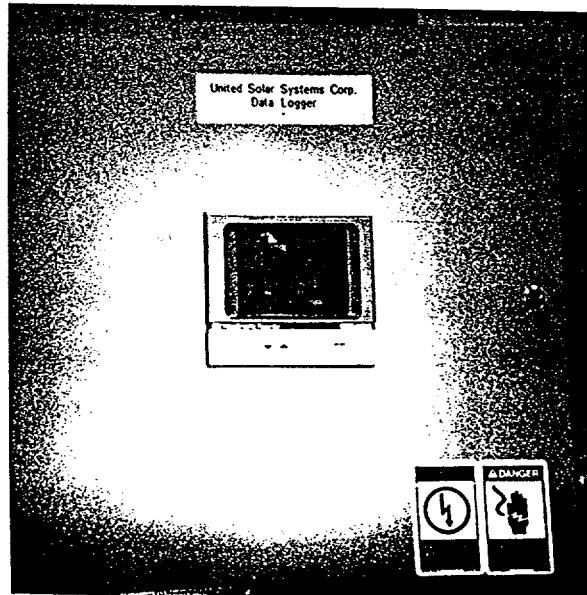
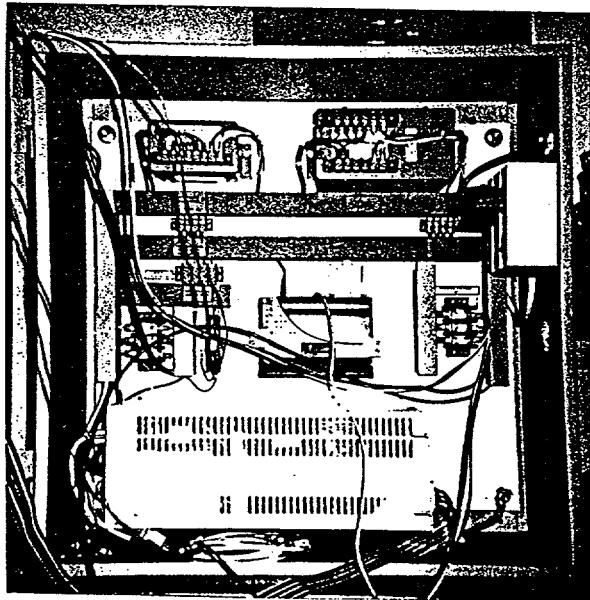


Fig. 1.B.3b. and 3c. Data Logger for the Southface House in Atlanta.

C. PV Shingle Installation on the Southface House

1. *PV Shingle Installation*

The installation of the PV shingles on the Southface House in Atlanta was completed on 25-26 June 1996. The mechanical installation of the modules went according to plan with few exceptions. Two licensed roofing contractors from the Detroit area performed the installation. Also, there were two engineers from United Solar there to oversee the project. The entire procedure took approximately 16 hours.

The installation began by first removing the old worn out felt paper and repairing problem areas to the plywood on the roof deck. This took approximately two hours to complete. The roofers then marked the approximate position of the five lines of feed-throughs for the modules. Next, they laid down the fresh felt paper and double-sided water barrier (see Fig. 1.C.1.). The double-sided water barrier was used only in the vicinity of the feed-through rather than over the entire roof deck. Double-sided adhesive is used for sealing the wire feed-through in the deck.

The first five rows of asphalt shingles were mounted on the lower portion of the roof deck. This was followed by the first PV shingle. The shingle was first aligned to the rain lines on the previous asphalt shingle row. While the module was held in its proper position, the wire template was placed under the module. The module was then moved about 12 inches down onto the previous rows holding the template in place. A mark was made on the release paper of the water barrier with a pencil at the location indicated by the template. A hole was then drilled through the plywood deck. The module was placed back into its original position and, the wires were fed through the deck. The module was then fastened in two spots on either side of the feed-through. The release paper was then cut around the module near the feed-through area and then removed, and the module was adhered to the adhesive. The fastening of the module was completed and the release paper under a corner of the module was removed and the module was adhered on the ends. This procedure was repeated to install all of the modules. Once the procedure had been executed several times and things were running smoothly, each module took 3-4 minutes to install.

The completion of the installation of the asphalt shingles on the sides of the array took place after a large section of the PV shingles had been completed. These side shingles overlapped an inactive half tab of the PV shingles on opposite sides of every other row. Since the asphalt shingles on the side were installed after the rows of PV shingles, the asphalt shingle overlaid asphalt and the PV shingles overlaid PV shingles. This provides superior adhesion between the materials as well as giving a cleaner-looking delineation between the asphalt and PV sections of the roof (see Fig. 1.C.2.).

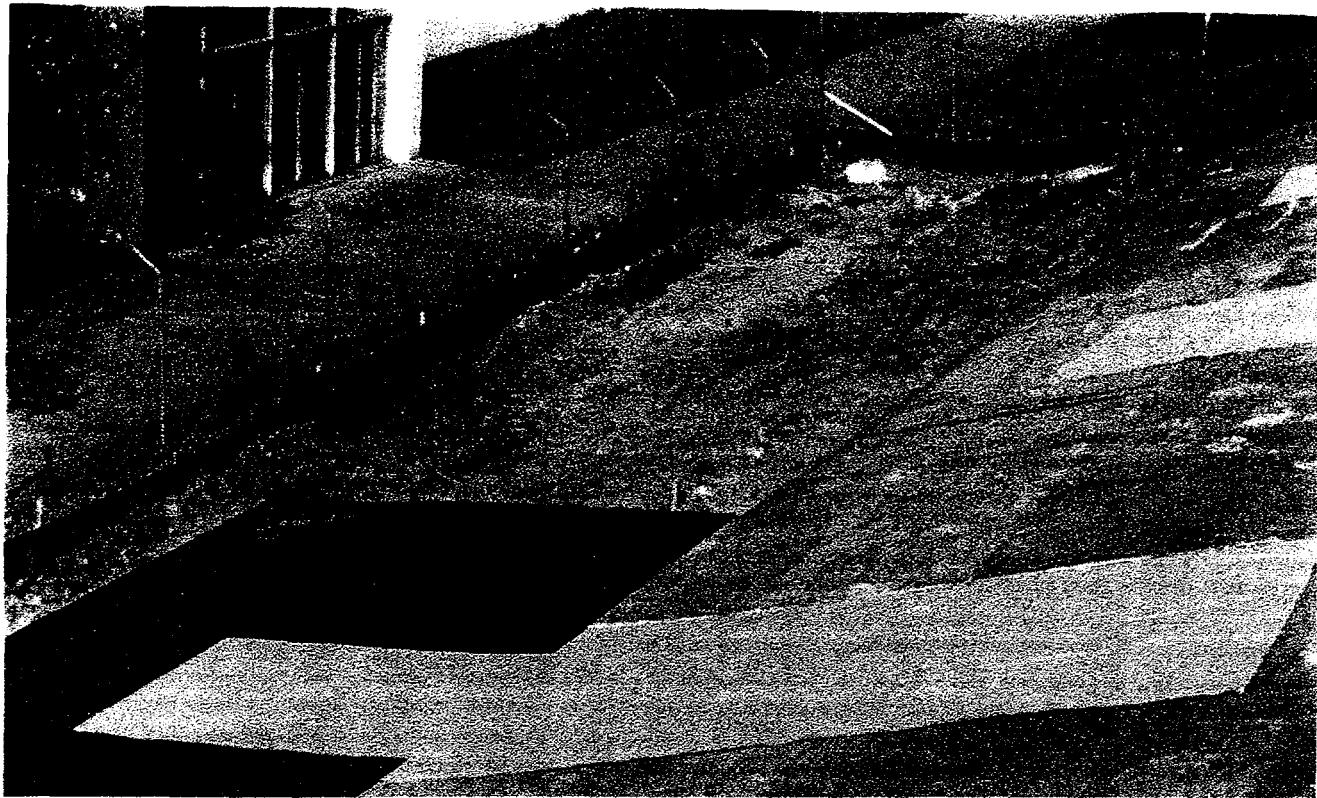


Fig. 1.C.1. The first step in installing PV modules: laying down fresh felt paper.

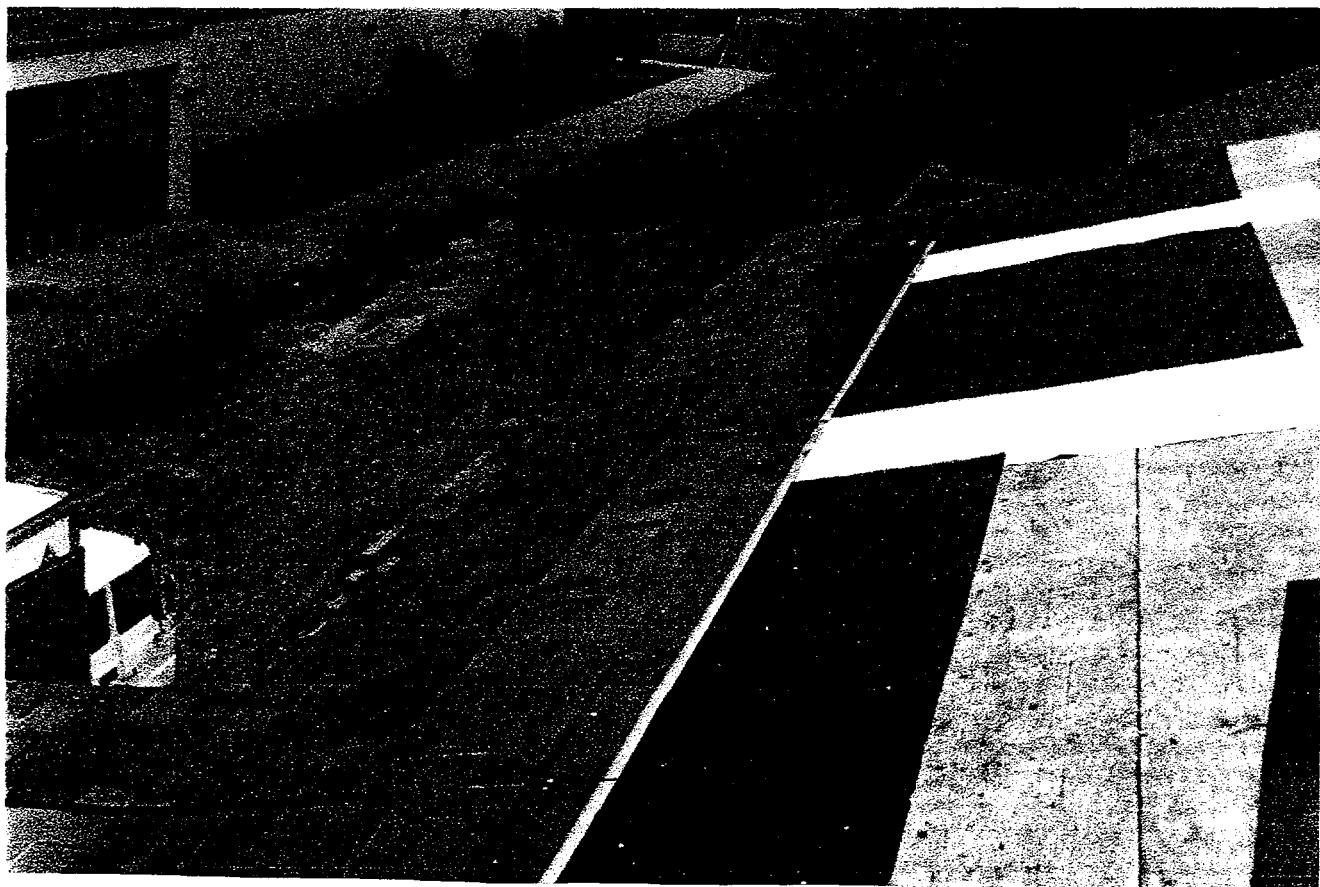


Fig. 1.C.2. Completion of installation of asphalt shingles on bottom side of the array, and the first row of PV shingles.

The original plans called for the installation of 120 shingle modules on this deck; however, we were only able to install 110 PV shingles, leaving off the final two rows. This was a result of the difficulty in installing modules close to the wall. Once the installation got near the wall on the upper story of the building, there was insufficient room for the installation of the last two rows of PV. Instead, asphalt shingles were installed in this area. This also gave a larger walkway for subsequent workers to gain access to work on the wall next to the deck since the work on this wall had not yet been completed. This reduction in the number of modules had little impact on the electrical installation. Since the array was still an integral number of strings (one series string consists of 5 modules), this only affected a reduction in the total number of strings from 24 to 22 and affected the power accordingly.

The final installation was very aesthetic (see Fig. 1.C.3-4.). The individual PV tabs were a variegated marble color that integrated quite well with the color variations of the asphalt. The modules laid quite flat on the roof deck giving a nice uniform look. The ends of the modules fit together very well giving an almost indiscernible seam between two modules.

2. *Electrical Installation*

The electrical system installation was performed immediately after the mechanical installation. The module series connections were first made under the roof deck. These connections between individual modules were made using a soldered wire nut. Electrical covered raceways were run along the feed-through under the deck. Each wire nut connection was made inside these covered raceways. In addition to the vertical raceways, a horizontal raceway was run to house the string wires that led to the mechanical room on the main floor.

Once all the series connections were made and string wires run, the open-circuit voltage and short-circuit current were measured on each series string. All 22 strings gave appropriate values for both V_{oc} (70-75 volts) and I_{sc} (2.0-2.2 amps). Each string was then terminated in a combining box mounted on the east wall of the mechanical room. This combining box also housed, for each string, a disconnect/over-current device as well as a blocking diode. The data logger, DC and AC disconnects and inverter have also been installed and are mounted to this same wall. A battery backup, contained in a vented battery box, is mounted on the floor near this east wall with the vent hose run to the outside through the south wall. The equipment and system grounds were tied into the house electrical ground in the garage, located near the mechanical room, on the same floor.



Fig. 1.C.3-4. Array after final installation. The ends of the modules fit together giving an almost indiscernible seam.

D. Southface Energy and Environmental Resource Center Array Monitoring

The PV shingle system installed at the Southface Energy and Environmental Resource Center in Atlanta GA has now been operational for more than one year. The array continues to operate as expected over this period of time. The normalized (for one sun) DC output still exceeds 2 kW. The integrity of the PV shingle system as a roofing system remains excellent.

In Fig. 1.D.1 we show the normalized DC array output at the peak irradiance for each day over the period of May through August, 1997. The array output has been normalized to standard test conditions of 1000 W/m^2 , 25°C . The DC power increases over this period from about 1.85 kW in May to about 2.0 kW in August, presumably due to thermal annealing.

Figure 1.D.2 shows the daily DC energy delivery of the system as well as the daily insolation energy for the Atlanta site for the time period of May through August, 1997. The average DC energy delivery for this time period was 9.1 kW-hrs per day, while the irradiance level averaged 4.4 kW-hrs/m^2 . Whereas the peak data shown in Fig. 1 yields an average peak normalized array power of $1.95 \text{ kW/(1 kW/m}^2)$, the normalized energy of the array is $2.07 \text{ kW-hr/(1 kW-hr/m}^2)$ (Fig. 1.D.3); consequently, the energy delivered by the system is 6% higher than would be predicted by standard test conditions. This is especially high in light of the performance of crystalline-Si modules which typically deliver 10-15% less energy than predicted by standard test conditions.

Figure 1.D.3 shows the daily variation in the ratio of array energy to insolation energy. As in Figure 1 we see the effect of thermal annealing on the a-Si array to be an increase in the energy ratio in the warmer months of July and August. During this time period the system is consistently delivering over 2 kW-hrs of power for every kW-hr/m^2 of insolation.

The array output power as a function of irradiance is shown in Figure 1.D.4. The array DC power, corrected only for temperature, is plotted versus insolation level. This shows that the output of these shingle modules are not significantly affected by series resistance at high irradiances and shunt resistance at very low irradiances. The y-axis intercept is

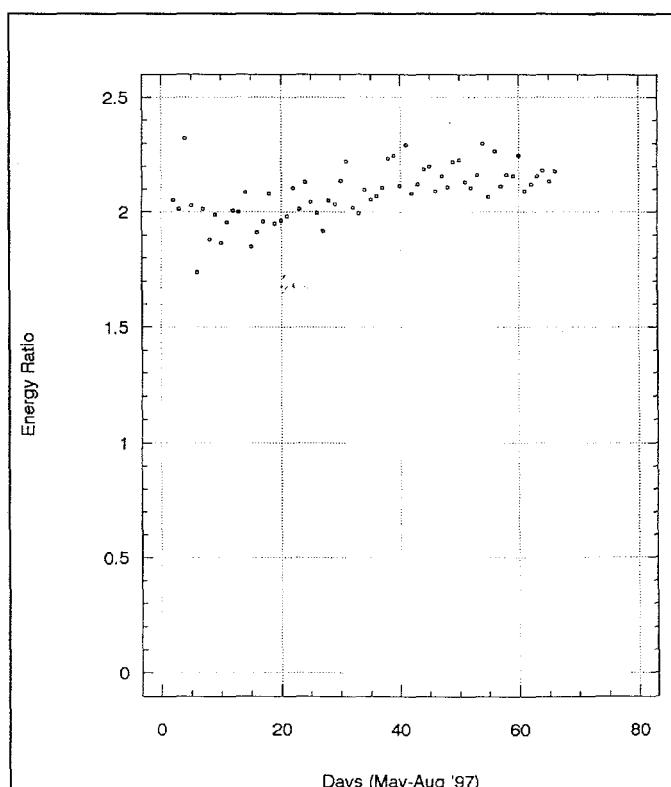


Fig. 1.D.3. Array daily normalized energy output.

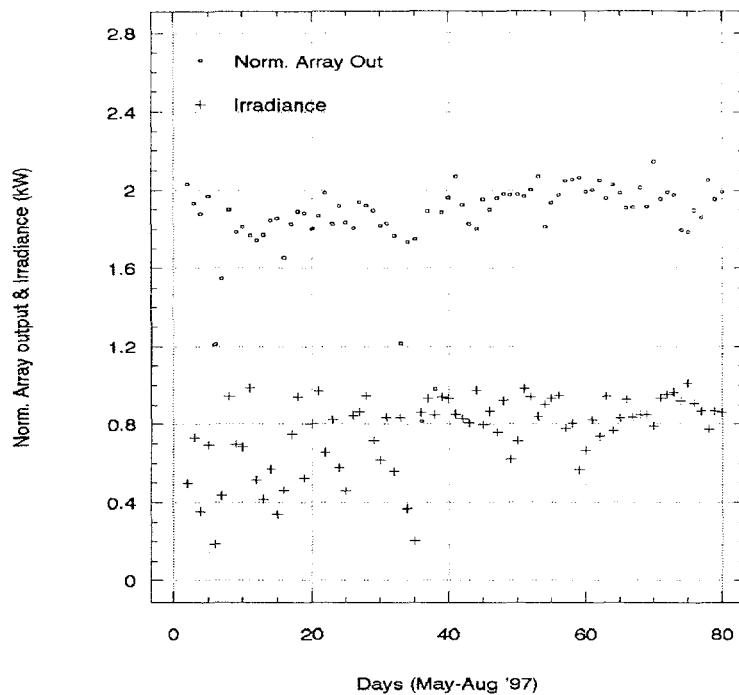


Fig. 1.D.1. Daily measurements of normalized power at peak irradiances.

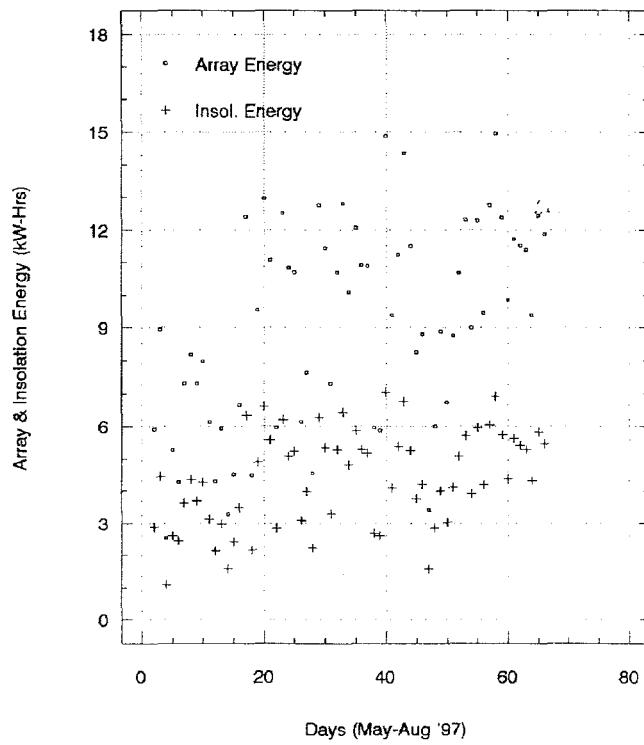


Fig. 1.D.2. Integrated array power and irradiance

approximately -40W, corresponding to the amount of power dissipated in the blocking diodes placed across each series string.

Figure 1.D.5 shows the temperature difference between the PV shingle module and the ambient temperature, measured near the array, as a function of irradiance. At full sun the modules reach a temperature of 35-40 °C above ambient. There is a large amount of scattering in this plot. This is likely to be the result of not correcting for conditions such as wind and the difference in the slow thermal response of the array versus the quick response of the ambient thermocouple under partly cloudy sky conditions. This graph predicts that the normal operating cell temperature (NOCT), which is defined at 800 W/m^2 at 20°C ambient, is approximately 52°C . This NOCT is slightly higher than that of our conventional ground mounted modules due to the PV shingles being mounted on the insulating wood deck.

Fig. 1.D.6 shows the peak daily module and ambient temperature for the time period of May-August, 1997. The peak module temperatures reach into the low 70°C range while the ambient temperatures in July and August in Atlanta were as high as 40°C .

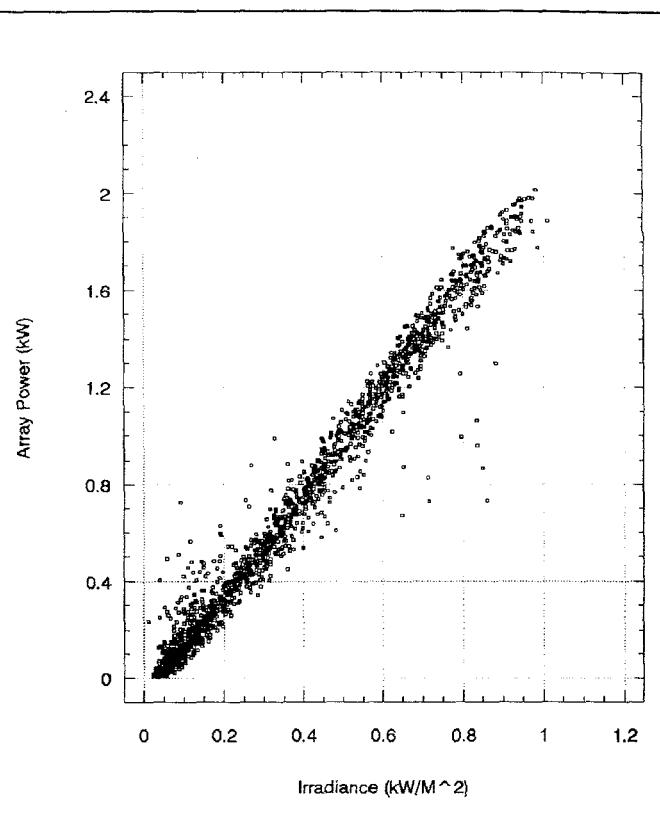


Fig. 1.D.4. Array power vs. irradiance

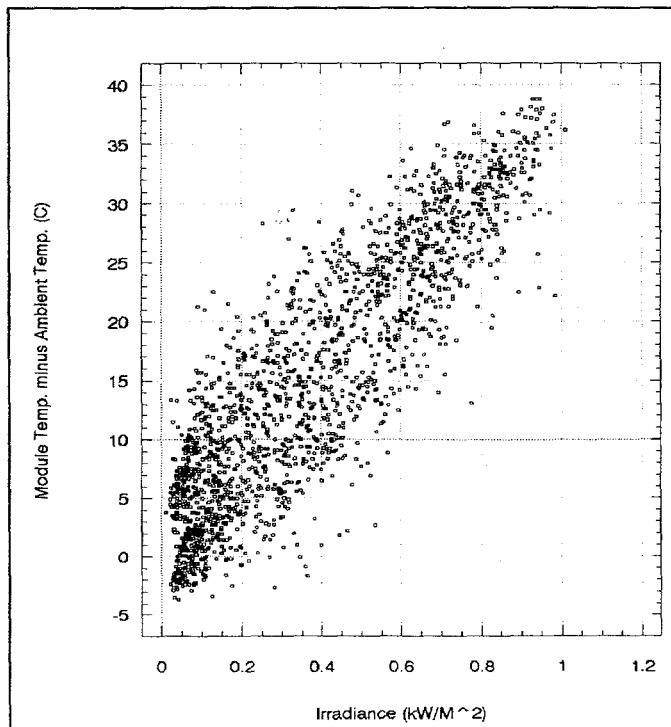


Fig. 1.D.5. Module temperature rise vs. irradiance.

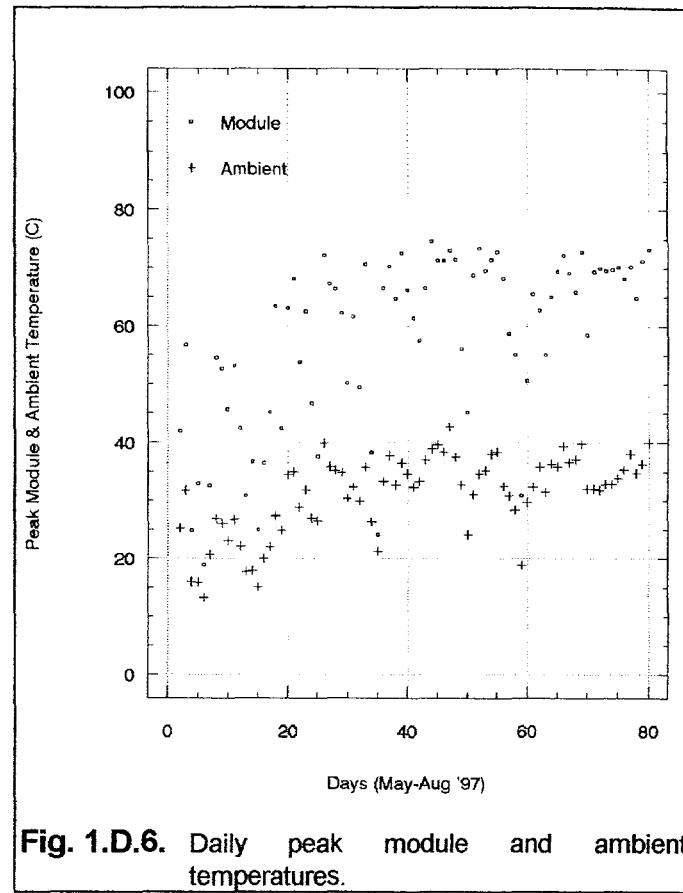


Fig. 1.D.6. Daily peak module and ambient temperatures.

TASK 2: COMPLETION AND MONITORING OF STANDING-SEAM METAL ROOFING ARRAY ON THE NAHB HOUSE



Fig 2.A.1. ECD's prototype BIPV metal roofing modules installed on the NAHB Research Center 21st Century Townhouse project in Bowie, Maryland, just outside Washington D.C.

A. Project Design

ECD showcased its prototype BIPV metal roofing modules on the NAHB Research Center's 21st Century Townhouse (Fig. 2.A.1.) Project in Bowie Maryland. The PV metal roofing modules (Fig. 2.A.2.) were designed to be exact replacements for the most common standing seam metal roofing pan manufactured by ATAS International: 15 1/4" wide pans made from 24 gauge steel with a Galvalume (zinc-aluminum) anti-corrosion coating finished with a fluoropolymer paint.

The panels are attached at the top of the roof by two screws, and secured along the length of both sides by clips attached to the roof deck. The panels are free to move lengthwise in these clips. A 1" tall batten, also attached to these clips, covers the seam between adjacent pans. At the roof eve, the panel is bent around the sheathing edge. Metal roofing details are available for valleys, rake ends, plumbing stacks, skylights, wall seams, etc. The PV-metal roofing, however, must be installed on open areas of the roof where the metal panel extends unbroken from the ridge the full length of the PV active area. The leads for the PV module are feed through the ridge vent consequently eliminating the need for any penetrations in the roof.

The 24 V modules consist of 19 prototype triple-junction spectrum-splitting cells connected in series with individual bypass diodes. This cell block assembly is laminated to the metal roofing pan with EVA and covered with a top layer of EVA, crane glass, and Tefzel. The lamination materials are thinned at the edges to allow the panel edges to be rolled up in a roll-forming machine, and to allow the bottom edge of the panel to be easily trimmed and folded around the eve edge of the roofing sheathing as is done for the conventional metal roofing pans.

Figure 2.A.3. shows the design layout of the metal roofing modules on the NAHB Research Center 21st Century Townhouse. There are 18 modules, 12 on the main roof section, and 6 on the side roof area. Although these two roofing sections are of different lengths, single length modules were fabricated and trimmed to the precise length in the field in the same manner as ordinary metal roofing pans.

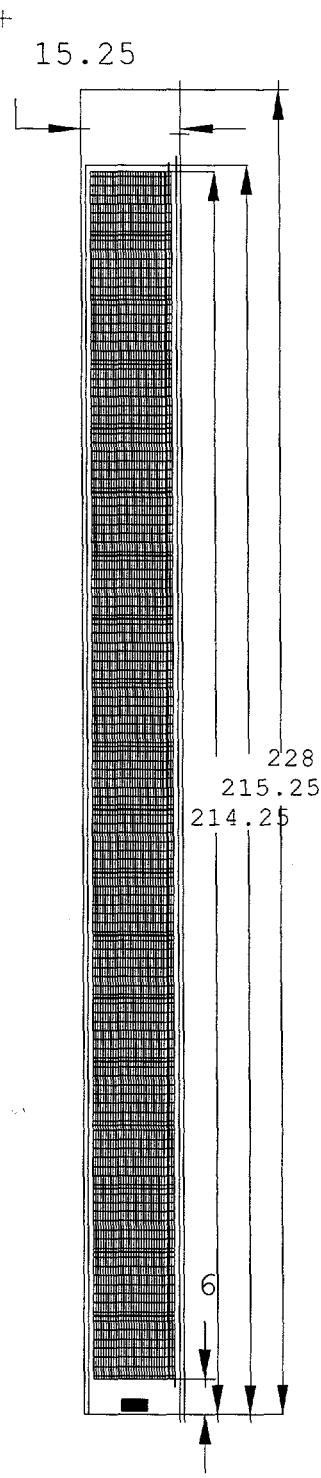


Fig. 2.A.2. Mechanical schematic of ECD's prototype, metal roofing module.

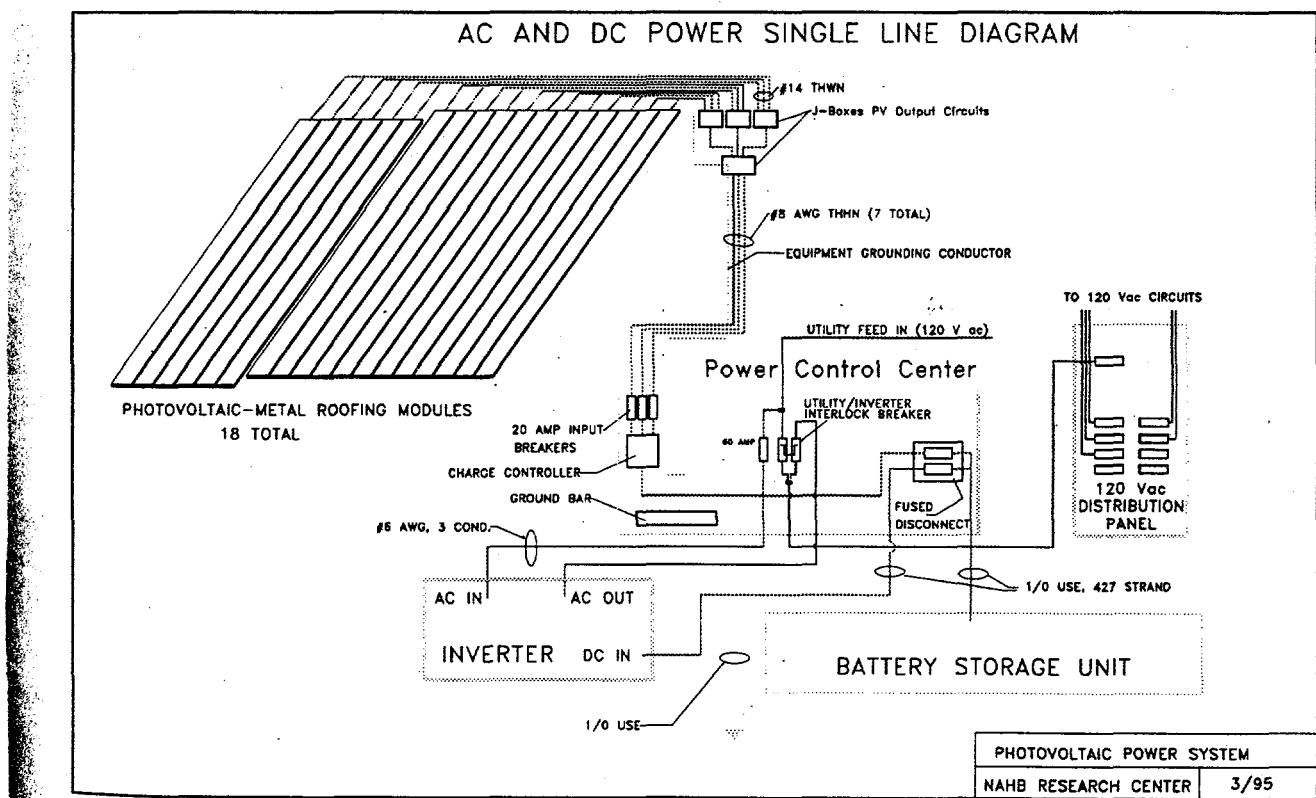
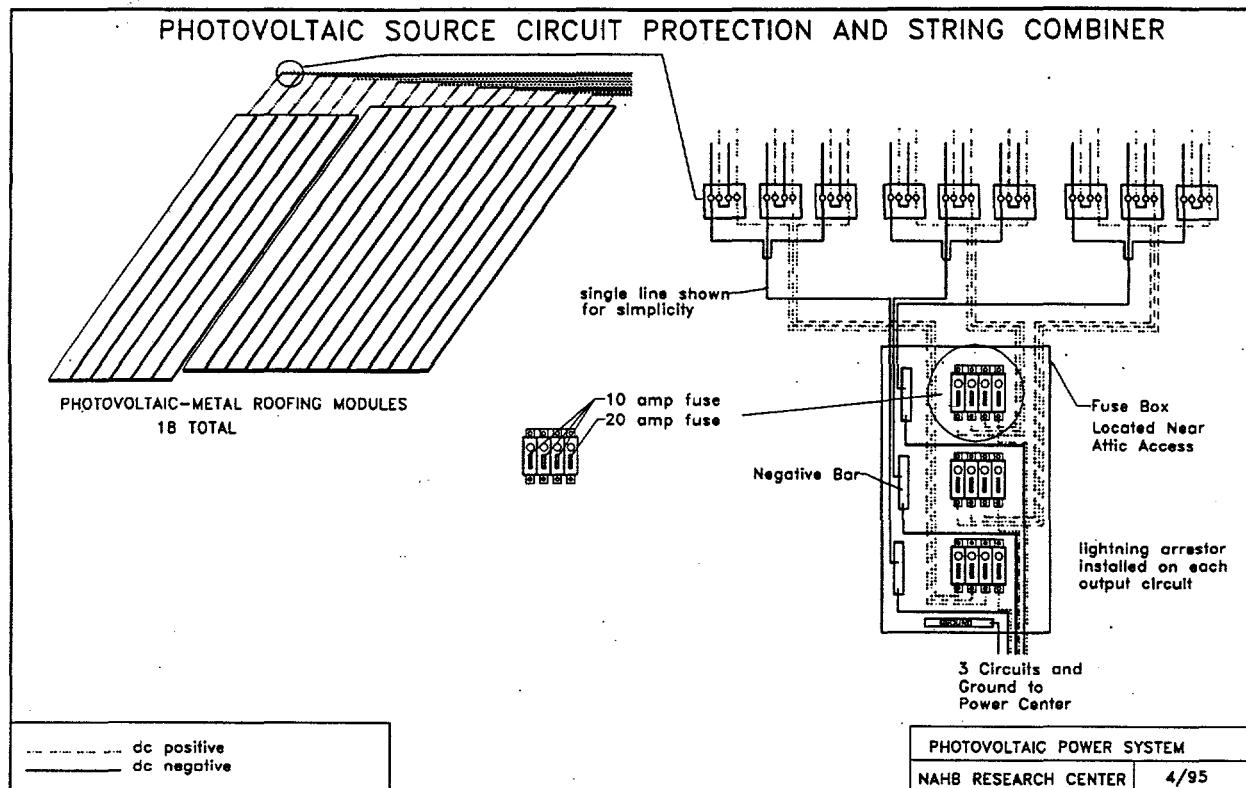


Figure 2.A.3. Design configuration of the 18 BIPV metal roofing modules on the NAHB Research Center 21st Century Townhouse.

B. Electrical System

Electrical diagrams of the NAHB Townhouse PV system are shown in Figs. 2.B.1 and 2.B.2. It was decided to use a 48 V system for the townhouse as a compromise between balance of system (BOS) costs and safety. Higher system voltages reduce the cost of wiring; excessively high voltages can lead to safety problems. The 18 modules are connected into 9 series-connected 48 V pairs in 9 junction boxes (J-Boxes). A blocking diode is also mounted in the J-Boxes. The J-Boxes are mounted to the rafters as shown in Fig. 2.B.3.

The outputs of the 9 J-boxes are connected to a combiner box. In the combiner box the 3 pairs of modules are connected in parallel into three “strings”; each of the 9 inputs goes through a 10 A fuse, and each of the three output strings through a 20 A fuse. The combiner box is shown in Figs. 2.B.4-5.



Figs. 2.B.1-2 Electrical diagrams of the NAHB Townhouse PV system.



Fig. 2.B.3. Photograph of one of the 9 Junction Boxes in the NAHB Townhouse in which two modules are series connected. Two conduits, one from each module, can be seen entering the box at the top; one conduit leaves the box and goes to the combiner box. The J-Box also has a series blocking diode.



Fig. 2.B.4-5 Photograph of the Combiner Box in the NAHB 21st Century Townhouse. The nine inputs from the J-boxes are at the top of the box; the three output strings to the charge controller leave from the bottom of the box.

The three strings are connected together in the basement at the charge controller in the Amanda Power Center, and then to a 16 kW-hr (8 220 A-hr) bank of deep cycle lead acid storage batteries and 4 kW Trace inverter. This portion of the BOS is shown in Fig. 2.B.6.

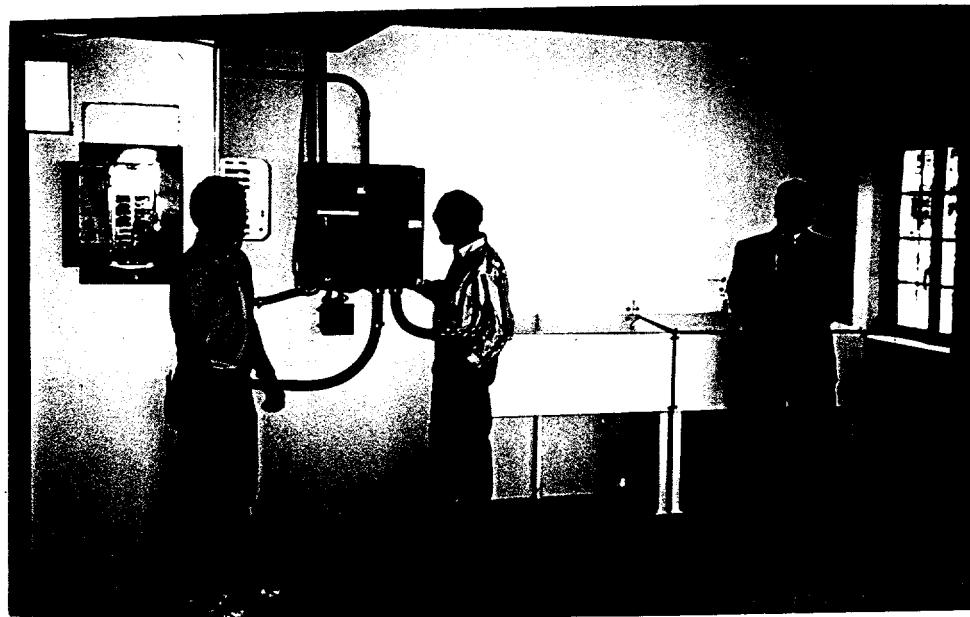


Fig. 2.B.6. BOS located in the basement of the 21st Century Townhouse. The batteries are located in the two boxes at the right of the picture; to their left on the back wall is the Amanda Power Center; to the left of the power center is the Trace inverter.

C. PV Metal Roofing Array Installation on the NAHB Research Center 21st Century Townhouse

The prototype modules were fabricated at ECD primarily during the first quarter of 1996. On Monday April 29, 1996 the modules were shipped to ATAS International and on Friday May 3, ATAS personnel roll-formed the modules into metal roofing pans. The first module was roll-formed using the standard rollers which crushed the lamination materials slightly resulting in a barely observable amount of "whitening" along the path followed by the rollers. The rollers were subsequently switched to the specially designed rollers for these modules which worked perfectly the first time and required no adjustment. The roll forming operation took 1 to 2 hours; the majority of that time was spent unpacking and repacking the modules. After roll forming the modules were hi-pot tested to check for possible damage; none was observed.

The modules were shipped by truck from the ATAS International plant in Allentown PA to the townhouse in Bowie, Maryland on Monday morning May 6. At the site the modules were once more given an electrical check before installation. No problems were found.

As mentioned previously, the ECD metal roofing module is an exact replacement for an ATAS International standing seam metal roofing pan; as such these modules can be installed by metal roofing tradesman with no additional or specialized training. This was demonstrated by the NAHB Research Center which contracted the same roofing company which installed the original metal roofs on the 21st Century Townhouses to install the PV metal roofing. The roofers received a short 5 minute "pep talk" before the installation. Approximately 5 minutes was required for installing each of the 18 panels; the bulk of the roofer's time was spent with trim work (independent of the PV installation). Installation of the 6 modules on the narrow (left hand) roof section was somewhat easier than the installation on the main center section since the roofers could walk on the convention metal roofing on either side of the array; on the main array, when installing the last module, it was necessary for the roofer wear knee-pads and "walk" on his knees up and down the module to complete the trim installation. In future installations, we may leave one conventional panel on either side of the array. This would also avoid the replacing the end-trim, a time-consuming project, on retrofit installations. No modules were damaged during shipment, roll forming, or installation. The roofers reported that: (1) installing the PV was no more time-consuming than installing a conventional metal roof; and (2) the PV panels, although somewhat heavier than conventional metal pans, were somewhat easier to manage due to the increased stiffness from the lamination. Portions of the installation process are documented in the photographs shown in Figs. 2.C.1-6.

The electrician performed the hookup to the Balance of System (BOS) on Tuesday and Wednesday May 7 - 8. The array has since been in operation charging the batteries and feeding excess power to the grid. The output of the PV metal roofing modules is used to charge a set of sealed lead-acid batteries or is converted to ac and fed to the house loads.



Fig. 2.C.1. Before installation the module is trimmed to the precise length and the end folded over to wrap around the sheathing at the eave of the roof.



Fig. 2.C.2. Two workmen easily holding the lightweight flexible PV metal roofing module prior to loading the module onto the lift to be carried up to the roof.



Fig. 2.C.3. Two workmen unloading the PV metal roofing module from the lift and positioning the module onto the roof deck.



Fig. 2.C.4. Photograph of workman "walking" up a module on his knees using knee pads.



Fig. 2.C.5. Photograph of roofer dropping the leads through the ridge vent for later hook-up by an electrician in the attic.

D. Array Monitoring

The PV array is data-logged at 10-minute intervals. Below we summarize some of the data. Fig. 2.D.1 shows the PV array power [kW-hr/day] and insolation [kW-hr/day/m²] for the 1st 15 months of operation. The insolation sensor has the same inclination as the array (8:12, $\approx 34^\circ$).

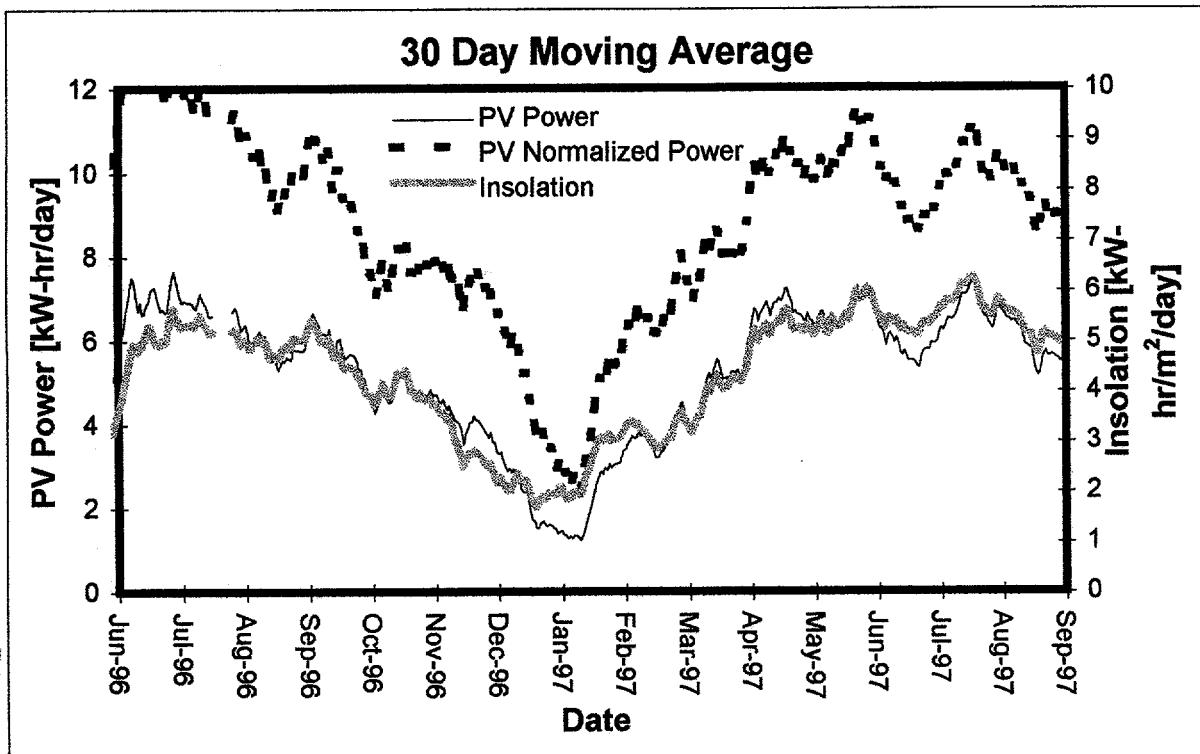


Fig. 2.D.1. Average DC power [kW-hr/day] from the array. The data are smoothed using a 30-day moving average to filter out some of the wide variations in insolation.

The daily peak temperature of the array typically varies from ambient temperature (low insolation days) to a maximum of 30 °C above ambient as shown in Fig. 2.D.2., regardless of ambient temperature.

Additional data summarizing the NAHB array installation and performance are presented in Appendix I, the NAHB Research Center Final Report.

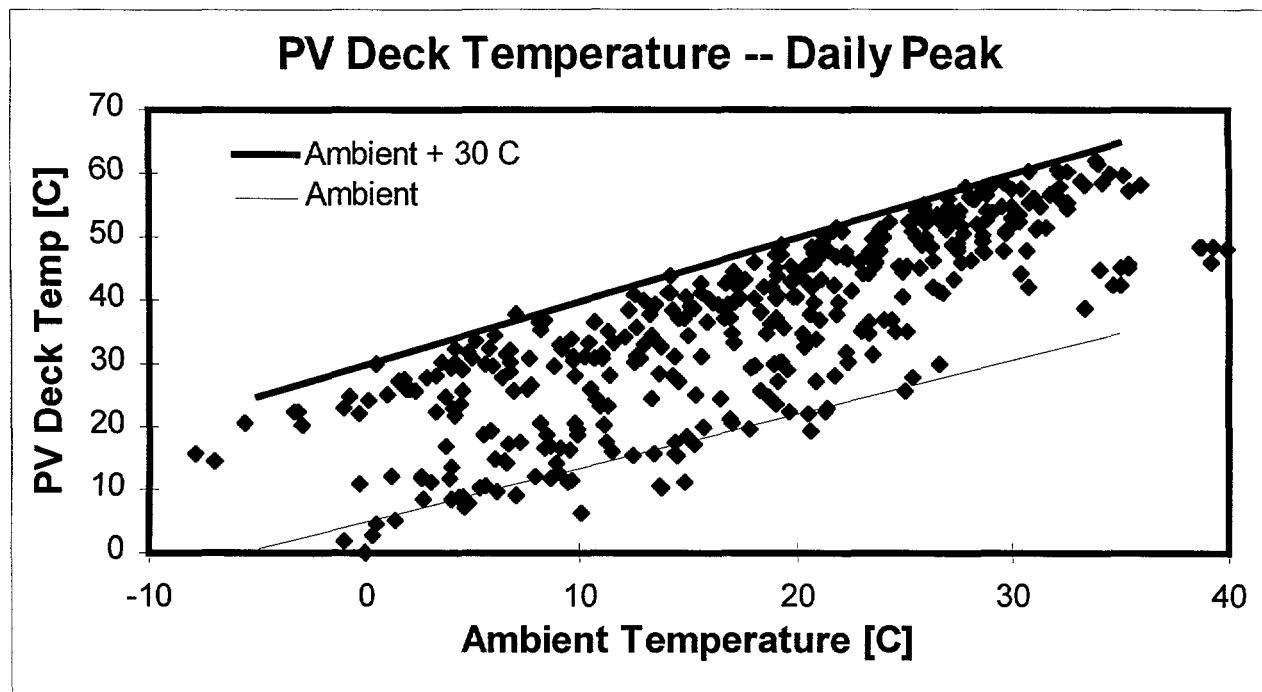


Fig. 2.D.2. PV deck daily peak temperature vs. ambient temperature.

TASK 3: INTRODUCTION OF THE PV SHINGLES AND STANDING-SEAM METAL ROOFING DEVELOPED UNDER PV:BONUS INTO THE UNITED SOLAR PRODUCT LINE.

These new BIPV modules have now been successfully introduced into United Solar's production line. There are now 5 standard products: the shingle module (SHR-17) that emulates standard asphalt/fiberglass shingles and a family of standing seam metal roofing laminates that can be integrated with either architectural or structural metal pans and are available in two different lengths, approximately 9 and 18 feet (ASR-64, ASR-128, SSR-64, SSR-128). The module specifications are summarized in Appendix II of this report.

Shingle Module

1. Introduction

We have now completed the introduction of the PV shingle into the United Solar production line. Presently this manufacturing line is producing approximately 40kW of PV shingles each month. During this program the PV shingle has gone from the initial concepts of the module to its application and installation. From there, various prototypes were built and evaluated from all aspects of its application. Rigorous testing proceeded during this entire time frame. Finally, the product was introduced into full-scale production, and continues today. The Underwriters Laboratory (UL) certification is expected to be completed before spring 1998. In this section, we will outline the key developments in the evolution of the PV shingle during this program.

The initial concepts for the PV shingle centered around several issues. These issues were module design, aesthetics, use of the PV shingle as a roofing system, integration with the remaining roof deck, installation, and delivery of array or module power into the building. The module was designed to emulate the asphalt shingle as much as possible to take advantage of the established building trades familiarity with this roofing style. The length of the module was eventually determined by the length that one installer could easily handle, as well as operating voltage requirements. To achieve an aesthetically acceptable product we decided to emulate the asphalt lines of symmetry, the 5" exposure of the asphalt shingle to keep the PV on the same lines as the asphalt. Initially the tab width was to match the conventional asphalt tab width of 12", but due to manufacturing constraints this length had to be changed.

It was decided that the power from the module would be delivered through the roof deck via penetrations made in the deck for each module. This would allow us to use a conventional asphalt shingle roofer to install the modules and completely separate the work of the electrician from that of the mechanical installer. The penetration in the deck would then be sealed using a heat sensitive adhesive mounted to the back of the module around the output wires, as well as the overlapped design of the shingle to resist water penetration through the deck.

We have developed a comprehensive installation procedure that can be readily used by a standard asphalt roofing contractor. The procedure has now been used on several installations. The time required to install the PV shingle is now only slightly longer than the time required to install asphalt shingles, thereby reducing installation costs. The installation procedure is summarized in Appendix V.

In the design evolution of the PV shingle several factors were considered. These included the size of the subcells and overall dimensions, lamination materials, power and voltage requirements and manufacturing constraints. We also looked into the reduction of lamination materials and the replacement of some materials with less expensive but more reliable materials. To achieve better structural support for the module and to reduce cost, we laminated the module to a commercially available, fiberglass reinforced, membrane.

In order to test the reliability of our modules we have undergone IEEE and UL testing of these products as well as developmental roofing tests with UL. We have also put up several installations around the country. The locations include Atlanta GA, Sacramento CA, Dallas TX, Mt Evans CO, Washington DC and our Troy site in Michigan. These installations have provided feedback in the module design and installation procedures.

For manufacturing we have built lay-up fixturing for the cell block assembly. We have written specifications and procedures for manufacturing of the PV shingle. We have gone through the mass trial stage and we are presently producing the PV shingle.

2. *Module Design*

a) *Basic concept:* Our basic goal in the conceptualization of this module was to produce a building integrated roofing system that would be most readily accepted by the building and photovoltaic industries. To achieve this we had to understand accepted building practices including the roofing and electrical trades. We wanted to develop a design that would allow us to use an accepted roofing design, the asphalt shingle, and emulate this, as much as possible, in order to gain acceptance of the product in the building industry. We also wanted to utilize the already existing trades, namely roofers and electricians, rather than create a network of specialized installers to deal with this new product. To aid us in this venture we teamed up with National Association of Home Builders from the building industry, Solar Design Associates from the photovoltaic industry, local roofing contractors from the roofing trades, a prominent shingle manufacturer, as well as architects and electric distribution companies. These collaborations proved to be valuable in maintaining a design that would be accepted by all parties that would encounter this product in the market.

We decided to emulate the basic dimensional aspects of the asphalt shingle. The concept of overlapping subsequent courses of shingle to provide environmental protection of the structure by including an inactive region above the exposed photovoltaic region of the module. The modules would be mounted with conventional asphalt roofing fasteners, either nails or staples, in approximately the same relative location. The roofing modules would be installed side to side and row to row as with conventional asphalt shingles.

The most unconventional aspect of this new shingle material, to the roofing professional, was the delivery of electrical energy to the building through the individual module output leads. We needed to interconnect the modules together as well as deliver the electricity to the power condition equipment. We considered many schemes by which the interconnects would be taken care of above the deck and brought into the building as a single wiring pair or series of string pairs. This was objectionable to the building industry because the roofer would not be equipped, nor willing to deal with the electrical interconnections. The electrician would then have to be coordinated with roofing installation of the modules which would create logistics problems for the builder.

It was decided that in order to alleviate this problem a penetration for each module would be made in the deck and the wires passed through this hole upon installation of the module by the roofer. The roofing contractors felt this was an acceptable addition to their normal procedures. The electrician could then come along any time after the roof installation and do the appropriate electrical connections under the deck. The technical considerations for this design, as a roofing system, in addition to the issues involving conventional shingles, are centered around the wires feeding through the deck. Primarily these issues involve the environmental protection of the building by the deck. The electrical system, once the modules had been mechanically installed, would be dictated by conventional building and photovoltaic electrical codes.

b) Dimensional considerations: Many factors came together to influence the overall dimensions and subcell dimensions of the shingle module. The first prototype that was built was a six foot wide by two foot high module with an active tab area of two feet by one foot and a one foot head lap (the portion of the shingle that is overlapped in subsequent rows or courses). This module was an optimal size for the research a-Si processor but was a problem in other ways. This design was difficult to handle even with two installers and also did not blend well with the balance of the deck asphalt shingles. We built a demonstration shed with these prototype modules in order to monitor their various performance characteristics. The shingles performed as anticipated in both functions, i.e. as a roofing system and as a photovoltaic array. The basic concept had worked and future changes would be dictated by aesthetics, ease of installation and manufacturing considerations.

To achieve an aesthetically pleasing roof the module design was modified dramatically. The individual tabs (or subcells) were changed to exactly match the most common tab size for the asphalt shingle, namely 5 inches high by 12 inches wide. When mounted on the roof deck, with conventional asphalt shingles, all the lines of symmetry were matched between the asphalt and PV. This matching of lines provided a more natural look, making the break between the two materials less obvious to the observer. The module was ten feet wide consisting of 12-one foot tabs and one foot high (also the same as asphalt). The feed-through wires were placed in the head lap area 42" above the active PV surface, coming out the underside of the module. This distance would allow the wires to clear the overlapped shingle (either asphalt or PV) from the previous row by 22". The interconnections between the subcells within the module were made above the active area in the first inch of the head lap.

This was the design installed on the Southface Energy Environmental Resource Center in Atlanta, Georgia. In this system the integration of the PV with the asphalt on the sides of the module were done by overlapping a half tab of the PV on every other row, providing a straight edge border between the two materials. This meant we must have an inactive tab on each module on this edge since the subcell would be half shadowed. We therefore had three types of modules, a 10 tab module and a left and right (for which side the inactive tab was on) dead tab module. From the Atlanta installation we came to the conclusion that it was too difficult for the roofer to deal with three different modules on the same roof deck. We also found that in order to properly handle the PV shingle, because of its length, two roofers were required.

The modules used in the Atlanta array were all R&D prototype modules. Due to the substrate size restrictions in manufacturing we decided we could not keep the 12" wide tab without producing a large amount of scrap material. We eventually settled on a 7" tab width since it would meet the manufacturing requirements as well as the industry trend in asphalt shingles toward smaller tab sizes. This 7" wide dimension closely resembles the laminated asphalt shingle being produced in the high-end asphalt shingle industry. The module length was set at approximately 7 feet long. This enabled us to achieve two design goals. The first was that this number of subcells (12) allowed us to match the 12 volt battery charging requirements (see Appendix II for the electrical specifications). The second design goal which was achieved with this new dimension was that the module could now be handled by a single roofer.

c) *Material considerations:* The basic lamination stack for the PV shingle is the same as that of all United Solar products. The basic strip or subcell utilizes a bonded wire finger for front surface current collection. These wires produce a lower profile than our previous products, allowing for thinner lamination stacks. On the top side of the cell block we use a lamination stack consisting of Tefzel/EVA/glass fiber. This new stack results in a reduction in the amount of

EVA used by 25% and glass fiber by 35%. We have also switched from a stretched Tefzel to an unstretched Tefzel. The unstretched Tefzel has better stretching properties which lead to elimination of microcracking observed in stretched Tefzel encapsulated modules, especially in high profile areas. In addition unstretched Tefzel has a potential for having lower cost. Behind the cell block we use a thin EVA/polyester combination. Both the Tefzel on the front and polyester on the back provide us with excellent dielectric strength. We have also modified the EVA formulation to utilize a rapid cure EVA. The lamination times have been reduced using this formulation which has helped reduce manufacturing costs. It is also accepted that this new formulation is considerably less sensitive to yellowing caused by exposure to UV and heat in the field.

The PV shingle deviates from the basic lamination stack at the back of the module as well as in the head lap region above the module where the overlap of consecutive rows occurs. For this region we needed a material that was rugged since the abrasion from surface features on the roof deck, such as fasteners, could be quite severe. This material also needed to be relatively inexpensive since it covers such a large area (240% of the active area). It also needed to be fire resistant since these modules would need to pass the UL fire tests. In addition to these constraint we needed this material to survive all the lamination processing and subsequent reliability testing. We decided to use a commercially available roofing membrane to serve this purpose. This membrane is a fiber glass reinforced Poly-vinyl Chloride flexible sheet with Chlorinated Polyethylene added for chemical resistance to asphalt. This membrane held up quite well through the lamination process as well as the reliability testing. The membrane was also flame resistant which has helped the module considerably in the flame tests at UL. The fiberglass mesh is very strong and resists abrasion from nails on the roof deck. We found we were able to drive a nail into the roof deck with the membrane over the nail without damaging the PV laminated to the top of the membrane. This would be very useful if roof jacks were needed to install the modules on the roof deck.

In order to save processing time and cost we decided to laminate the output leads directly into the PV package. This was done in the head lap region above the cell block. The ends of the pig tail leads were soldered to the bus bar and the first two inches of the pig tales were laminated with EVA and the membrane. This provided excellent strength to the pig tail and easily passed all the terminal robustness tests. This style of output leads also enabled us to have a very flat region at the back of the module where the wires come out so that the module would lay flat on the roof deck.

Once the modules are laid out on the roof deck in this overlapping fashion they must be leak tight even under conditions of strong wind and rain. To achieve this we have laminated to the back of the module a heat activated low melting

temperature EVA. This material is put down as a one inch strip running the full length of the module at the back of the module near the bottom edge. When overlapped, the strip of low temperature EVA melts and laminates to the front of the module in the previous row just above the 5" active region. This material must melt, laminate and seal in less than 16 hours at a temperature of 60EC in order to pass UL specifications.

3. Roofing and Installation Considerations

One of the most unique features of the PV shingle is that it is truly a building material. It must provide the same function to the building as the material it is replacing. In this case the PV shingle obviously replaces the asphalt shingle and must perform the same functions. It must be a weathering skin. It must protect the building, to at least the same degree as the asphalt roof, from weather, rain, wind, snow, hail, etc. According to the modern building codes it must also serve as a barrier for fire protection. In addition, it must complement the building in terms of aesthetics.

As with the module design these building integrated considerations have also evolved. From the beginning of the program the largest concern, other than electrical generation, was a sound water tight deck. Much of the attention in this area surrounded the wire feed-through. Initially we planned to use an ice and water bituminous membrane between the deck and the shingle in place of the more common felt paper. This material was very tacky and would stick readily to the back of the module providing a good seal around the deck penetration. The installation at Southface Energy as well as the test shed at United Solar utilized this membrane. Although this membrane performed as anticipated it also had problems. As a result of the two installations we found that the application of this sticky double sided membrane was not easy to work with for the installer. Also, it was not a commercially available membrane, which meant it would need to be supplied, at least initially, by United Solar with the roofing modules. We also found later that under very extreme temperature and humidity conditions it was possible to make the membrane run onto the front surface of the PV.

In the later installations, and eventually in the commercial product, we utilized a low melting temperature EVA that was laminated to the back of the module around the output pig tail. This adhesive was not so tacky at low temperatures (30-40EC) as to be an impediment to the installation. However, at higher temperatures, as will be seen under full sun (60EC), this EVA will melt and bond to the asphalt saturated felt paper underneath to form a seal. In addition, as discussed earlier a row of this material runs the length of the module at its base, which in addition to resisting wind induced lifting will also prevent water penetration. This combination has proved quite effective. We will later describe tests performed at UL that prove this method provides a more than adequate deck seal.

To provide a flat featureless deck we have specified the use of #30 asphalt saturated felt paper as the underlayment. We found on earlier demonstrations that, as a result of the use of more conventional #15 felt paper (due to thermal expansion of the felt paper) the PV shingles telegraphed the unevenness of the underlying felt. The #30 felt paper, which is commercially available, alleviated this problem.

a) *Mechanical installation:* One of the goals of the PV shingle design was to introduce a PV product that would be relatively inexpensive to install. We felt this could be best achieved by using roofing contractors rather than a specialized photovoltaic installer. We needed to make the installation as easy and as quick as possible. This was done by making the installation as much like conventional asphalt roofing as possible in order to take advantage of the roofers familiarity with the shingle. The layout therefore emulated the asphalt shingle with the exception of the feed-through holes. As a consequence this is where most of the effort was focused.

For the Atlanta installation registration between the output pig tails and the through hole was achieved by first laying the module into position. We then slid a tool with a slot in it that would butt up against the pig tail. The tool was held in place while the module was moved aside and the top of the slot was marked, the tool was then removed and a hole drilled through the deck. The module was then placed back in its original position, wires fed through the hole, and module laid down and fastened. The largest problem with this methodology was the amount of time it took to exchange the various items, namely, the tool, marker, module, drill and brush (to sweep away debris). We were also concerned about the accuracy of the mark since the position at which the position tool was to butt up against the output pig tail was not always certain.

In subsequent installations it was decided to implement a methodology which would enable the roofer to utilize one tool at a time. The roofer would first measure and chalk a set of horizontal and vertical registration lines (this procedure is already familiar to the roofer). He would then use a template with holes in it at the predetermined feed-through locations. This template would be guided into position by the registration chalk lines and up to 10 holes marked at the same time. Once the marking of holes was complete the roofer would put away his marker and take a drill and drill all the feed-through holes consecutively. They would then sweep the deck clean of wood chips and debris with a broom. Now the roofer was ready to start laying out the modules one by one and fastening them to the deck. This proved to be significantly faster than the previous procedure as well as being more familiar to the roofer (running alignment chalk lines).

The major installation steps, as outlined in Appendix V, are to first install conventional asphalt shingles up to the point where the first row of PV shingles are to be installed. The roofer would then measure and mark the registration lines followed by the drilling of the feed-through holes. The modules would then be positioned into place while feeding the pig tail through the hole laying the module flat on the deck and nailing the

shingle down in the prescribed locations in the head lap region. The next module would be installed in the same manner aligning it next to and butted up against the side of the previous module. On the ends of each row the asphalt shingle would be installed in the normal manner to finish each row to the edge of the deck. The next row would be installed in the same way with each module staggered with respect to the previous row by 2 tab as is the custom with asphalt shingles. Once the proper number of rows of PV shingle had been installed the roofer would finish the area above the PV shingle area with asphalt shingles in the conventional manner. Finally, a Polyurethane sealant would be used to seal the asphalt shingle to the PV shingle wherever it overlapped the PV shingle.

a) *Electrical installation:* Now that the mechanical installation of the PV shingles has occurred, the deck is sealed from the weather the electrician can begin work at any time. The pig tail wires are now hanging through the underside of the deck and ready to be connected. The first step is to fasten the wire raceway to the underside of the deck aligning the existing holes in the deck with the holes in the raceway. The shingles are then connected black wire to red using a butt splice connector and crimping tool. The system voltage will determine how many shingles are wired in series per string as shown in Appendix V. Each string will then be run to the combining box at a convenient location within the building. The rest of the electrical system will depend on overall system requirements, possibly including batteries, inverter, etc.

4) Testing and Systems

In the evolution of the design of the PV shingle we continually tested new ideas with a battery of tests that included PV tests from IEEE and UL documents. We also, where appropriate, tested the PV shingle as a roofing system by running UL and various building code tests. Finally, to tests all aspects of the performance of various designs, systems were installed in many locations.

a) *Photovoltaic tests:* Throughout this program we have tested each new design according to the IEEE PAR 1262 and UL 1703 photovoltaic test standards. We have utilized individual tests, various test sequences or the full test programs from these test standards. The most common individual tests where the humidity/freeze cycling, humidity soak and thermal cycling in conjunction with the various evaluation tests, hi-pot, electrical performance test, etc., depending on the nature of the design modifications.

In the photovoltaic testing some of the areas we have focused on have been the basic lamination stack, qualification of the grid and interconnect design, backing material and the module output design. The basic lamination stack is the same as all of United Solar's products. This design underwent rigorous testing and optimization. The optimization pertained to all various materials in the stack. The type of EVA was changed in order to decrease manufacturing time and add to UV stability. The

thickness of the EVA was minimized without compromising adhesion and complete coverage. The thickness of the fiberglass was minimized but still exceeded scratch test specifications. We tried various binder materials to optimize adhesion to the EVA. The polyester and Tefzel films were chosen and optimized for their dielectric properties, scratch resistance, adhesion and thickness. All of this optimization was carried out using the respective tests or test sequences from UL and IEEE.

The qualification of the grid and interconnect design was rigorously tested with the humidity/freeze and thermal cycling test for adhesion and changes in resistance that could effect electrical performance. In addition, rigorous flex tests were performed by wrapping the flexible laminate around a 5" mandrel for many cycles and electrical performance evaluated. The backing material was tested for dimensional stability, adhesion to the lamination stack and puncture resistance. The primary tests for these evaluations were the humidity/freeze and thermal cycling as well as damp heat. Since the module is mounted to a wood deck with nail fasteners it is possible that protrusions of the nail head above the surface could damage the module. To test this problem we mounted the module over a nail that was sticking up above the surface. We then drove the nail into the deck through the module to test the puncture resistance of the backing material. Although this may result in a dent in the solar cell no electrical damage was incurred. The pig tail terminations were tested under cycling, humidity soak and terminal pull tests in conjunction with hi-pot measurements to test the strength of the laminated pig tail connections.

In addition to the controlled environmental test, outdoor testing of systems were performed. The first systems, including the test shed at United Solar and array at Southface, were evaluated for their electrical performance over time. The test shed at United Solar, which has been operational for 22 years has performed as expected electrically. We did observe some delamination at the Tefzel/EVA interface at the bottom edge of some of the modules. The Southface array has been operational for more than 12 years and a detailed description of its performance is presented in the section summarizing Task 1. Some of the Southface modules did exhibit the same Tefzel delamination problem. This problem did not result in a hi-pot or ground fault failure. This problem was a result of the amount of EVA at the leading edge of the module and was corrected in later designs.

In addition to the systems at Southface and United Solar, test arrays have been deployed in a variety of environmental conditions. A system was installed in Sacramento, representing a very dry hot climate, another system in Dallas, representing a hot/humid climate and one at the 14,000 ft elevation of Mt. Evans in Colorado, represents very cold, windy conditions. To date, all of these arrays have performed as expected.

- a) *Roofing tests:* Since the PV shingle is an independent prepared roofing system in itself it must, in addition to the photovoltaic tests described above, meet or exceed testing specifications applied to asphalt shingle roofing systems. These tests

focus on the protection of the structure as offered by the roofing system. The primary tests for the PV shingles (the same as asphalt shingles) were fire, wind and wind driven rain tests. The fire tests consist of three separate tests, spread of flame, intermittent flame and burning brand. These tests are performed in various classifications from class A (most stringent) to class C and no classification (for failed roofing systems). The severity of the test is varied by changing conditions such as temperature of test flame, slope of deck, wind velocity, flame time duration and burning brand size. A failure is interpreted for a given test if the flame spreads beyond a distance limitation, flaming occurs under the wooden deck, flying burning brands are produced or portions of the deck become dislodged. Developmental tests have been performed in the C classification on the PV shingle. The final design has passed each of the three types of fire tests. The official testing is in progress at the time of this report. According to Boca Code, a classic fire rating is suitable for types 2, 3, and 4 construction – all but type 1 (non-combustible).

In addition to the fire test, wind loading and wind driven rain tests were performed on the PV shingle roofing system. The wind driven rain tests were performed on a sealed deck with a wind velocity of 40 mph and a flow of 1.4 gallons of water per minute for one hour. The deck was first mounted in the usual fashion including the feed-through holes. The deck was sealed or cured at 60EC for 16 hours before being placed in the wind tunnel. The water was sprayed into the output of the wind tunnel onto the deck. The amount of water over the test deck area was equivalent to 6" of water in the one hour of exposure. After termination of the wind and rain the deck was dismantled and inspected for any water getting under the PV shingles and underlayment. The PV shingle system performed very well with no water reaching the felt (the test was only considered a failure if water was found below the felt). This gave us a great deal of confidence about the integrity of our seal design for protecting the wire feed-through penetrations in the wood deck. The wind test was performed at 60 mph for two hours. The PV shingle system also passed this test with no lifting of any modules at any time during the test. The test was performed after a 16 hour soak at 60EC as in the rain test. In developmental tests, after an additional heat soak of several days outdoors in Dallas, TX the test was performed again and passed using a wind velocity of 118 mph for two hours. This is the equivalent wind force of a category 3 hurricane! As with the fire test, official testing is now under way at UL.

As with the photovoltaic testing at the system level the same PV systems are asked to perform as roofing systems as well. None of these systems, mentioned above, have reported any compromise the integrity of the PV shingle roofing system. The most interesting system in terms of the PV shingle system as a roofing system is the Mt. Evans installation, which was installed in August of 1997. This system will undergo wind velocities in excess of 100 mph on a routine basis, torrential snow and ice storms, extreme lightning conditions and sub-freezing temperatures for nine months of the year. For this system we used, in addition to the low temperature EVA, a polyurethane adhesive (under the asphalt as well as the PV) because of the extreme

temperature conditions (the ambient temperature rarely reaches 60EF). To date the system has performed as to our expectations.

4) *Manufacturing*

The final design for the PV shingle was transferred to manufacturing in the spring of 1997. We have written detailed drawings, specifications and procedures for the assembly of the PV shingle. We have built lay-up fixturing for assembling the cell block, including subcell interconnections, by-pass diodes, output bus bars and pig-tail output leads.

Manufacturing has obtained, optimized and is utilizing a large area oven capable of laminating approximately 50 PV shingles in a single batch run. Production has been running at a rate of about 40kW of shingles per month since production began in May of 1997.

Metal Roofing Modules

The metal roofing module followed the same development as the shingle module with regard to improved and lower cost lamination materials and IEEE 1262 and U.L. 1703 testing. Here we focus on aspects unique to this new product.

Whereas the Shingle Module product was a new roofing material, and considerable work concentrated on qualifying the product as a roofing product (e.g. wind lift, water penetration, fire resistance, etc.), the metal roofing product is based upon already approved roofing products. Metal roofing, according to BOCA code, has a Class B fire rating, and the metal roofing systems are already designed to be resistant to wind and water. The metal roofing product does not change the metal roofing installation procedure, and does not require any additional penetrations in the roof, as the electrical connections are fed through the ridge vent.

As with the shingle product, however, the metal roofing module design has also evolved considerably from the prototype design installed in the beginning of the PV:BONUS Phase 3 program on the NAHB Research Center's 21st Century Towhees in the spring of 1996. In this demonstration project the PV cells were directly laminated to galvalume sheet metal. After lamination, the sheet metal was sent through a modified roll-forming machine to shape the metal into a standard metal roofing panel. This design, although technically successful and aesthetically appealing, presented daunting logistical problems when considering how the module would be marketed and inventoried --

- Metal roofing pans are available in a wide variety of colors, are of almost arbitrary length, and can also vary in width – even from a single manufacturer.
- Metal roofing pans from different manufacturers are roll-formed and shaped in different ways. Pre-lamination of the cells to the roofing material prior to

final forming would have to be looked at in detail for each manufacturer. In some cases, final roll forming takes place at the site of installation.

- Given that the metal roofing market is a small, though growing, fraction of the total U.S. roofing market, it would be necessary to make our product compatible with nearly all the metal roofing products on the market in order to easily market this product.

As a result of these considerations, it was decided in the Phase III part of this program to redesign the metal roofing product in the form of a laminate that could be applied to both architectural (requiring roof sheathing underneath the metal panels) and structural standing seam products produced by any manufacturer. The solution was a family of flexible laminates that could be bonded to standing seam metal panels after final forming of the panel. There are four laminates, two designed for architectural panels (the ASR series), and two designed for structural panels (the SSR series). The principle difference between the panels is the location of the connector – on the top side for architectural panels, and on the bottom side for the structural panels. These laminates are shown in Appendix II.

The use of these laminates also required the development of the technology to bond the laminates to the metal roofing pans. The first approach used a widely used asphalt-based roofing material as the bond. This system was tested on an outdoor array at United Solar and on a customer's home. Small problems were observed with technique due to the combination of high temperatures and differential thermal expansion of the metal roofing and the laminate. Since then a new technique, using a low temperature EVA has been developed and tested in a number of installations without any problem. United Solar is still working on developing new methods of the bonding the material to the metal roofing pans that can be used by conventional roofing contractors in the field.

As with the shingle product, the metal roofing product has also completed IEEE 1262 and U.L. developmental testing. Final U.L. approval of this product is expected in early 1988.

TASK 4. SUMMARY OF MARKETING ACTIVITIES

During the two and one half years since the initial installation of the demonstration sites in Atlanta, Georgia and Bowie, Maryland, several aspects of the United Solar Systems Corp. (United Solar) marketing program have evolved. Fundamental to this evolution are changes in the product line.

The original metal roof in Bowie, Maryland has expanded to four products (8 products including different power ratings available). The products differ from one another in several basic areas (see attached specifications).

ELECTRICAL SPECIFICATIONS -- From the original product, several variations have been developed to meet market demands. United Solar now produces a total of four electrical specifications within their metal roofing product line ranging from 60 to 128 watts. Twelve and 24 volt products are available.

MECHANICAL SPECIFICATIONS--From an original standing seam product, two basic panels have developed. The architectural panel (**ASR**-series) is mounted onto a continuous or nearly continuous decking usually made of wood. The structural panel (**SSR**-series) is designed to mount onto widely spaced purlins as in metal buildings and carports. Each of the standard panels is 16 inches wide with two standard lengths, 9.5 feet and 18.3 feet long.

OPTIONS -- Despite the standardizing production of the basic laminates, United Solar kept the ability to modify metal roofs for a wide variety of applications. Electrical terminations can be potted pigtails mounted front or back or junction boxes with terminal strips usually mounted on the back providing for conduit connections. Tests of several adhesives have assured United Solar of its ability to bond to painted and unpainted surfaces To date United Solar has bonded to roofing segments as long as 24 feet long.

The shingle (**SHR-17**) product has also undergone significant improvement. Its aesthetics were improved with its ability to merge with standard asphalt shingles by reducing the tab size to seven inches from the twelve inch tabs of Atlanta. New adhesives have been introduced giving assurance of a minimum of UL-60. Finally the overall length of the shingle was reduced to seven feet from ten feet making it much more manageable.

UL LISTING -- UL Listing of United Solar's standard framed products was accomplished in 1997. Testing has been underway with UL for the metal roofing and shingle product. It is anticipated that UL will complete their testing and perform a cross-discipline review by the end of February. UL approval is therefore anticipated for March 1998.

IEEE-1262 -- United Solar has performed reliability testing to IEEE-1262 standards for the metal roofing. Additional testing to achieve full qualification to IEEE-1262 standards is underway for both the shingle and metal roofing panels. Anticipated completion is April or May 1998.

United Solar is in the process of obtaining international certification in both Europe and South America.

During this product evolution, significant progress was made in getting it to the marketplace. Over 43 kW of **UNI-SOLAR** ®roofing products were used in 14 domestic projects, and over 200 kW were sold internationally. Projects were completed with Central and Southwest Services, TU Electric, and Southern California Edison (via Solar Utility Inc.). A list of the installed projects is included in this report.

Key achievements are as follows:

- United Solar 5 MW Triple-junction plant production began in Troy, Michigan in March 1997 for cells and April 1997 for finished product. Prior to Troy start-up, cells for standard production came from a Canon facility in Japan. During that time United Solar customers could not receive DOE subsidies through UPVG.
- Arrangements with Elk Corporation, ATAS International, McElroy Metals, Trace Engineering, and Solar Utility Inc. have assure a supply of balance of system components at discounted prices.
- Packaged system designs have been completed for PV Electric Vehicle Covered Parking Systems and Home Energy Security Systems. We are very near a packaged design for a 2kW residential grid intertied system with or without battery storage.
- UL Listing of United Solar standard framed and flexible panels was obtained in September 1997. This set the stage for listing of metal and shingle roofing products because of the many similarities in construction materials. Listing of roofing products is anticipated by March 1998.
- Preliminary IEEE- 1262 testing was completed using internal facilities. Full qualification by an outside laboratory, Arizona State University, is planned for completion in March and April 1998, for both metal and shingle products.
- A variety of marketing materials has been completed, including a web site at <http://ovonic.com/unisolar.html> and a toll free line at 1-888-UNI-SOLAR. A specification guide was completed and distributed to architects and builders

through Sweet's Catalog (21,000 catalogs and 65,000 CDs were mailed out in January '98).

- Projects in six states were completed with associated agents and dealers (see listing).
- United Solar shipped over 200 kW of shingle product to export customers.
- Solar Utility Inc. and United Solar signed an exclusive national distribution agreement in July 1997.

The most significant development during the period is the agreement with Solar Utility Inc. of Culver City, California (Solar Utility) as the exclusive national distributor of **UNI-SOLAR®** roofing products. Solar Utility has the resources and experience to multiply United Solar's domestic marketing impact. The management and staff of Solar Utility are committed to the development of a distribution network plan modeled along the lines of United Solar's commercialization plan provided in the Team-Up 95 contract. A majority of United Solar efforts over the past 6 months have been to transfer product and market information to Solar Utility. Solar Utility's plans are similar to United Solar's original plan, except that Solar Utility prefers working with dealers rather than commissioned agents. As a result of this change in policy, candidate agents under United Solar's direct sale program are being encouraged to function as dealers, taking ownership of product and responsibility for its sale. Both candidate agents and Solar Utility are approaching this effort pragmatically. Seven agents or dealers have completed projects in six states and Canada.

By September 1998, **UNI-SOLAR®** roofing products will be UL listed and IEEE approved; and Solar Utilities, Inc. plans to have installed at least 50 kW domestically. An additional 50 kW by December 1998, and 100 kW by May 1999, is projected by Solar Utilities. International sales are forecast at over 150 kW in 1998. A more rapid increase is not projected because of the time necessary for the architectural community to incorporate PV into projects. The California market alone should support most of the domestic growth because of the \$ 3.00 per watt subsidy program from the California Energy Commission and United Solar's improved market position.

Coordination of increasing direct international sales by United Solar, a focused domestic effort by Solar Utilities, and continued support of various federal and state programs should result in a small but self supporting building integrated photovoltaic industry by the year 2000. Major contributions to domestic energy production in the 21st century will require additional plant capacity.

United Solar Systems Corp. is a joint venture of Energy Conversion Devices, Inc. (Troy, Michigan, USA) and Canon, Inc. (Tokyo, Japan). **UNI-SOLAR®** is a registered Trademark of United Solar Systems Corp.

UNITED SOLAR SYSTEMS CORP.
SELECTED PROJECT EXPERIENCE

McMillan Home	May-97	CA	J.P. & K. McMillan	ASR-128	2
TU Electric-Energy Park	May-97	TX	TU Electric	SHR-17	0.8
CSW PV/EV Cov. Prkng	Jun-97	TX	Central and Southwest Svs	SSR-128	4
CSW PV/EV Cov. Prkng	Jun-97	OK	Southwestern Electric	SSR-128	4
Auvernier Community Cntr	May-97	Switzerland	Community of Auvernier	BSR-18	2.1
Centex – Home of the Future	Jun-97	TX	United Solar	SHR-17	0.95
UC Irvine	Aug-97	CA	Solar Utility Co./SCE	SSR-64/128	6.1
Mt. Evans	Aug-97	CO	Solar Utility/BTU	SHR-17	1.6
Solatek	Sep-97	Africa	Solatek	SSR-64	0.64
International (Confidential)	Aug-Dec '97	Middle E.	Confidential	SHR-17	200
Natural Environments	Oct-97	Arkansas	Solar Utility/Nat. Environments	SHR-17	1
9oETM Solar	Oct-97	NY	Solar Utility/ETM Solar/residence	SHR-17	2
National Inst. of Standards	Nov-97	MD	Solar Utility/United Solar Tech.	SHR-17	2
East Lansing	Nov-97	MI	MMTC/Urban Options	SHR-17	2
U of Michigan, Architecture	Jul-97	MI	MMTC/U of M	SSR-128	2
Chino Hills School	Nov-97	CA	Solar Utility/SCE	SSR-128	12

APPENDIX I

NAHB RESEARCH CENTER INTEGRATED PV-METAL ROOFING PROJECT SUMMARY

(This Appendix is under revision)

NAHB RESEARCH CENTER INTEGRATED PV-METAL ROOFING PROJECT SUMMARY

APPENDIX I

Table of Contents

INTRODUCTION	1
BIPV Module Development	1
PV-Metal Roofing Module Electrical Characteristics and Installation	2
BIPV System Design-PV Grid Connected with Battery Storage and Standby.....	3
System Sizing.....	5
System Characteristics.....	5
System Control.....	5
User Interaction	6
Benefits/Restrictions	6
Balance-of-System Power Equipment and Components.....	6
Energy Storage.....	7
Circuit Protection	7
Inverter	8
PV System-Unique Electrical Issues	9
PV System-Unique Energy Storage Issues	10
BIPV Roofing Operation	10
PV-Metal Roofing Performance Summary.....	10
CONCLUSIONS	14
Appendix 1.A. – NAHB 21 st Century Townhouse Project Press Release	
Appendix 1.B. - Plots of PV Array Output vs. Temperature	
Appendix 1.C. - Normalized PV Output for 15-month Period	

Appendix I

BUILDING INTEGRATE PV-METAL ROOFING

PROJECT SUMMARY

Introduction

The NAHB Research Center participated in the development of the ECD PV-metal roofing product. One of the primary objectives of this effort was to demonstrate the interaction and application of PV systems in the construction of new homes. This was accomplished by installing a PV system as part of one of the units in the NAHB Research Center's 21st Century Townhouse project (see Appendix I.A. for a description of the project). The PV system included photovoltaic cells integrated with metal roofing to form a PV-metal roofing module. It was developed by Energy Conversion Devices (ECD) through support of the Department of Energy PV:BONUS program. The balance-of-system electrical equipment included an inverter to convert dc power to utility compatible ac power, battery storage, protective fusing, and other basic electrical equipment. The PV system and the electrical system of the home were monitored to measure energy consumption, PV array output, and electric utility supply to the home. The PV system was installed in May 1996 and has been operational since June 1996. Power output of the PV system was used directly by the house electrical loads, furnished to the utility grid, or used to charge a set of lead-acid batteries

BIPV Module Development

The PV-metal roofing module product was the combined development effort of the PV module manufacturing, the home building, and the utility industries. Under the auspices of the PV:BONUS program, the design of the PV-metal roofing module was refined and tested resulting in a successful demonstration system. The PV system, designed as an integral part of the home electrical system, continues to operate today as an important renewable energy power source. As a building integrated PV (BIPV) module, the new product was designed to meet challenging demands of the home building industry. The separation of trades in the installation of the modules, use of prescriptive rather than engineered system design requirements, and the need for simplicity of operation posed problems for design of the module. This BIPV product development effort achieved new levels of competence in overcoming these obstacles.

The mechanical trades in the residential market are organized to perform specialized construction tasks. Specialized crews and subcontractors prepare the building foundation, construct the shell and interior framing, install roofing sheathing and exterior finish, complete the siding exterior finishes, install the HVAC systems and plumbing, and install electrical wiring and outlets, etc. Although, these specialized trades are dependent on one another, they often operate in a disjointed manner. The BIPV product must fit into this fragmented construction process. The realities and demands of this process guided the

product development effort for the PV-metal roofing and resulted in the PV system shown in Figure 1.

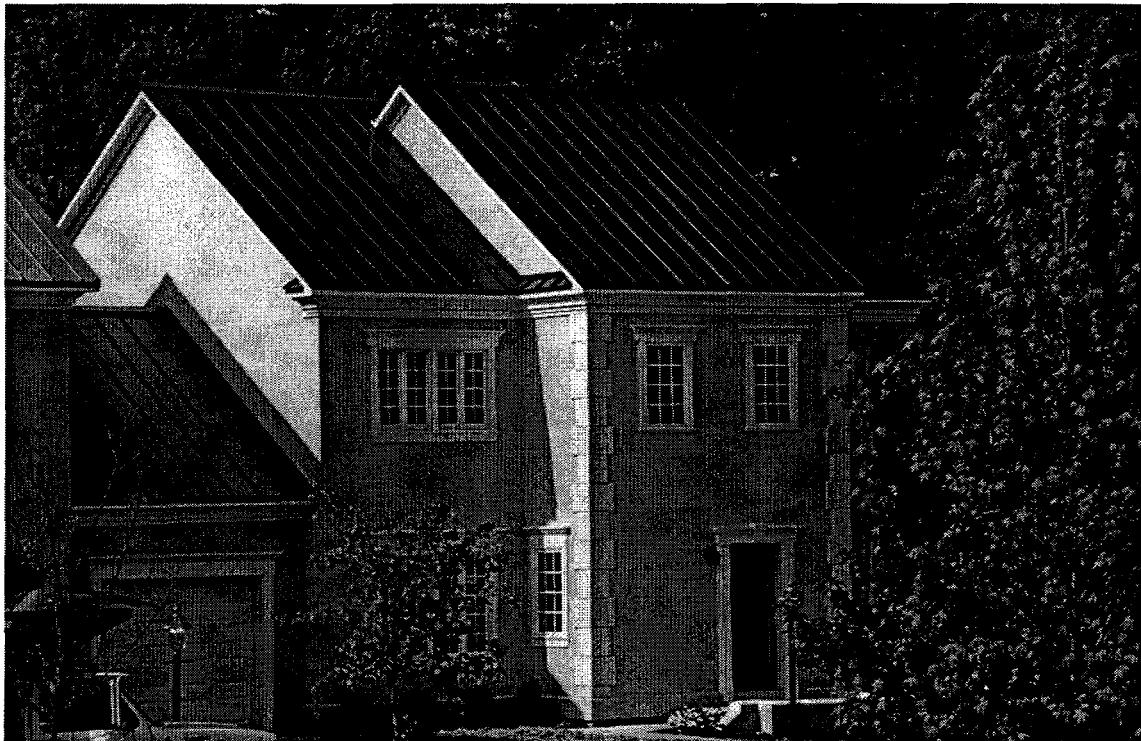


Figure 1: ECD PV-Metal Roofing Installed (PV darker areas)

PV-Metal Roofing Module Electrical Characteristics and Installation

All of the modules were electrically identical. The PV cells, 19 per module, were connected in series to produce a nominal operating voltage of 24 volts for each module. Series connection of two modules provided a nominal 48 volts. Nine pairs of modules were installed on two sections of roofing. Wiring from the interconnecting cells terminated at the top of the module in an encapsulated junction. Two cables extended from this junction and were joined by a third wire directly attached to the metal pan. This third wire served as an equipment grounding conductor and was attached in a location where the bare metal pan had been exposed. The nominal 48 volt system was selected to minimize electrical losses and fuse sizes.

Use of procedures and equipment common in residential construction and familiar to the installers has the advantage of contributing to lower installed costs. Calculation of current levels and determination of wiring losses is necessary as part of the PV installation, but is typically not part of the residential electrical system installation. Rather, sizing of conductors is based on familiar and specific code requirements.

The PV module wiring extended through the ridge vent (Figure 2) and was sleeved through flexible non-metallic conduit to a junction box. The wiring from two modules terminated at a junction box where the modules were connected in series through a blocking diode. The wiring requirements for this portion of the PV system were outlined by the PV manufacturer. The use of devices, such as blocking diodes, is not usual practice in residential wiring unless they are an integral part of installed equipment or are specifically outlined by an equipment manufacturer. In this case, it was necessary that either the manufacturer or a third party, such as a systems integrator, communicate the requirements for use, selection, and installation of blocking diodes for the electrical installer.



Figure 2: PV-Metal Roofing Wiring

From the junction boxes, the wiring extended to a fuse panel designed for use in a dc system. The rated voltage was greater than 100 volts dc and contained dead-front fuse holders. The nine series-connected PV pairs were each wired to a fuse-holder containing a ten amp fuse. In the fuse panel, three fuse outputs were connected together, functioning as a combiner circuit and merging three PV output circuits into one PV supply circuit. Three PV supply circuits were then routed to the garage where they were connected to the power equipment.

BIPV System Design-PV Grid Connected with Battery Storage and Standby

A residential PV system that is interactive with a utility grid consists of a number of hardware components, primarily a PV array, an inverter, and battery storage as shown in Figure 3. The inverter manages all functions of power conversion and control. The utility

and the consumer benefit most when PV energy is produced during the time of day when utilities experience their greatest demand, and offsetting the utility's and consumers' highest costs. The design would seek to have peak PV system output coincide with utility peak periods.

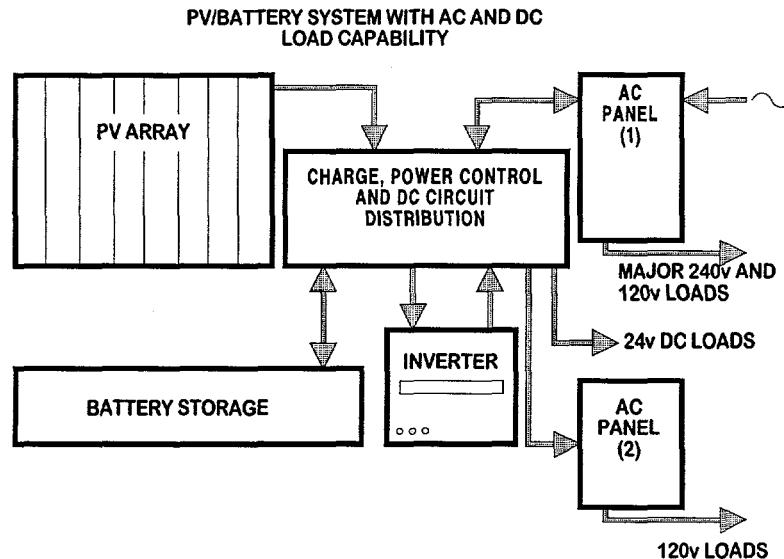


Figure 3: PV System Simplified Block Diagram

Since the inverter output feeds into the home electrical system and/or the utility system, the inverter must meet the requirements of the utility for power quality and safety. The PV output will supply varying amounts of power to the home or the grid at any given moment since the solar resource varies throughout the day. Due to its intermittent character, PV power may not be available at times when the utility would find the PV generation most beneficial. Conversely, the PV may be producing power when the utility already has enough base power to supply its demand. The PV output fits with a utility DSM program when it matches a specific load requirement.

The option of 'standby power' is part of the system design and permits the user to take advantage of the available storage and/or PV power in the event the utility power is not available. The stand-by feature requires installation of one additional component, the control unit, not required in other PV configurations. The control unit is capable of numerous functions such as power control and distribution. The inverter connects with and can serve certain ac design loads supplying inverted PV or battery power, or simply passing power to the utility ac power to meet the design loads. For example, the inverter will feed PV power back to the utility if the batteries are charged and the house design load is satisfied. If the utility power is disconnected, the inverter can supply available battery and PV power to satisfy the house load. Low voltage dc loads can also be fused and distributed from the central control unit in this design.

The above PV system configuration functions primarily as a demand side management tool, reducing the utility load. The system can also be programmed to feed power to the utility at

designated periods while the PV and/or batteries continue to satisfy the house design loads. The inverter can also be programmed to never draw utility power during certain times of the day, and support the charge cycle only at off-peak times. Further the system can be used for load shifting (i.e. using utility power at off periods times rather than throughout the day) if the PV array and the battery storage size can meet the house design loads for the specified period.

System sizing

The PV system size is dependent on the size of the inverter and battery storage as well as the available surface area for the array. The design must ensure the ac design loads do not exceed the inverter rating or, if desired, that the batteries can supply the design loads for the period of time when the utility might be disconnected. The size of the battery bank will have to be sufficiently large if the utility seeks to gain generation from the system. The PV array does not need to handle all of the battery charging requirements if the utility is available to charge the batteries.

System characteristics

The control unit is the primary interface between the PV array, the house design loads and the batteries. The control unit and the inverter serve all functions of power control and safety, including imposing constraints on current to the battery bank. A system configuration of this type will include the following features:

- inverter-utility disconnect if loss of utility ac
- inverter-utility disconnect if frequency or voltage mismatch
- inverter switch to battery power if loss of utility ac
- inverter shutdown if over current, over voltage, under voltage
- optional electrical isolation (through use of a transformer)
- PV voltage range typically a nominal 12 to 48 volts
- PV open circuit voltage which may approach 60 Vdc depending on ambient temperatures

System Control

While the inverter functions to control the general power flow, the user can design and adjust parameters to manipulate battery charge and discharge levels, charge rates, utility charge periods, etc. If necessary, the utility's ac can be programmed to charge the batteries at only certain periods. When a low battery condition exists and the utility power is not available, loads can be disconnected, but this feature requires additional equipment. When sufficient intensity of sunlight is available, the inverter can use the PV output to either charge the battery or serve the load directly. The inverter is operational at any time the ac design load requires power. A reduced power level may be part of the inverter circuit, if all design ac loads are off. All safety controls are automatic.

User Interaction

The PV system operates as designed providing the control unit and the inverter are functioning properly. No user interface is necessary, except for periodic checks to verify the inverter is functioning and the batteries are in good condition. The user in this case will have immediate feedback if the inverter fails completely since a number of circuits will disconnect. The control unit can be designed to include a switch that completely bypasses the inverter in the event the inverter requires removal for servicing. Use of maintenance-free batteries simplify the battery upkeep but, increase cost and decrease service life. A qualified technician would be required to determine whether the array was functioning according to specifications.

Benefits/Restrictions

The PV system is designed to supply power to the ac or dc design loads, or for battery charging. The available sunlight can provide charge capability, but if the batteries are charged, the excess PV power can supply the utility grid. In this configuration, the system will lower the overall electrical demand of the home and may offer grid support. The PV power will most likely be used to charge the batteries and/or supply the design ac loads.

The above configuration does permit use of the system if the utility power fails. The inverter will be programmed to function at all times even if the utility power is not available. The inverter will disconnect the house loads if a low battery condition exists. In the event that the batteries are fully charged and the ac and dc design loads are insufficient to consume all of the PV power, the excess will be fed back to the utility. In the event that the utility does not permit interconnection with the grid, the inverter can be configured to prohibit feed back to the utility, but if this feature is used, the array size must be more carefully matched to the battery storage and the design loads.

This system has a great deal of flexibility in that it can be made to draw power from the grid at specified times, supply the design loads as needed, and cycle the batteries to obtain optimum life-cycle economics. The system can also function as a backup power supply, permitting use of vital equipment in the event of a utility power outage.

Balance-of-System Power Equipment and Components

A set of electrical balance-of-system (BOS) power equipment was used for power conversion, storage, and safety. The equipment was located along the rear wall in the demonstration home's garage. Although the equipment was installed by the electrician, help from the builder was required for the installation of the battery container. The overall PV power system design included battery storage and power conversion to ac electricity. The dc power available from the PV was directly connected to the battery storage unit. The battery storage unit was connected to the inverter which converted the dc power to ac power at 120 volts. The ac power was used directly in the home or was

fed back to the utility grid where it was used on the utility electric system. Fuse and circuit breaker protection equipment was also used to protect the occupants and the equipment from damage if a problem should occur, much in the same way circuit breakers are now used in the home. A dedicated circuit distribution panel was used for a number of 120 volt ac circuits which were connected to the inverter output. These circuits were an addition to the circuits which were available through the main electric distribution panel.

Energy Storage

Energy storage capability was included in this project to provide the range of capability available for renewable energy power generation in residential and light commercial buildings. For example, storage provided a new level of electric power reliability and autonomy from power outages due to storms. In utility service areas where electricity costs are based on a time-of-use rate structure, battery storage can effectively shift home energy use to utility off-peak periods when prices are lower and utility demand is typically less.

The energy storage technology selected for use in this application was a lead-acid battery set manufactured by Concorde Battery Corporation. The batteries were maintenance-free, valve-regulated units with the electrolyte absorbed in a glass mat. Each battery was rated at a discharge capacity of 220 amp-hours at an eight hour rate. The manufacturer stated the benefits of this type of battery included non-spillable electrolyte, lower operating resistance, greater charge retention, negligible hydrogen production during charge, and high reliability. Another important feature was the stated temperature range for operation, from -40°F to 160°F. This last feature permitted the batteries to be used in a garage space without damage due to temperature swings. These features may play an important role in residential applications where consumer interaction with the batteries is limited. Each of these features, however, increase the battery cost. When standard, flooded, lead-acid technology is acceptable and owner involvement in maintenance and care is available then standard, deep cycle, lead-acid batteries are most cost-effective.

Circuit Protection

PV systems, except for very specifically designed systems, require over-current and short-circuit protection. The equipment which satisfies these requirements may include panels, disconnects, or other listed equipment. Specific labeled¹ equipment to satisfy the requirements of provisions of the NEC are available for use in either dc systems or as equipment specifically suited to PV and renewable energy systems.

Equipment for over-current protection is required in all circuits of the PV system except in some very specific instances. The equipment must provide protection from all current sources. In some PV systems, different current sources may be involved such as a battery

¹ "Labeled" according to the NEC includes "Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation"

bank, PV modules, and a charge circuit from an inverter. This feature of a PV system is unfamiliar to many contractors and places restrictions on the type of equipment used. Also, fuse and circuit breaker ratings are often available for ac circuits but may not be as available for dc circuits. Particular attention to equipment ratings is important in electrical systems where dc power supplies are used.

Similar issues to those listed above for the PV module wiring should be considered when installing PV circuit and battery storage equipment. The dc ratings necessary for some of the equipment are not obvious on some fuse and circuit breaker equipment. Other specific ratings for voltage and short circuit current may need to be calculated. In contrast, in many ac systems, these particular calculations are rare. The current-carrying capacity of wiring is often not considered in ac systems beyond the standard ranges of ac circuits such as 15, 20, or 30 amps, used commonly in residential construction. In PV and battery storage dc circuits, the voltage losses due to current flow may be significant and will easily affect the size of the wires used in a dc circuit.

Equipment used for circuit protection is available including labels recognized by local code enforcement jurisdictions. Some of this equipment, however, is available only through certain distribution channels not commonly used by electrical trade contractors.

Inverter

PV systems often include an inverter to convert the dc power to ac for use in the home. The inverter, is designed to approximate—in varying degrees of accuracy—the ac voltage supplied by the electric utility. Generally, inverters are supplied with dc power from either the PV array or batteries, or a combination of both. The inverter output is connected to a standard power distribution panel which, in turn, supplies ac circuits used in the home. With some inverters, the ac supplied to the house loads may also be directed back to the utility grid. Specific inverter requirements are available through Underwriter's Laboratory for such an inverter connection.

The inverter equipment is the most straightforward of the all BOS equipment to install, since dc and ac connections are typically all that are required. The ac connections are typical of those used in residential construction. Inverter connections at an ac distribution panel are regulated by the NEC with requirements for the types of circuits to be connected, the ratings of the equipment, and necessary markings to be included.

Depending on the complexity of the inverter, the operation may require extensive knowledge of the PV system. Inverters which utilize no battery storage are the simplest devices, typically requiring very little interface from the user. Many of these devices operate whenever the PV output is sufficient to activate the inverter. Their operation is transparent to the house loads, the utility signal, and the available sunlight. Typically, no maintenance is required unless a problem has occurred which may require the operator to reset the inverter unit.

When battery storage is included, the inverter complexity increases with such options as battery charge control, connection to the utility, and connection to the loads. Battery storage capability increases the flexibility to supply power from the battery and/or PV system to the house loads at any time. The inverter may be capable of directing power to house loads, to battery storage, to the utility, or to none of these—depending on how it is programmed.

In addition, the inverter may be capable of supplying different levels of charge current at different times of the day. The inverter, in some cases, may also be used as a battery charger or as a regulated supply to the utility grid. This range of programming options, or control parameters, make the inverter extremely flexible, but the complexity of programming, with so many options, may easily become overwhelming to the operator. Once the electrician has installed the unit, homeowner communication with the inverter operation may also be difficult.

PV System-Unique Electrical Issues

A particular area of concern is the sizing of wiring conductors and equipment ratings used in the PV circuits. Since the PV module operation is dependent on sunlight levels, the rated output of many PV modules is determined using standard operating conditions. Deviance from the standard conditions may change the operating characteristics of voltage and current. Selection of equipment used in the PV circuits is dependent on the assumed maximum voltage and current in each part of the wiring system. The NEC provides some guidance in determining the voltage and current rating of the PV system. These ratings are dependent on a particular PV module and connection scheme, as well as the necessary *safety* factors to account for changes in ambient weather conditions.

Particular areas of concern to the residential electrical installer which are significantly different from typical residential installations include:

- determination of individual PV module ratings and combined PV circuit and array ratings,
- proper sizing of conductors from the PV module to the conversion equipment,
- proper sizing of fuse and circuit breaker components,
- determination of components required in the PV source circuit combiner junction,
- requirements for surge protection, and
- requirements for location and installation of PV equipment.

Installation of the wiring, combiner fuse panel, and associated junction boxes are more easily installed in new construction since the attic space and wall chases are open and easily accessible. It is expected that costs associated with retrofit installation will be higher than in new construction, unless the installation is part of a substantial renovation project such as an addition. Use of devices which simplify connections such as plug connectors, polarized caps and push tabs may speed the installation and limit errors in wiring connections. During this prototype installation, one series connection and diode

were found to be improperly spliced causing the series set to not function. Errors such as this may be limited with improved connection devices.

PV System-Unique Energy Storage Issues

Some installation issues relating to use of battery storage in residential buildings include:

- production of flammable gases during charge cycles,
- protection from temperature extremes, either very cold or very hot,
- protection from acid spillage,
- sizing and type of battery conductors,
- sizing and type of circuit protection equipment,
- suitable charge control,
- adequate short-circuit protection, and
- location of storage units and circuit protection equipment.

Design and installation of battery storage units in residential buildings is addressed in the National Electric Code in Section 480-Storage Batteries and Section 690-Solar Photovoltaic Systems. Section 480 includes provisions for racks or trays, ventilation, and protection from accidental contact of live parts. Section 690 provides more specific requirements than section 480 since battery storage systems are common in PV systems. Section 690 also requirements for voltage, fusing, charge control, and grounding.

BIPV Roofing Operation

The PV-metal roofing, requires little maintenance which is a major advantage in the residential market where maintenance opportunities may be irregular or non-existent. It is expected that the metal roof warranty would extend to the PV-metal roof, however the PV manufacturer would warrant the electrical output different from the mechanical performance of the roof.

PV-Metal Roofing-Performance Summary

The PV array output is measured every five seconds and the data collected every 10 minutes. Figure 4 shows the daily dc energy production from the array. The days are in Julian calendar notation with day 153 representing June 1st, 1996. The fifteen months of operation shown represent 457 days. Missing data account for less than two days total. The average daily PV dc output was 5.44 kWh. The average daily PV ac output from the inverter (minus the charge energy) was 4.80 kWh.

Daily PV Output

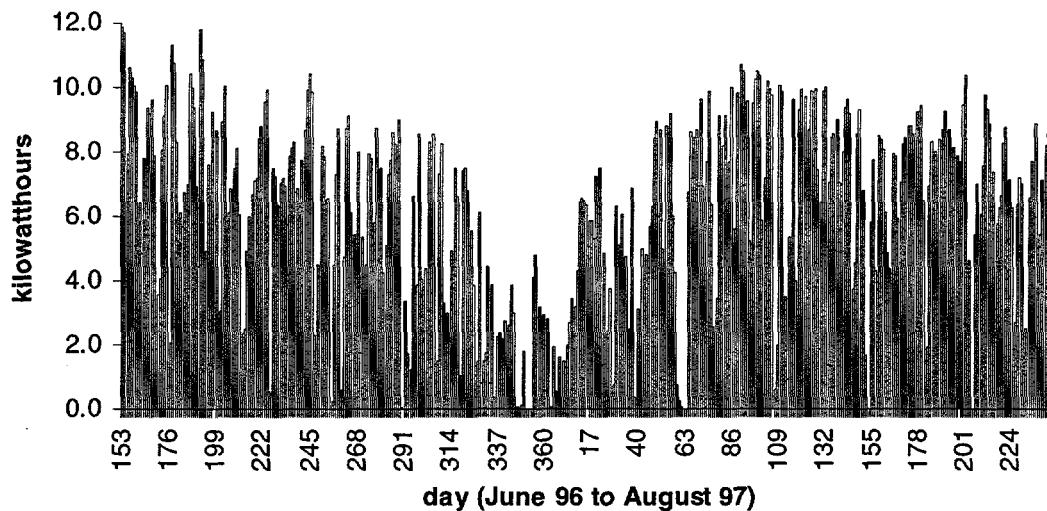


Figure 4: Daily PV Output Summary

The graph indicates that periods of near zero PV output, less than 1 kWh, represents about only 15 percent of the days. Figure 5 shows how the PV output influenced the house loads during the period.

ECD PV-Metal Roofing System - NAHB Research Center Research Home Park 15 Month Summary

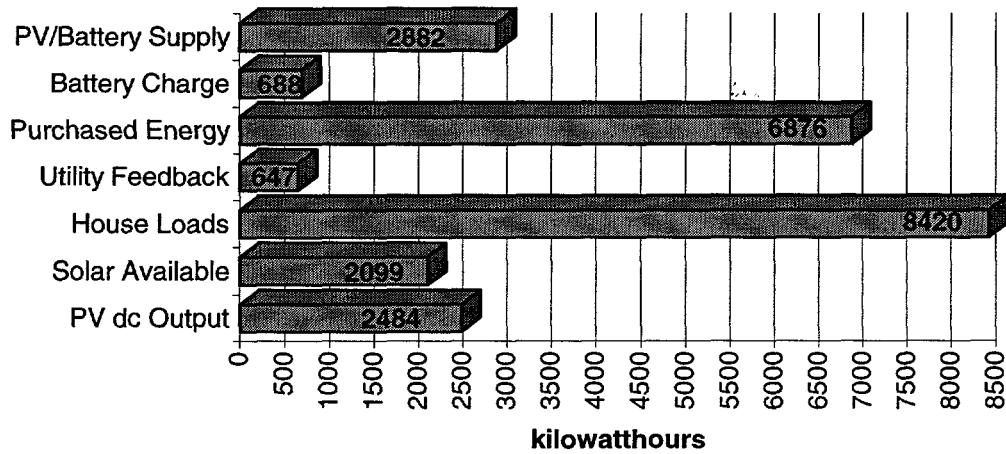


Figure 5: Energy Consumption and Supply

The PV/battery system supplied about 25 percent of the house loads for the period, with the primary load being space conditioning equipment operation. An additional five percent was directed back to the utility. The house loads, excluding battery charge

energy, consumed an average of 18.4 kWh per day. The house electrical consumption and supply is summarized in the following data:

PV dc Output	2484.1	kWh
Solar Available	2098.9	kWh
House Loads	8420.4	kWh
Utility Feedback	647.5	kWh
Purchased Energy	6876.3	kWh
Battery Charge	688.0	kWh
PV/Battery Supply	2881.5	kWh
Total PV ac Output	2193.5	kWh
PV Supply of Total Loads	24.5%	
PV Supply of Total Loads if Net Metering	29.5%	
Number of Days in Period	457	
Average Daily Consumption	18.43	kWh
Missing Data	0.40%	
Average Daily Solar Output	5.44	kWh
Average Daily AC Solar Output	4.80	kWh
Overall Inverter Efficiency	88.30%	

The house consumption included HVAC operation. Air conditioning operation accounted for approximately 4787 kWh or almost 57 percent of the house loads. The house was unoccupied but open for tours during the period of evaluation.

The performance of the PV array was compared during the June to August periods for 1996 and 1997, operation as shown in Figure 6. The stabilized performance visible in the 1997 data contrasts with the fluctuating—but higher—normalized output of 1996.

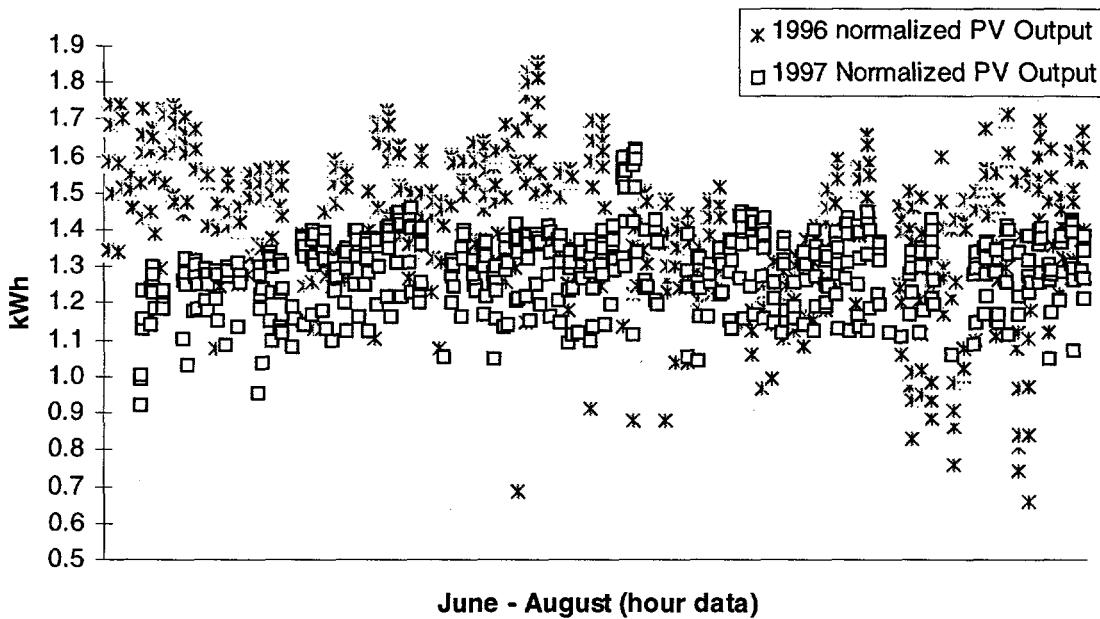


Figure 6: Normalized PV Output for Two Summer Seasons

A plot of the PV output versus PV deck temperatures is shown in Appendix I.B. The PV deck temperatures were taken below the metal roofing pan and #15 felt paper. The 1996 period showed a large amount of scatter with the lowest normalized output at the higher pan temperatures. However, the data was inconsistent. A similar plot for the subsequent year, 1997, was much more consistent and even showed a slight increase as the PV deck temperatures increased. The battery bus voltages indicated on the plot varied minimally over the operating period.

Appendix I.C. shows the normalized PV output throughout the 15 month period. The output was relatively stable, with small change during the year.

Conclusions

A new PV-metal roofing integrated PV module has been developed and successfully implemented in a home in Maryland. The PV modules were installed identically as the rest of the metal roofing on the home. The roofers installed the PV modules placing the wiring through the ridge vent are into the attic. The roofers encountered no unique problems with the installation.

The PV array electrical connections were made in the attic space to a combiner fuse panel. Three PV output circuits were routed to the garage area where a Power Center battery set and inverter were installed.

The PV output was paralleled with a set of lead-acid batteries operating at a nominal 48 volts dc. The PV/battery output was connected to a programmable inverter with a 120 volt ac output. The inverter could be programmed to supply a 120 volt house sub-panel, or send power to the house main panel. The PV output, if not used in the home, was directed to the utility grid.

The house was supplied with a time-of-use meter which was prohibited from turning in reverse. The PV output fed back to the utility grid was monitored by the house data acquisition equipment but not by the utility.

The PV output supplied 25 percent of the total house loads during the period. If the energy fed back to the utility is considered, the PV output supplied 30 percent of the total house loads. The PV output and system operated continuously throughout the period.

The home has been open as a demonstration home available for tours. Consumers, builders, manufacturers, government officials, as well as industry representatives from abroad have reviewed the system during their visits.

The demonstration home will be offered for sale in the coming year.

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APPENDIX I.A
NAHB 21st Century Townhouse Project Press Release

NAHB RESEARCH CENTER

400 Prince George's Boulevard • Upper Marlboro, MD 20774-8731 • (301) 249-4000 • FAX 249-0305

FOR IMMEDIATE RELEASE
PHOTOS AVAILABLE

Contact: Ralph Lee Smith

21st Century Townhouses Feature Innovative Products and Systems



The NAHB Research Center has built four research townhouses, called the Twenty-First Century Townhouses, in the NAHB National Research Home Park in Bowie, Maryland.

The project highlights innovative products and systems that illustrate two home-building themes:

21st Century Townhouses

NAHB Research Center is an Equal Employment Opportunity employer.

Page 1

- alternatives to dimensional lumber; and
- innovative approaches to achieving advanced energy efficiency.

Both themes represent important frontiers of home building during the balance of this decade. The purpose of the project is to hasten the arrival of successful products in both fields into the home building mainstream.

Wall and Floor Systems

Each house features a different structural system. The systems are as follows:

House #1: Structural insulated panels. The panels consist of a foam-core center clad on both sides with oriented-strand board. The panels were used for all walls above grade, and for roof panels.

House #2: Concrete forming system. The system, which was used to create footer-to-roof exterior walls, utilizes foamed plastic stackable forms that are filled with concrete.

House #3: Steel. Light structural-gauge steel was used to frame exterior walls and interior partition walls, and for flooring, steel roof trusses, and roofing.

House #4: Autoclaved aerated concrete units. The units used to build the houses are made of autoclaved aerated concrete. They are lightweight and can be cut with a handsaw or bandsaw. The units

accept nails or screws for attachment of finishes. Raceways for wiring and plumbing can be made by routing the wall.

Foundations

The foundations of the first three houses were built with the concrete forming system that was also used to build the walls of House #2.

House #4 was built with a pre-cast and pre-insulated foundation system. The system's panels, which arrive by truck, utilizes high-density, reinforced concrete with integral insulation and treated wood nailers. The system eliminates the need to form and

pour concrete footings, and is designed to reduce dampness, moisture, and mildew.

Roofs, Windows, Doors

All four townhouses have roofs made of standing-seam steel roofing. Steel roofs typically have a useful life of over 50 years, during which they require little or no maintenance.

Energy-efficient glider and casement windows installed in the townhouses have high-performance argon-filled glazing panels.

Energy-efficient fiberglass entry doors are insulated, and can be finished with stain to look like traditional six-panel wood doors.

Photovoltaics

A first-of-its-kind photovoltaic roof that integrates photovoltaic modules into steel roof panels was installed on House #4. In the summer of 1996, the roof generated enough electricity to accommodate 21 percent of the house's electrical needs.

In addition, 17 percent of the roof's electric output was transmitted back into the utility grid. In the future, such

feedback can cause the home owner's meter to "run backward," reducing utility bills.

Natural Gas Refueling Station

Natural gas vehicle refueling stations are installed in Houses #1 and #3. The refueling station taps into the house's natural gas line, compresses regular low-pressure gas from the line, and supplies it to vehicles when they are not in use.

Illustrated Guide Available

The Research Center has issued a publication entitled, *The Twenty-First Century Townhouses: An Illustrated Guide*. The 51-page Guide, containing 39 photographs, is available from the Research Center for \$10.00 plus \$4.00 postage and handling. Payment can be made by check, or by phone, using VISA or Mastercard. Contact the NAHB Research Center, 400 Prince George's Blvd., Upper Marlboro, MD 20774-8731, phone 301/249-4000, fax 301/249-0305.

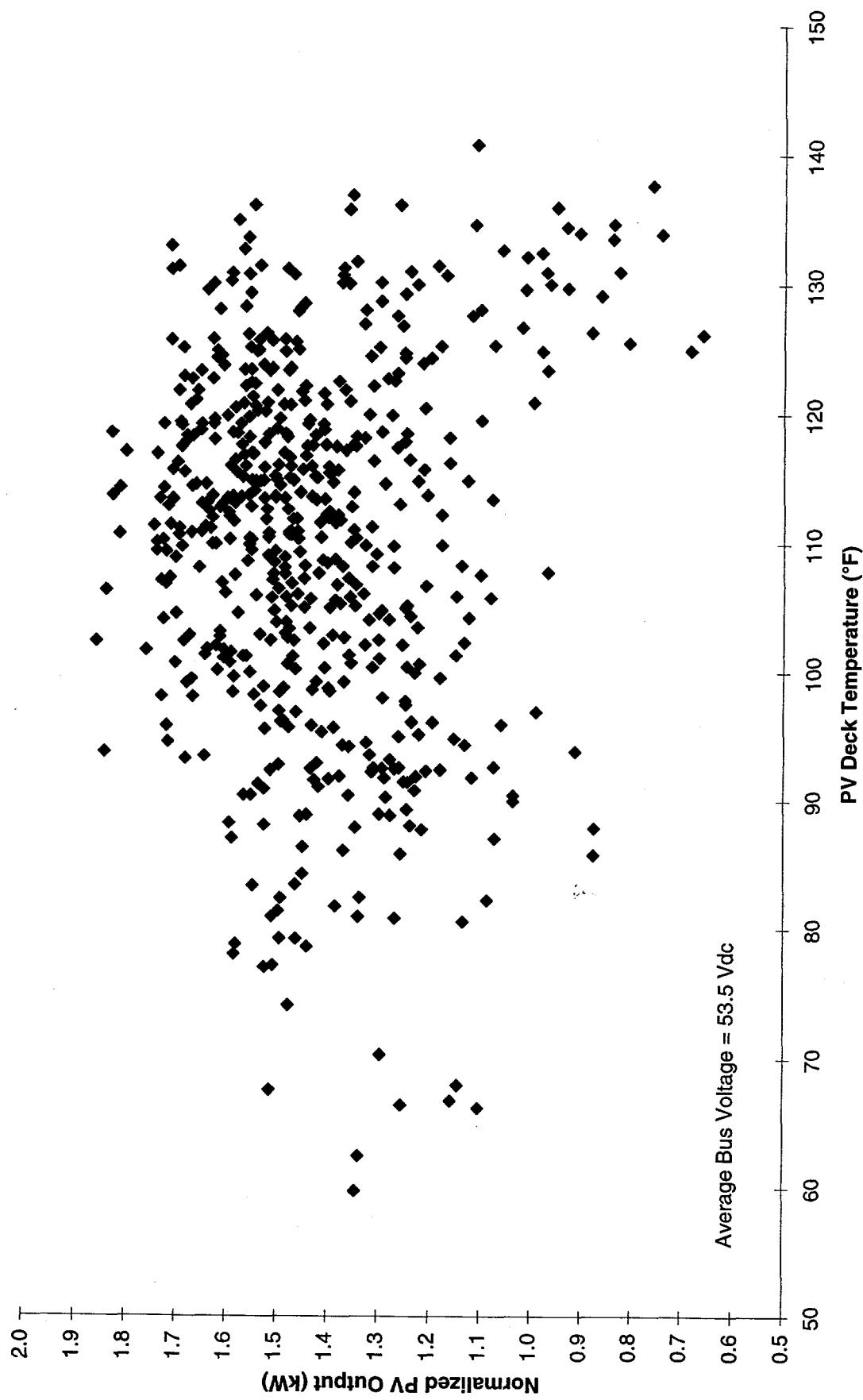
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6/97

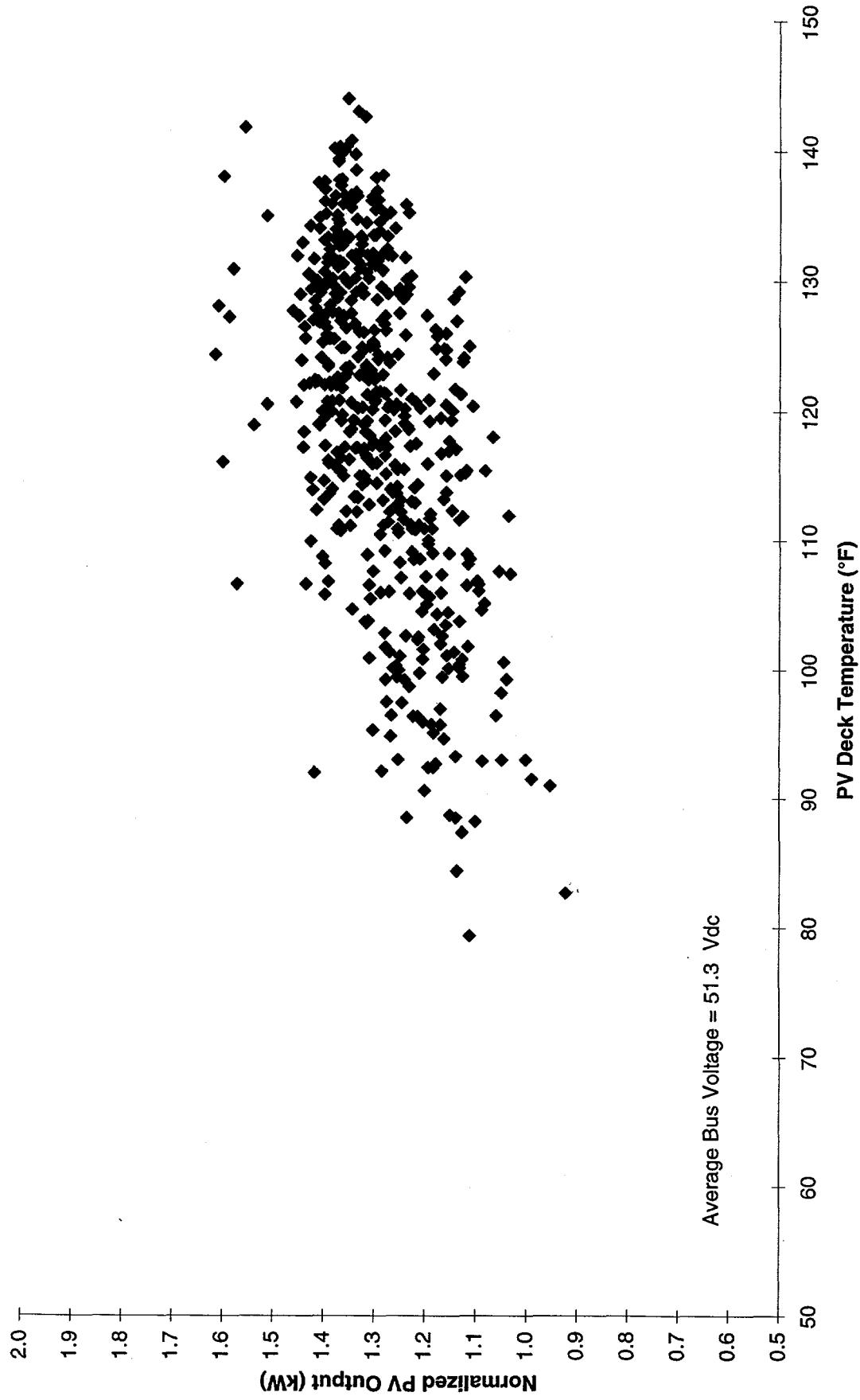
APPENDIX I.B

Plots of PV Array Output vs. Temperature

Days 153-244, 1996

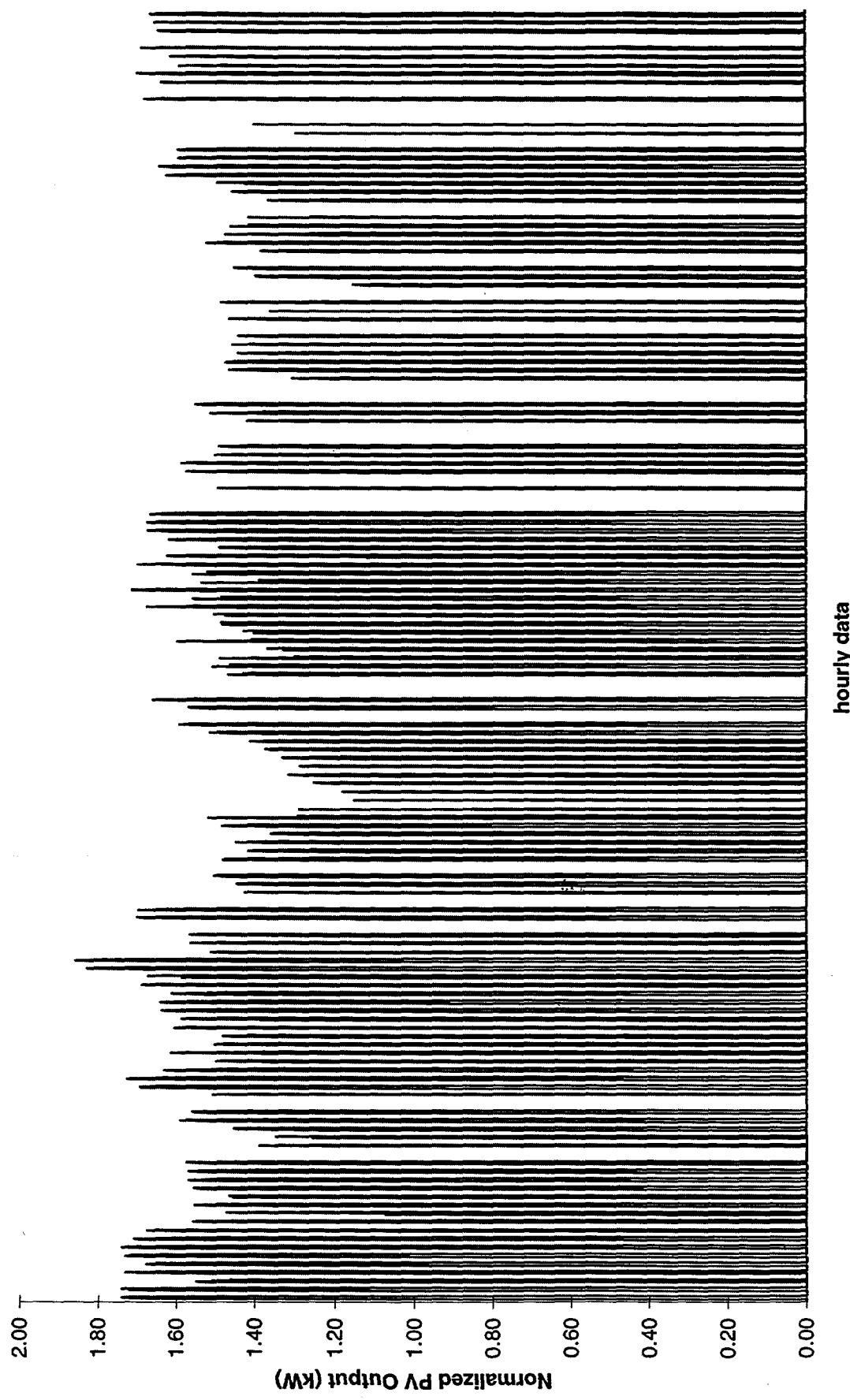


Days 152-245, 1997

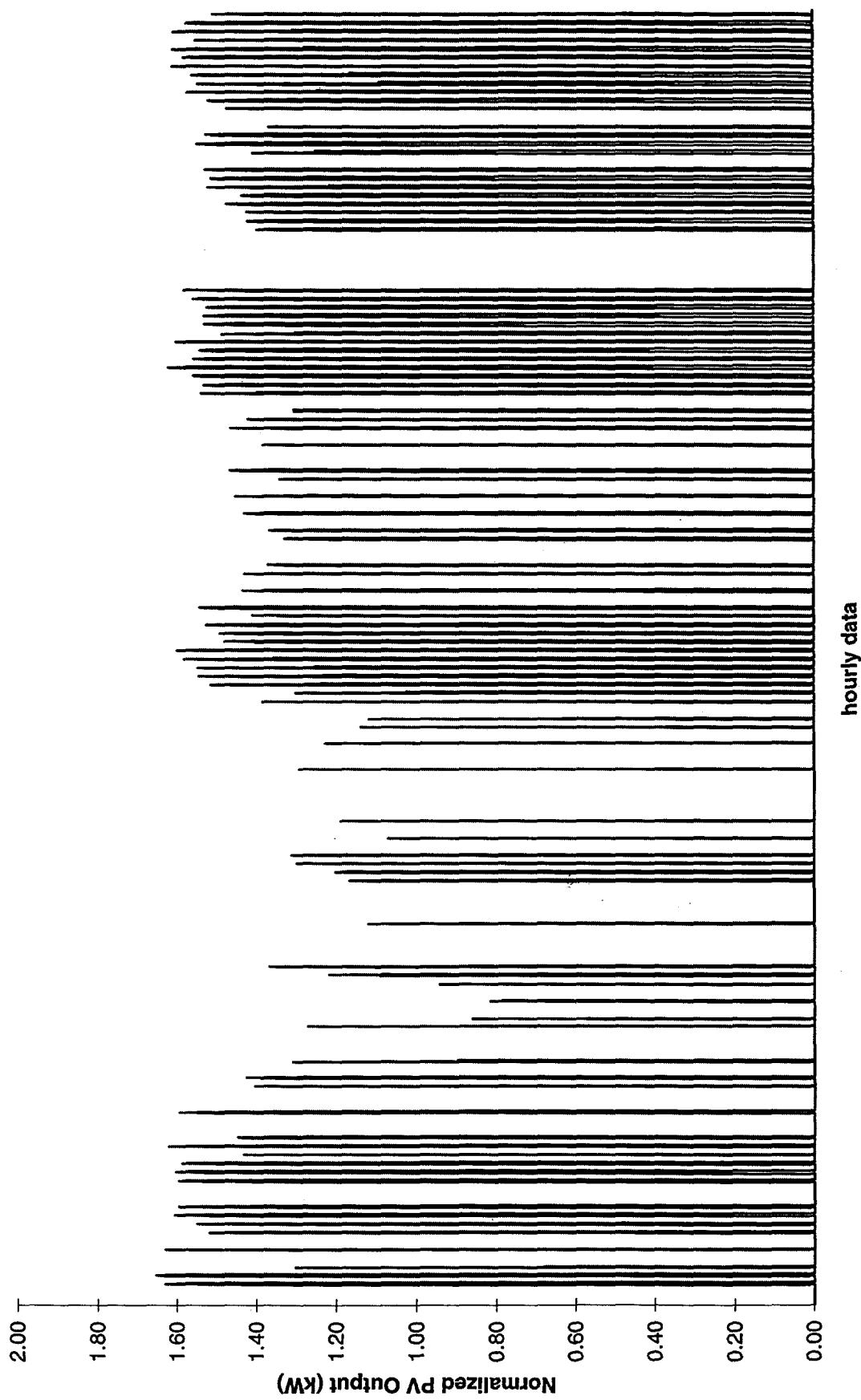


APPENDIX I.C
Normalized PV Output for 15-Month Period

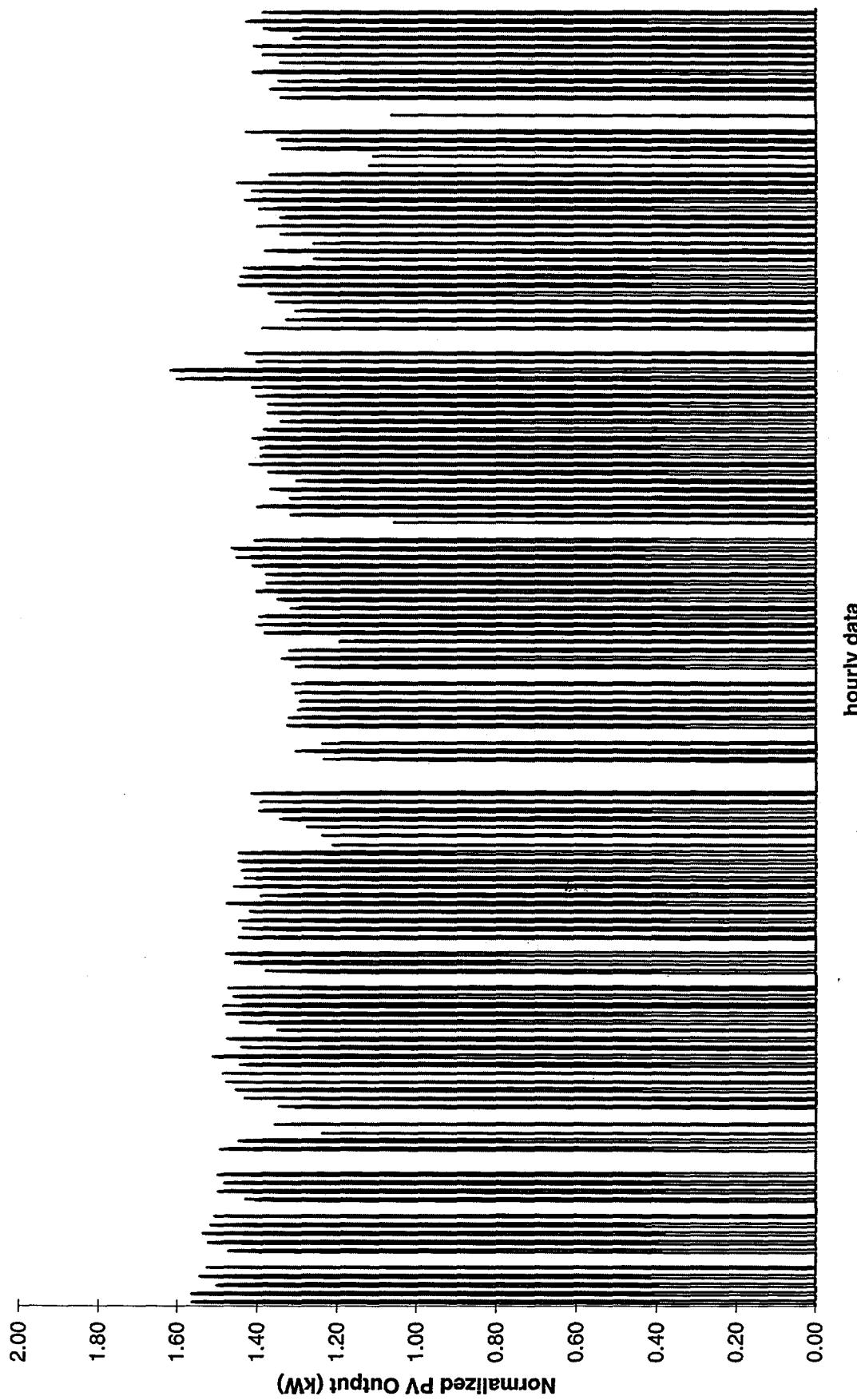
June-October, 1996



November, 1996 - March, 1997



April - August, 1997



APPENDIX II

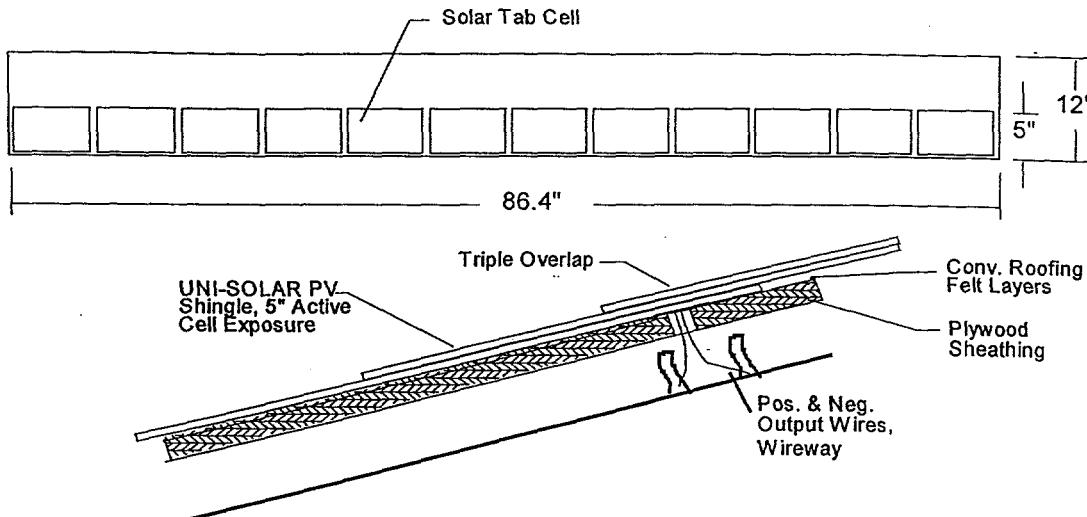
United Solar BIPV Product Specifications

UNI-SOLAR Roofing

Product Specifications

Product	Watts	Volts	Amps	Dimensions (nom.)*	Wdc/ft ²
ASR-64	64	16	4	16.75 in. x 9.5 ft. +	5
ASR-128	128	32	4	16.75 in. x 18.3 ft. +	5
SSR-64	64	16	4	16 in. x 9.5 ft. +	5
SSR-128	128	32	4	16 in. x 18.3 ft. +	5
SHR-17	17	8.5	2	86.4 in. x 5 in. (exposed)	5.5

* For ASR & SSR, actual in-situ dimensions depend on metal panel and seam design.

**Solar Electric Shingle
For Residential and Commercial Applications****UNI-SOLAR PV Shingle**

United Solar Systems Corp. SHR-17 PV Shingle is a flexible 17 watt solar electric roofing module designed to look like and function as a conventional roofing shingle. It is made of UNI-SOLAR Triple Junction, amorphous silicon alloy cells, interconnected with bypass diodes and laminated in Tefzel and EVA to form a "dimensional" roofing shingle. It is installed on conventional roof decking and felt underlayment using common roofing nails. The shingles are applied to the roof in consecutive overlapping layers with each shingle layed over the inactive top 7" of the previous shingle. As the sunshine warms the PV Shingle, an adhesive bonds shingles together forming a weather resistant roof covering. Electrical connections from each shingle are by two 12" long, 18 gauge lead wires, from the underside of each shingle. Connections are made below the roof deck by making one roof penetration per shingle and passing the lead wires through the roof deck. UNI-SOLAR PV Shingles meet conventional shingle wind load tests. The SHR-17 is warranted for 10 years to produce not less than 90% of its Rated Power.

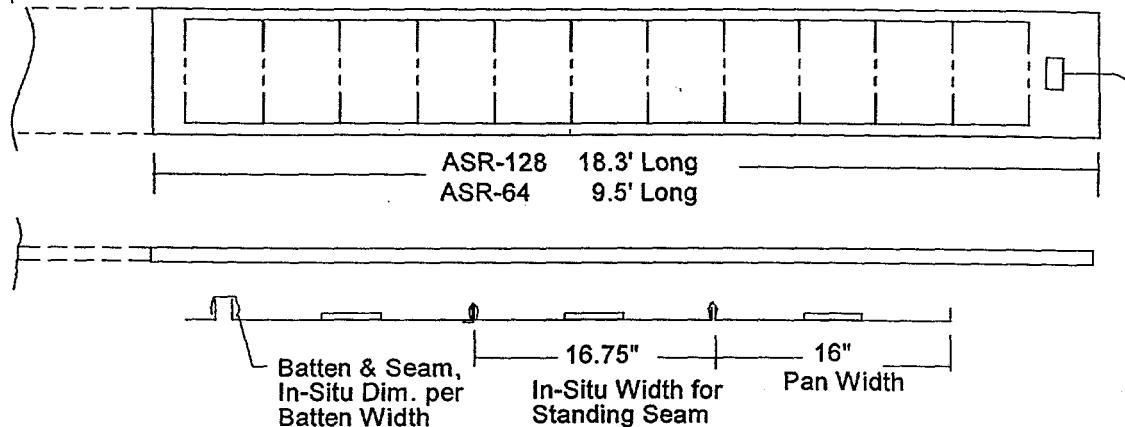
SPECIFICATIONS*

Rated Power (Watts)	17.3	Open Circuit Voltage (Volts)	12.0
Operating Voltage (Volts)	8.6	Short Circuit Current (Amps)	2.5
Operating Current (Amps)	2.0	Weight (lbs./kgs)	4.2/1.9

*Electrical specifications (+/-10%) are based on measurements performed at standard test conditions of 1 kW/m² irradiance, air mass 1.5 and cell temp of 25°C after long-term stabilization. Performance may vary up to 10% from Rated Power due to low temp. operation, spectral and related effects. During initial 8 to 10 weeks of operation modules have higher electrical output than rated output. The output power may be higher by 15%, operating voltage may be higher by 11%, and operating current may be higher by 4%. Specifications subject to change.

**Architectural Standing Seam Roofing Panel
For Commercial Buildings and Residential Homes**

Panel Length to 24'
for Customer Specified
Panel, UNI-SOLAR Roofing
Active Length per ASR-64 or 128

**UNI-SOLAR ASR Roofing Panel**

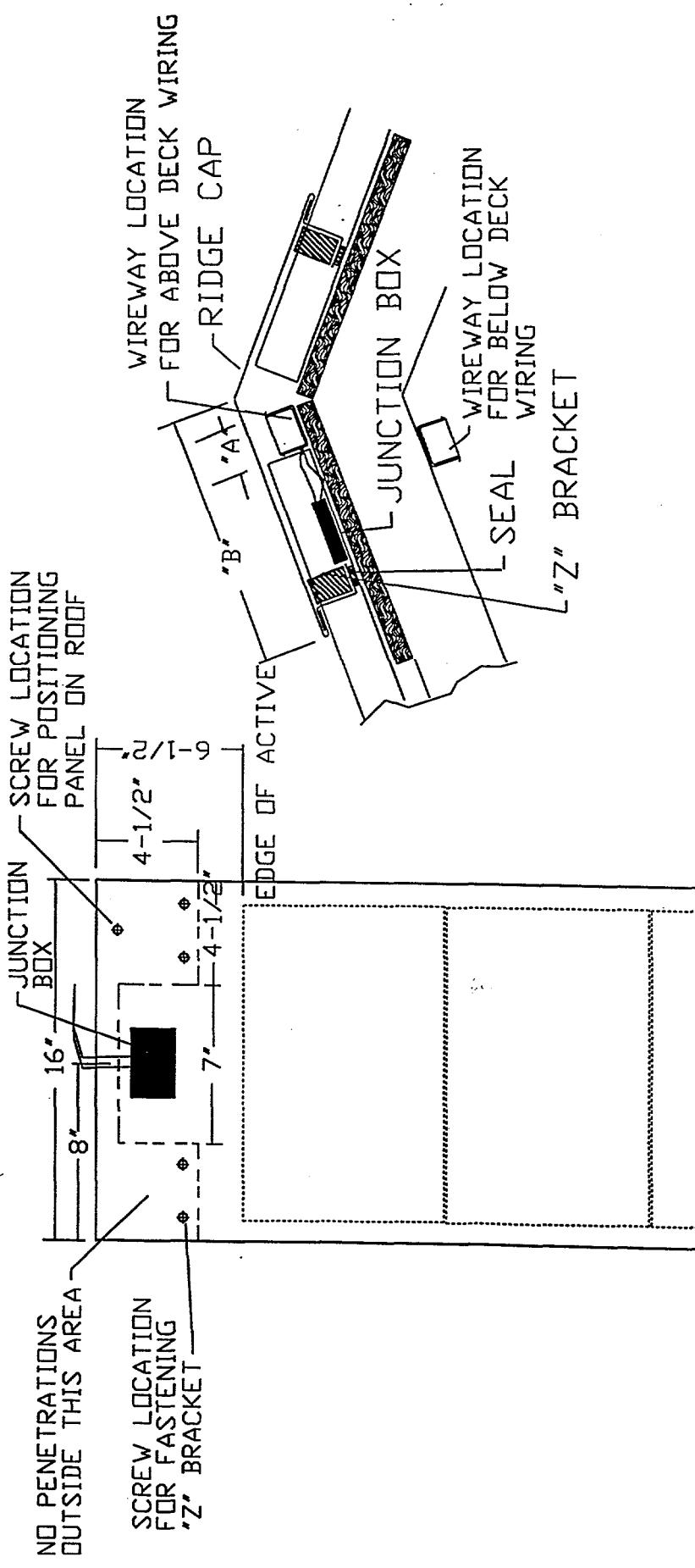
United Solar's Architectural Standing Seam Roofing panel is a "building integrated" photovoltaic roofing element for commercial buildings and residential homes. It is fabricated using United Solar's proprietary multi-junction amorphous silicon photovoltaic cell material laminated in weather resistant Tefzel and EVA polymers and bonded to conventional metal roofing panels. Electrical termination is on the top of the panel, hidden and protected by the ridge cap. Designed to fit metal roofing pans of 16" width, ASR-64 and ASR-128 panels, have standard lengths of 9.5 ft. and 18.3 ft., respectively. United Solar also offers ASR-64 and ASR-128 laminates to customer supplied panels to 24 ft. length. ASR panels are warranted for 10 years for 90% of their rated peak output.

SPECIFICATIONS*

Product	ASR-64/128		ASR-64/128
Rated Power (Watts)	64 / 128	Open Circ. Voltage (Volts)	23.8 / 47.6
Operating Voltage (Volts)	16.5 / 33	Short Circ. Current (Amps)	4.8
Operating Current (Amps)	3.88	Weight (lbs./ft ²)	2

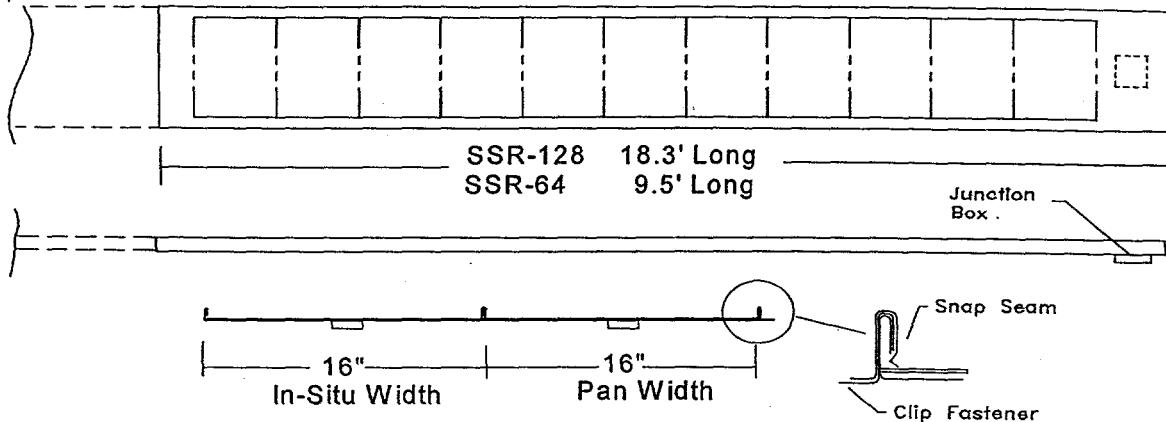
*Electrical specifications (+/-10%) are based on measurements performed at standard test conditions of 1 kW/m² irradiance, air mass 1.5 and cell temp of 25°C after long-term stabilization. Performance may vary up to 10% from Rated Power due to low temp. operation, spectral and related effects. During initial 8 to 10 weeks of operation modules have higher electrical output than rated output. The output power may be higher by 15%, operating voltage may be higher by 11%, and operating current may be higher by 4%. Specifications subject to change.

UNI-SOLAR METAL ROOFING TOP TERMINATION & RIDGE CAP DETAILS



**Structural Standing Seam Roofing Panel
For Commercial Bldgs, Covered Parking Systems, Power Stations**

Panel Length to 24'
for Customer Specified
Panel, UNI-SOLAR Roofing
Active Length per SSR-64 or 128

**UNI-SOLAR SSR Roofing Panel**

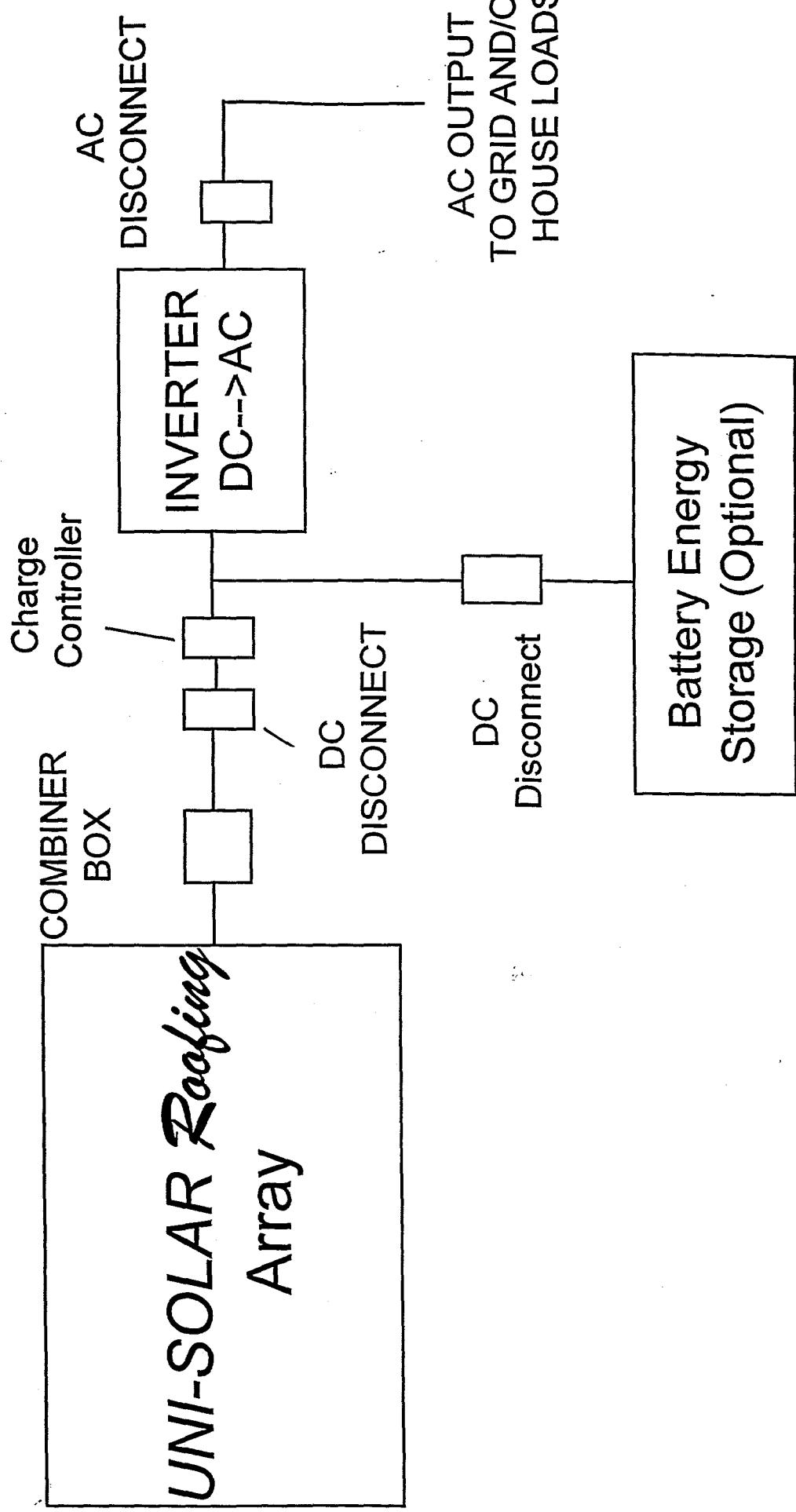
United Solar's Structural Metal PV panel is a "building integrated" photovoltaic roofing element. Fabricated using UNI-SOLAR Triple Junction, amorphous silicon alloy photovoltaic cells, cells are connected with bypass diodes, laminated in Tefzel and EVA and bonded to conventional flat metal roofing panels. Electrical termination is by pig-tails at the bottom of the panel. A junction box (shown) is optional. Designed to fit flat pan structural roofing panels with inside pan width of 16", SSR-64 and SSR-128 panels have standard lengths of 9.5 ft. and 18.3 ft., respectively. United Solar also offers SSR-64 and SSR-128 laminates on customer supplied panels to 24 ft. length. Structural characteristics (section properties and allowable loads for given spans), are per metal panel supplier. SSR panels are warranted for 10 years to produce not less than 90% of Rated Power.

SPECIFICATIONS*

Product	SSR-64/128		SSR-64/128
Rated Power (Watts)	64 / 128	Open Circ. Voltage (Volts)	23.8 / 47.6
Operating Voltage (Volts)	16.5 / 33	Short Circ. Current (Amps)	4.8
Operating Current (Amps)	3.88	Weight (lbs./ft ²)	2

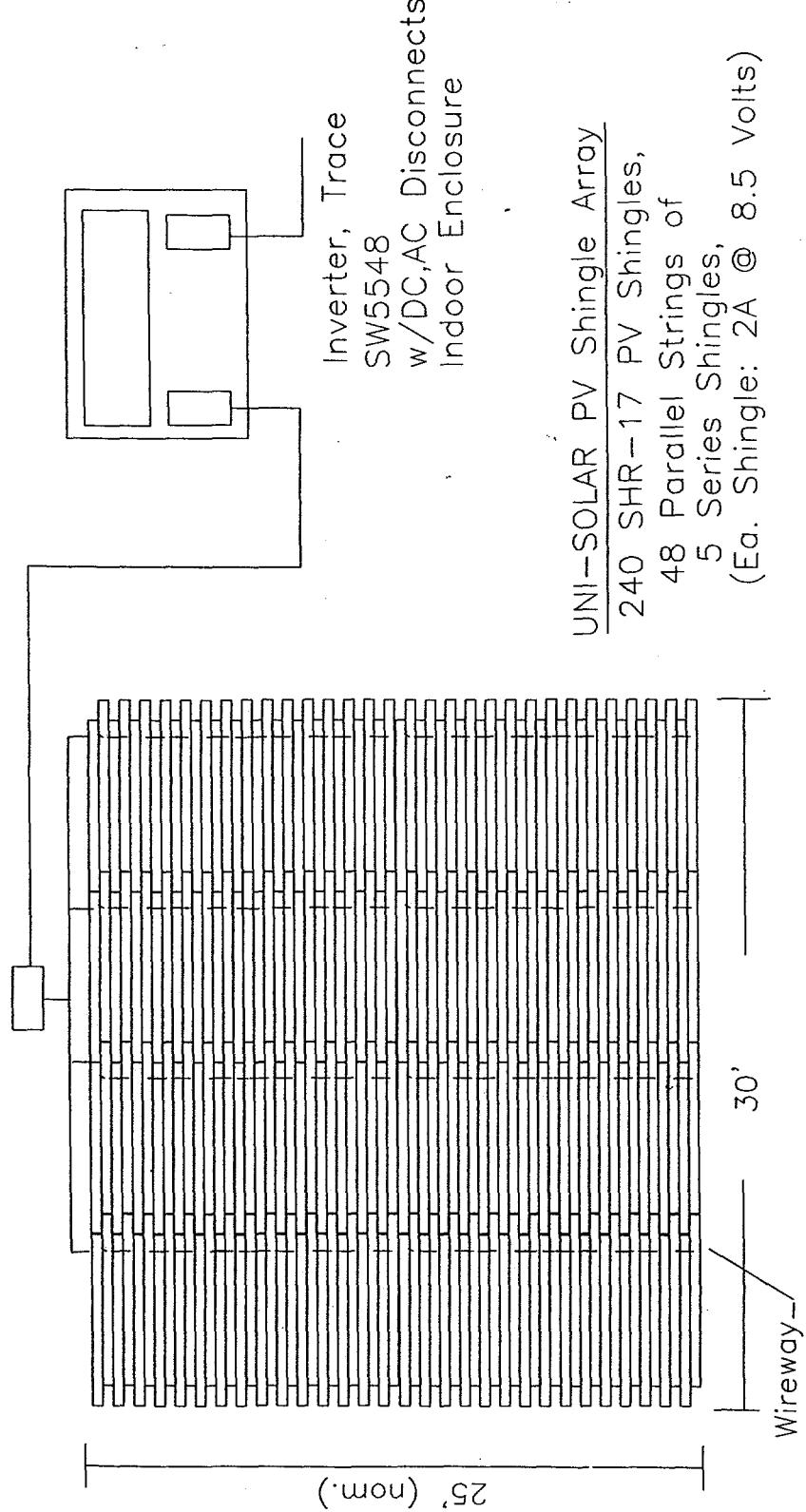
*Electrical specifications (+/-10%) are based on measurements performed at standard test conditions of 1 kW/m² irradiance, air mass 1.5 and cell temp of 25°C after long-term stabilization. Performance may vary up to 10% from Rated Power due to low temp. operation, spectral and related effects. During initial 8 to 10 weeks of operation modules have higher electrical output than rated output. The output power may be higher by 15%, operating voltage may be higher by 11%, and operating current may be higher by 4%. Specifications subject to change.

UNI-SOLAR Roofing Systems



UNI-SOLAR PV Shingle Roofing System

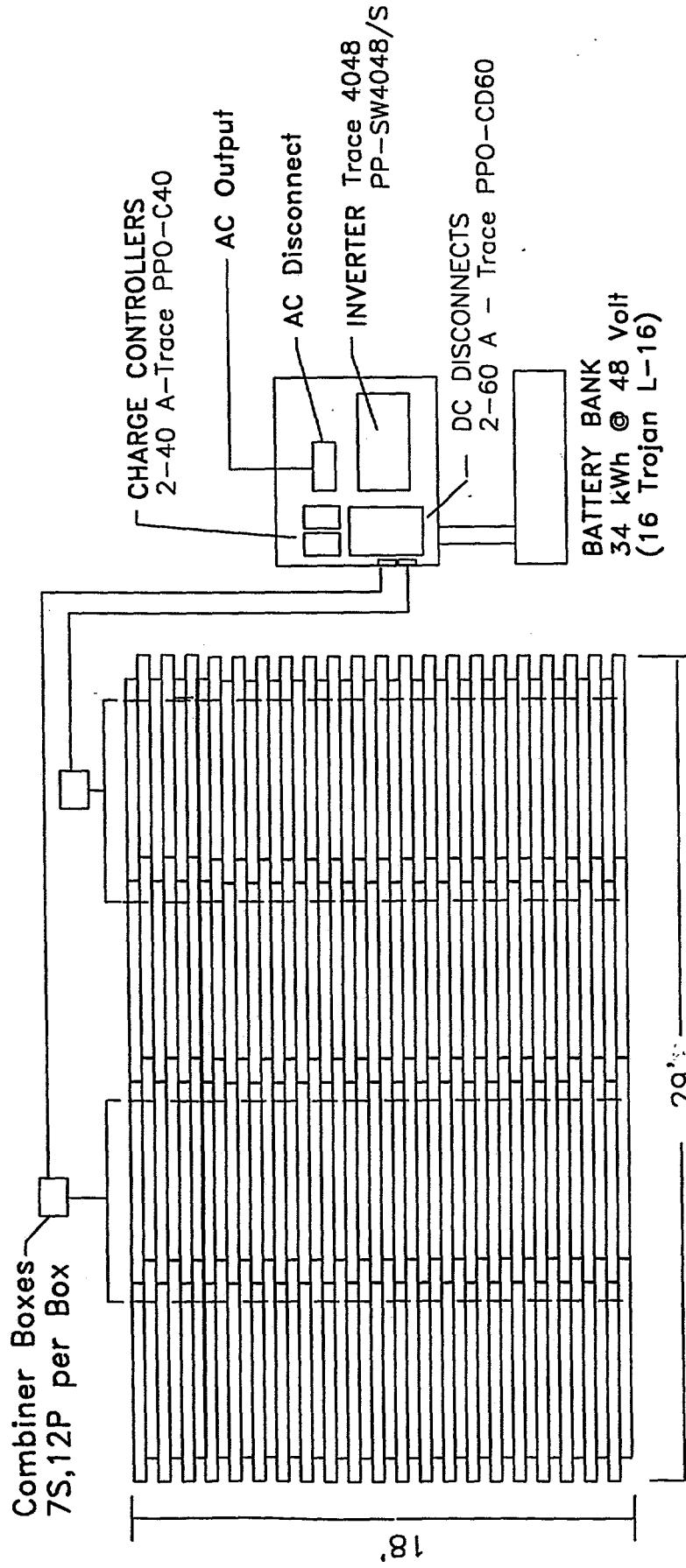
3.6 kWdc UNI-SOLAR SHR Roofing Array



SPECIFICATIONS		COMPANY	
CONTRACT NO.		DATE	UNITED SOLAR SYSTEMS CORP.
DRAWN BY		TITLE	
CHECKED BY			
DESIGNED BY		SIZE	DWG NO. / FILE NAME
DESIGN ACTIVITY		FSCHM NO.	
CUSTOMER		SCALE	DATE
		No	SHEET
		1 of 1	

UNI-SOLAR Roofing
Array Performance Cha

UNI-SOLAR 2.2 kWac PV Shingle Roofing System



UNI-SOLAR PV Shingle Array: 168 SHR-17 Shingles
7 Series, 24 Parallel

SPECIFICATIONS		CONTRACT NO.	COMPANY
		DRAWN BY	DATE
		UNITED SOLAR SYSTEMS CORP.	
checked by			TITLE
designed by			2.2 kWac PV Shingle System
design activity		SIZE	FILE NO. / FILE NAME
customer		SCALES	DWG NO.
		No Scale	DATE
			SHEET
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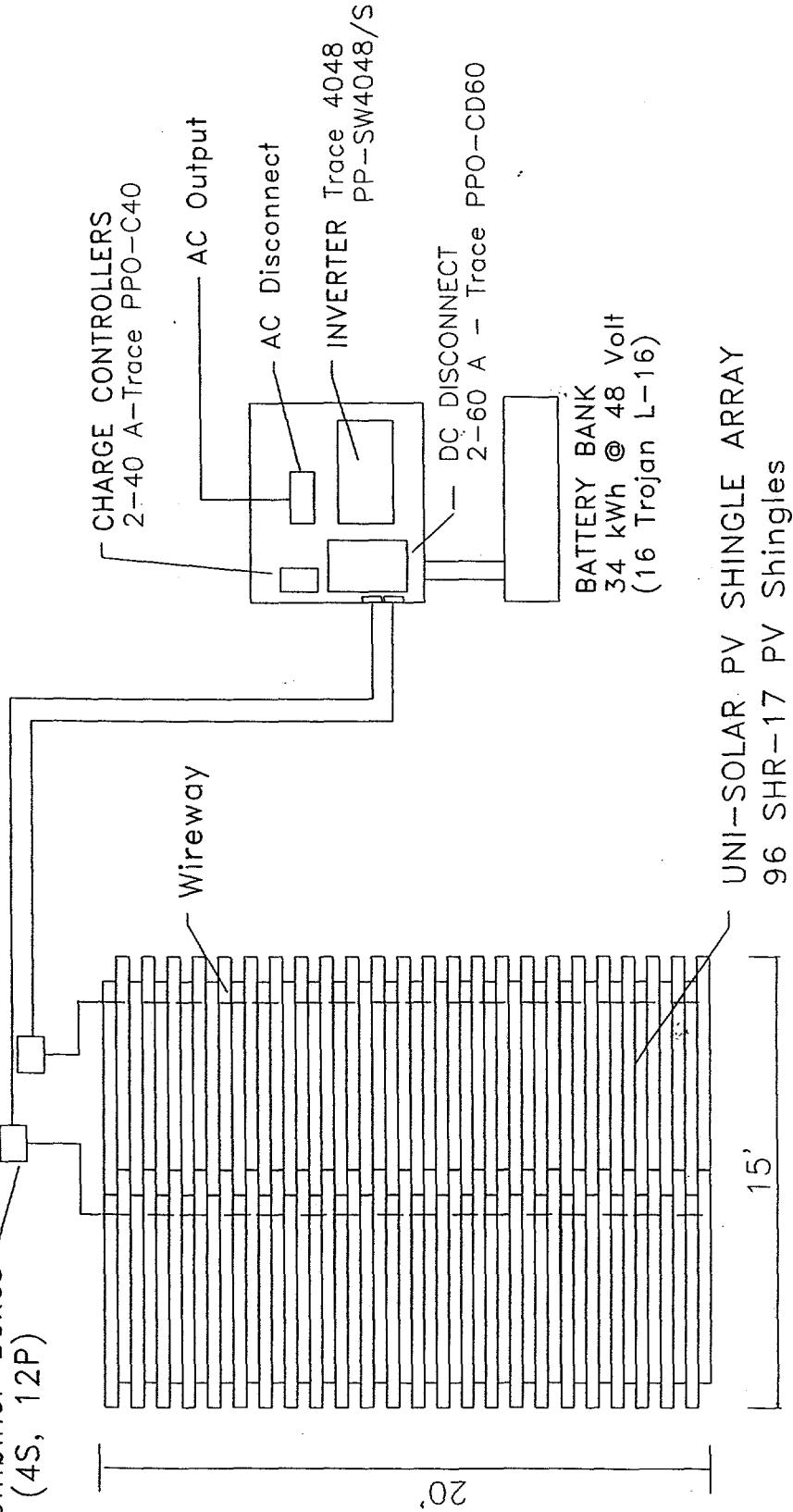
UNI-SOLAR Roofing

Array Performance Chart

UNI-SOLAR PV Shingle Roofing System

1.4 kWdc UNI-SOLAR SHR Roofing Array

Combiner Boxes -
(4S, 12P)



UNI-SOLAR PV SHINGLE ARRAY
96 SHR-17 PV Shingles

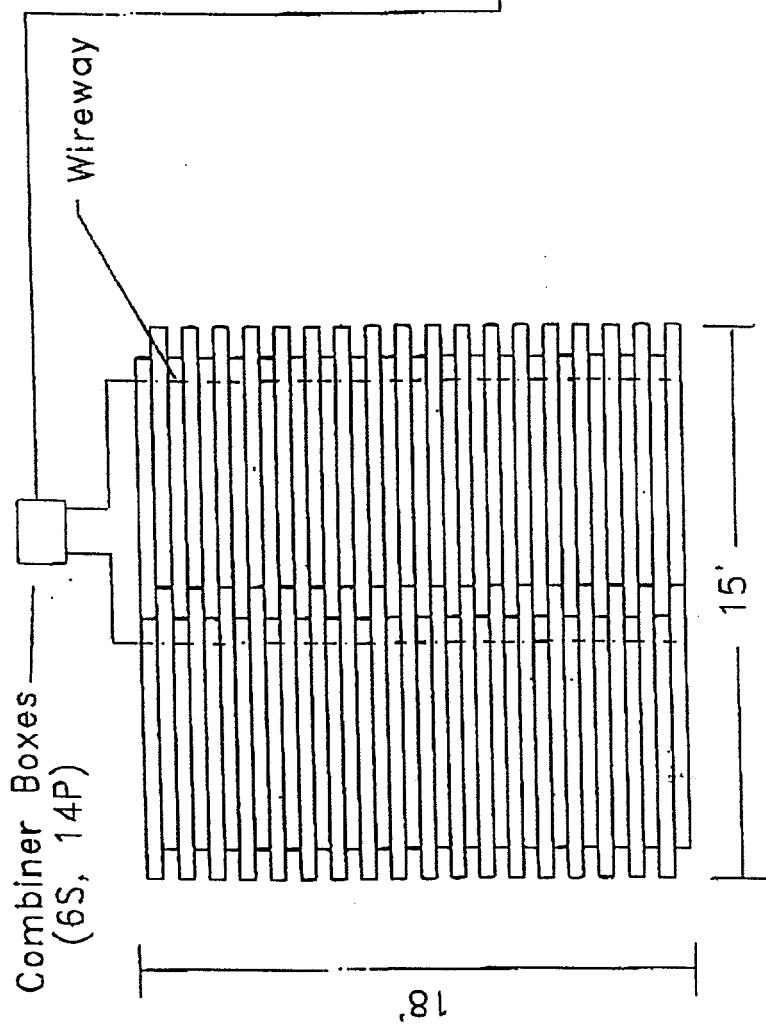
UNI-SOLAR PV SHINGLE ARRAY																
1.3 kWdc Shingle Roofing System																
Grid-Connected - 6 Series, 14 Parallel		Panel		# Series	SHR-17											
		# Parallel		14												
		Total Number		84												
Array DC @ PTC (Est.)																
1.27																
Array AC @ PTC (Est.)																
1.09																
Output																
Combiner																
Inverter																
ac value																
ac value																
factor																
String,dc																
String,dc																
winding,ms																
pitch,degree																
0.94																
0.86																
Rated Conditions																
Voc	-5	25	1	11.6	volts	6	69.0	volts	1							
Isc	-5	25	1	2.52	amps	1	2.52	amps	14							
Vop	-5	25	1	8.5	volts	6	51	volts	1							
Iop	-5	25	1	2.03	amps	1	2.03	amps	14							
Watts,p	-5	25	1	17.3	watts	6	104	watts	14							
Voc	0	-0.4	1	12.8		6	77	volts	1							
Isc	0	0.1	1	2.5		1	2.5	amps	14							
Vop	0	-0.45	1	9.5		6	57	volts	1							
Iop	0	0.1	1	2.0		1	2	amps	14							
Watts,p	0	-0.29	1	18.6		6	111	watts	14							
Voc	30	60	1	10.0		6	60	volts	1							
Isc	30	60	1	2.6		1	2.6	amps	14							
Vop	30	60	1	7.2		6	43	volts	1							
Iop	30	60	1	2.1		1	2.1	amps	14							
Watts,p	30	60	1	15.5		6	93	watts	14							
Mod. PVUSA (PTC)	20	50	-0.4	1	10.4	6	63	volts	1							
Voc	20	50	0.1	1	2.6	1	2.6	amps	14							
Isc	20	50	-0.45	1	7.5	6	45	volts	1							
Vop	20	50	0.1	1	2.1	1	2.1	amps	14							
Iop	20	50	-0.29	1	16.0	6	96	watts	14							
Watts,p	20	50	-0.29	1												

UNI-SOLAR PV Shingle Roofing System

1.3 kWac UNI-SOLAR SHR Roofing System

INVERTER (TBD)

Trace 4048
PP-SW4048/S
Charge Controller
PPO-C40
DC 60 A Disconnect
PPO-CD60

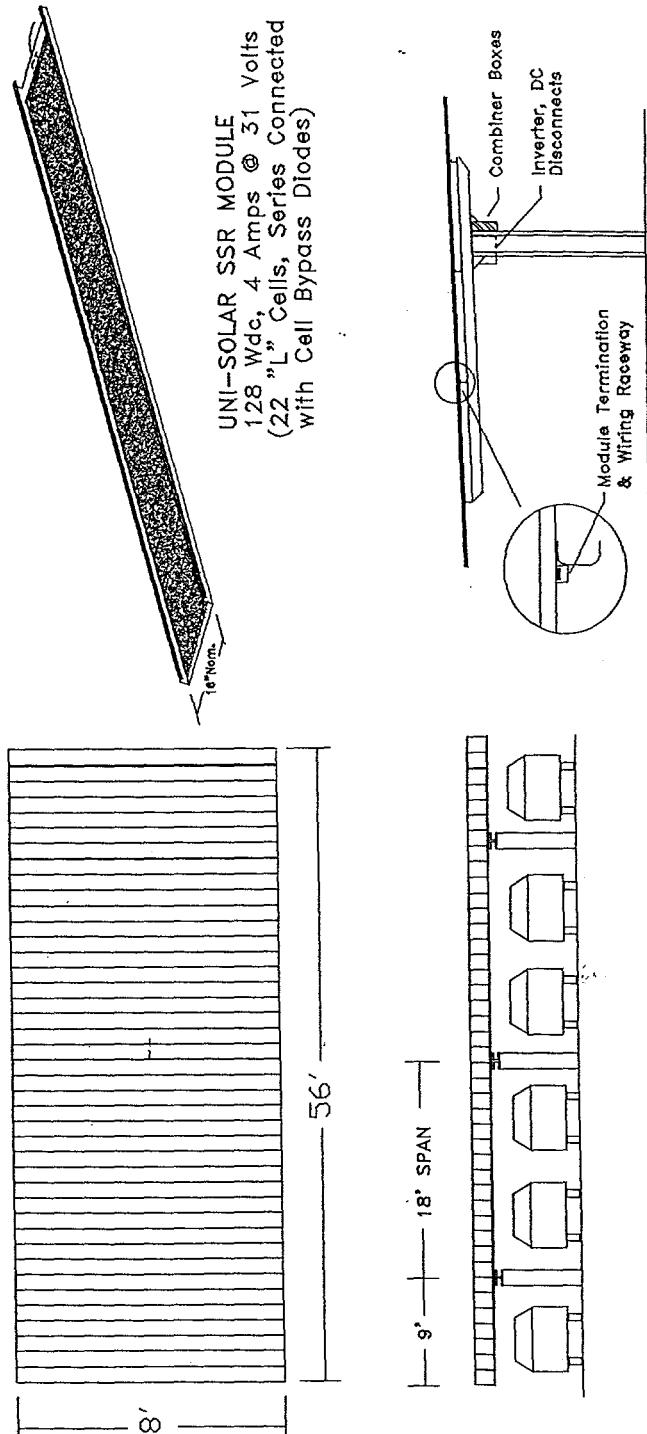


UNI-SOLAR PV Shingle Array 84 SHR-17 PV Shingles

SPECIFICATIONS		CONTRACT NO.	1	COMPANY
		DRAWN BY	DATE	UNITED SOLAR SYSTEMS CORP.
		CHECKED BY		TITLE
DESIGNED BY				Grid Con. w/Battery System
DESIGN ACTIVITY				SIZE FILE NO. / FILE NAME
CUSTOMER				A
		SCALE	DATE	Sheet 1 of 1
		No Scale		

UNI-SOLAR PV/EV Charging Station

A 4.2 kW Solar Electric Covered Parking System for EV Recharging



4.2 kW PV/EV CHARGING STATION

42 - 128 W UNI-SOLAR SSR-128 Panels
Triple-Junction a-Si PV Technology
Conventional Covered Parking Structure

UNI-SOLAR

UNI-SOLAR ASR Roofing System 4.0 kWdc UNI-SOLAR ASR Roofing Array

4.0 kWdc UNI-SOLAR ASR Roofing Array

2' Long, 16 Ga. Wire
For connection to user
supplied wiring to
Combiner Box

Combiner Boxes

ASR-128
PV Roofing Panel

19 ff. (nom.)

48 ft. (nominal)

- Charge
- Controllers

AC Disconnect

Inverter - 4.5 kW

Dr. Disconnect

**Battery Bank
(18 Volt)**

COMPANY

UNITED SOLAR SYSTEMS CORP

System

SIZE	ESCM NO.	DWG NO.	FILE NAME
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SCALE No Scale DATE SHEET 1 of 1

CONTRACT NO.

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CHECKED BY

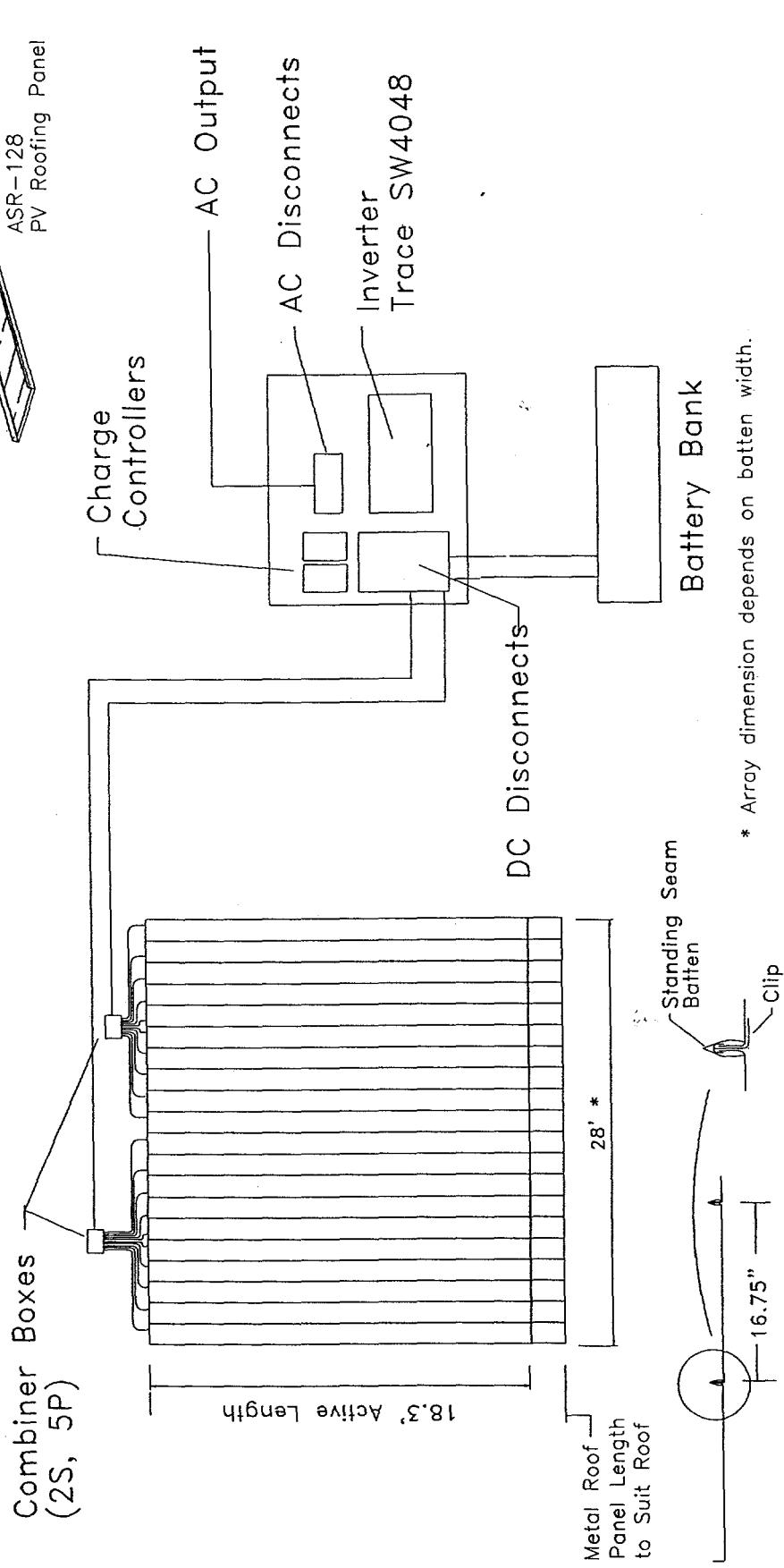
DESIGNED BY

DESIGN ACTIVITY

CUSTOMER

2.0 kWac UNI-SOLAR ASR Roofing System

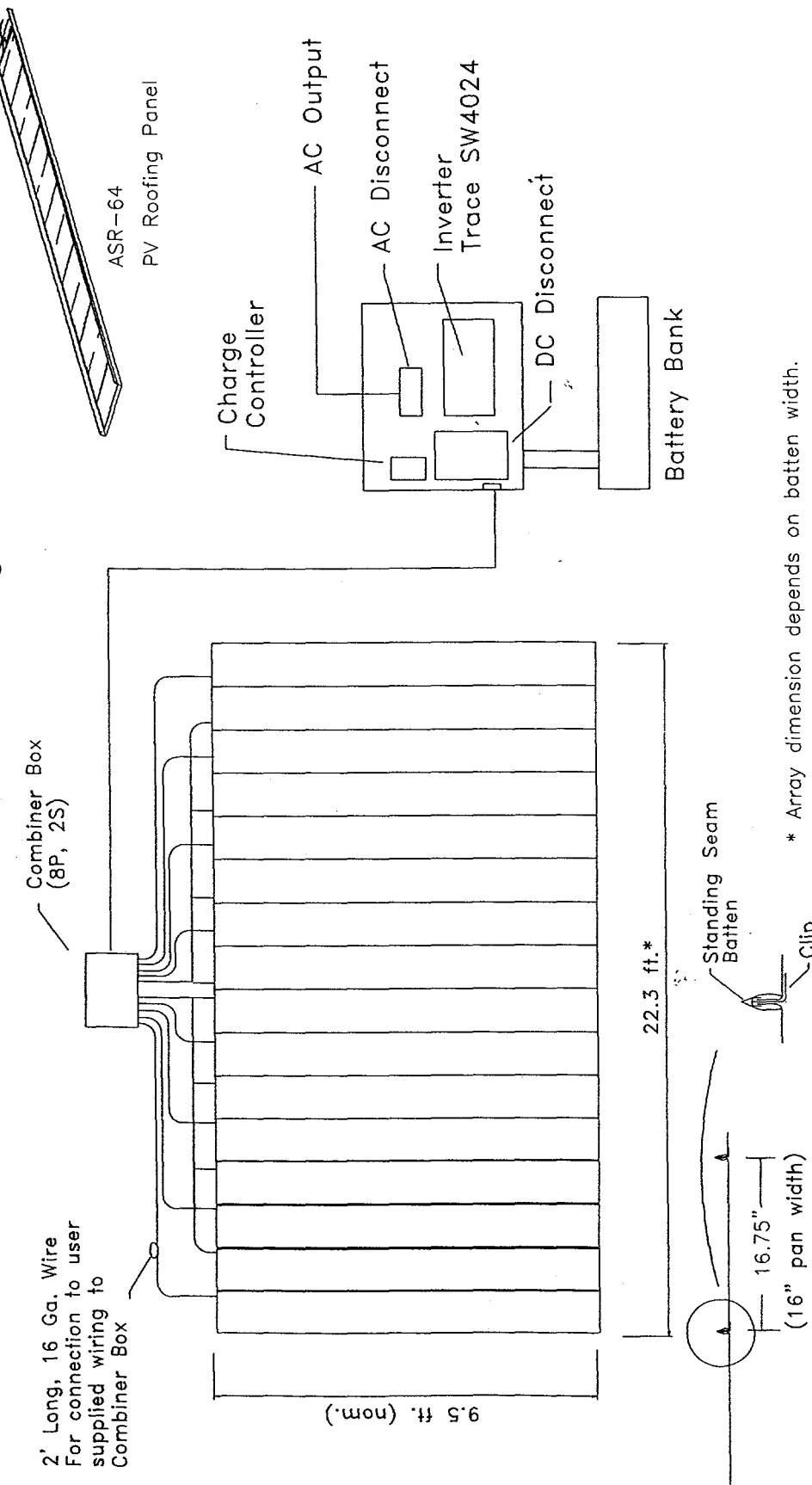
20 UNI-SOLAR ASR-128 Roofing Panels



SPECIFICATIONS		COMPANY	DATE	TITLE	
		DRAWN BY	DESIGNED BY	SIZE FSCM NO. DWG NO. / FILE NAME	
		DESIGN ACTIVITY	CUSTOMER	SCALE	DATE
		A		No Scale	SHEET 1 of 1

1.0 kW UNI-SOLAR ASR ROOFING SYSTEM

16 UNI-SOLAR ASR-64 Roofing Panels

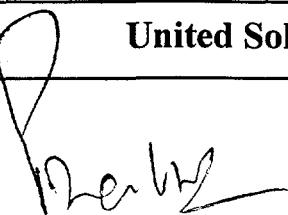


1.0 kWdc ASR-64 Roofing System	A	No Scale	1 of 1
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APPENDIX III
IEEE 1262 Test Report for Uni-Solar Roofing Products

IEEE 1262 Test Report

United Solar SSR Panels



1. INTRODUCTION

Amorphous silicon alloy based triple junction solar cell material is made using roll-to-roll deposition onto thin (0.005") 2500-foot long rolls of stainless steel. This generic solar cell material is cut into appropriate sizes, assembled, interconnected and laminated as finished PV element. A typical laminate is 18 feet long and 16 inches wide. The large area laminate is bonded to a commercial roofing panel using a layer of thermal setting EVA adhesive. A waterproof top or bottom termination finishes a true building integrated photovoltaic roofing element for residential, commercial and industrial applications.

Testing has been conducted at United Solar to evaluate this building integrated photovoltaic (BIPV) roofing element for module design performance, safety and susceptibility to known failure mechanisms. This report describes the test results and serves as background for United Solar Systems certification that United Solar BIPV metal panels pass IEEE 1262.

2. PURPOSE

To qualify the United Solar System Building integrated photovoltaic module design for potential degradation of module performance resulting from environmental weathering and long-term use.

3. APPROACH

The following are key elements of United Solar's qualification approach:

- Use IEEE-1262 recommended procedures and specification for qualification tests that are structured to evaluate terrestrial flat plate photovoltaic modules for power generation applications.
- Use UL 1703 Safety Standard for Flat Plate Photovoltaic Modules and panels for qualification of Flat-Plate PV modules for installation on or integral with buildings. Since these modules are intended to be integral part of buildings, the modules were tested for fire resistance by subjecting full size modules to tests for fire resistance, Test Standard for Roof Covering Material, UL-790 (results to be published later).
- Since United Solar metal BIPV panels are extremely large the environmental qualification testing was performed on representative modules. Special care was taken to ensure retaining all the key features of full size modules. Typically 3 feet long modules were specially fabricated for this study.
- Since the metal panels used in United Solar metal BIPV line have been certified by the manufacturer for uplift resistance in accordance with UL-580 and for air and water infiltration in accordance with ASTM E238 and ASTM E331-86, the structural portion of the qualification testing was not carried out.

4. TEST MODULE DESCRIPTION

The building block of the large area module is a cell 14 inches wide and 9.4 inches long. Typically 22 cells are interconnected, laminated and bonded to commercial metal roofing panel to yield the large area PV module. Contact redundancy and flat chip bypass diodes are included to provide reliable operation under partial shadow conditions. Module termination is either potted pigtail or junction box. For IEEE-1262 qualification testing, three cell modules were built using the same construction methods as well as the same materials. Special representative samples were built to qualify different termination schemes.

5. QUALIFICATION TEST DESCRIPTION

Figure 1 is a schematic outline of the test procedure used at United Solar Systems to qualify building integrated photovoltaic modules. The program is based upon IEEE-1262 recommended test procedures and specifications for evaluating terrestrial flat-plate PV modules for power generation applications. Exceptions to the IEEE-1262 test standard are noted. Figure 2 is a schematic of additional tests performed by United Solar to qualify bypass diodes and j-box designs. Brief descriptions of the individual tests follow.

5.1 INITIAL TESTS AND INSPECTIONS

Baseline Visual Inspection	Performed per IEEE-1262.
Baseline Electrical Performance	Performed per IEEE-1262, except for the full size SSR-128 module entering sequence D. The module cannot be measured under United Solar's solar simulator, but instead was measured outdoors under natural sunlight.
Ground Continuity	Ground continuity testing is not performed due to the fact that there is only one continuous, exposed, metal part.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262, except the module entering sequence D was measured with a 1000 volt megger.
Wet Insulation Resistance	This value is not directly measured, rather, it is based on a calculation using wet hi-pot data.
Electrical Isolation (wet hi-pot)	Performed per IEEE-1262, except wet hi-pot was not performed on the module entering sequence D.
Annealing	Not performed due to the fact that the modules have been exposed to room light only, prior to test inception.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262, except for the full size SSR-128 module entering sequence D. The module cannot be measured under United Solar's solar simulator, but instead was measured outdoors under natural sunlight.

Figure 1: United Solar Systems PV Roofing Module Qualification Test Program

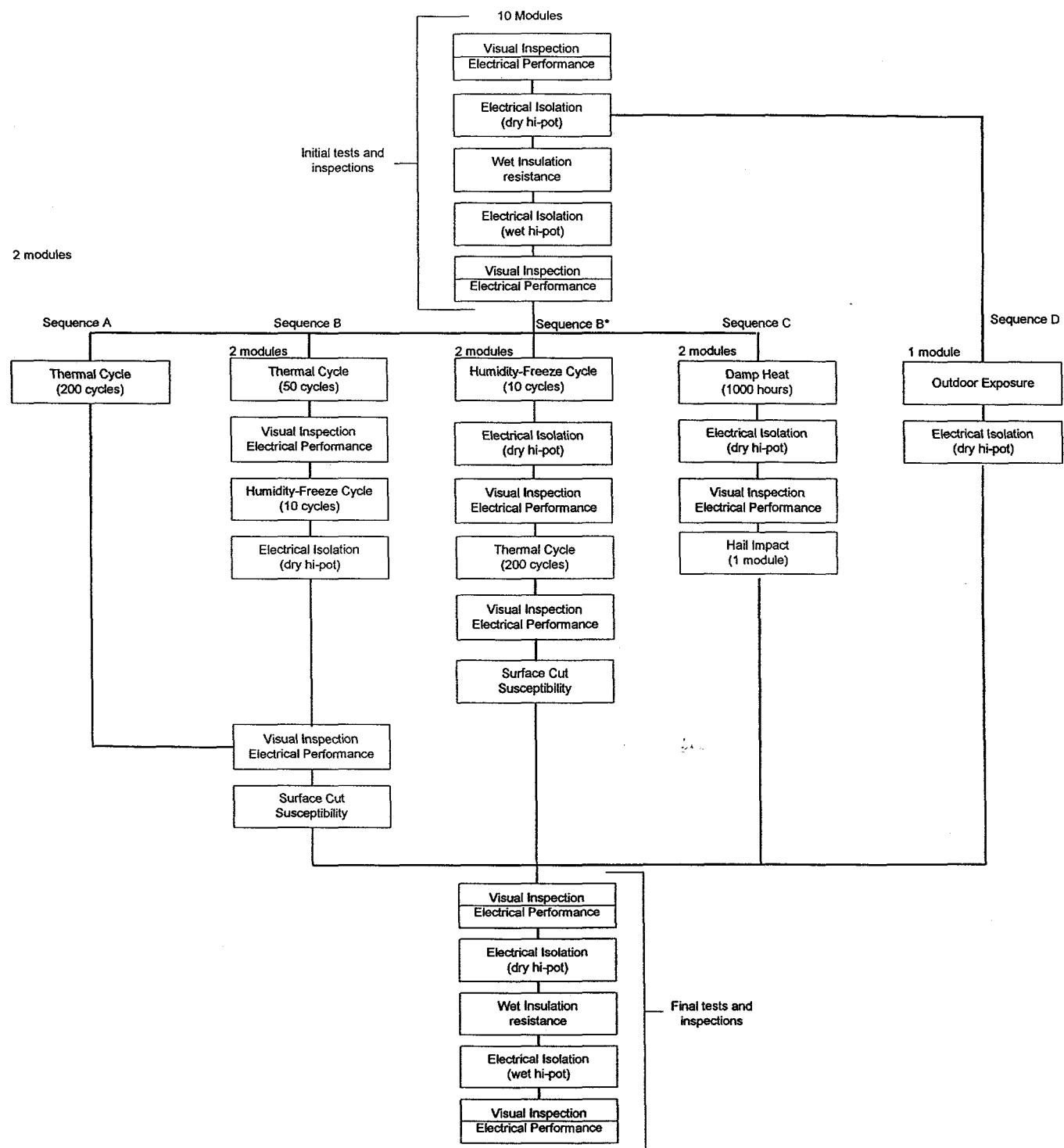
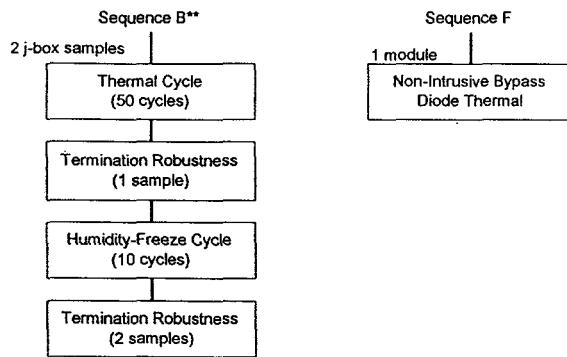


Figure 2: United Solar Systems J-Box and Bypass Diode Qualification Test Program



5.2 TEST SEQUENCE A

Thermal Cycle Test

Performed in accordance with IEEE-1262 with the exception that the individual modules are not monitored for open circuit and ground fault conditions during the test.

Visual Inspection

Performed per IEEE-1262.

Electrical Performance

Performed per IEEE-1262.

Surface Cut Susceptibility

Performed per IEEE-1262.

5.3 TEST SEQUENCE B

Ultraviolet Test

Not performed at United Solar due to unavailability of test equipment.

Note: UL has tested 6 samples of this laminate design. After UV exposure conditioning, a cut test and dielectric voltage withstand test were performed. UL qualified this laminate structure (file E182242, project 96NK17110, 5-7-97).

Annealing

Not performed due to the fact that the modules have been exposed to room light only, prior to test inception.

Thermal Cycle Test

Performed in accordance with IEEE-1262 with the exception that the individual modules are not monitored for open circuit and ground fault conditions during the test.

Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.
Humidity-Freeze Cycle Test	Performed in accordance with IEEE-1262 with the exception that the individual modules are not monitored for open circuit and ground fault conditions during the test.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.
Termination Robustness	Not performed on these modules due to the fact that these modules were manufactured with a non-standard junction box due to lack of tooling at the time of manufacture. Samples with the proper junction box were tested later (see sequence B**).
Twist	Not performed. United Solar modules are fairly flexible and can easily pass the twist test requirements. United Solar modules do not contain any glass or other brittle components that may fracture under such a test.
Mechanical Loading	Not performed due to the fact that the metal panels have already been qualified (UL-90 classification).
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.
Surface Cut Susceptibility	Performed per IEEE-1262.

5.4 TEST SEQUENCE B*

(an additional United Solar sequence -- due to environmental chamber scheduling conflicts)

Humidity-Freeze Cycle Test	Performed in accordance with IEEE-1262 with the exception that the individual modules are not monitored for open circuit and ground fault conditions during the test.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.

Thermal Cycle Test	Performed in accordance with IEEE-1262 with the exception that the individual modules are not monitored for open circuit and ground fault conditions during the test.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.
Surface Cut Susceptibility	Performed per IEEE-1262.

5.5 TEST SEQUENCE C

Damp Heat	Performed per IEEE-1262.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.
Hail Impact	Performed per IEEE-1262.
Mechanical Loading	Not performed due to the fact that the metal panels have already been qualified (UL-90 classification).

5.6 TEST SEQUENCE D

Outdoor Exposure	Performed per IEEE-1262, except modules were open-circuit and total irradiance was not measured.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262, except were measured with a 1000 volt megger.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262. Measured outdoors under natural sunlight.
Non-Intrusive Hot Spot Endurance	Not performed. These modules contain a bypass diode across each cell and therefore is exempt from this test per IEEE-1262.
Non-Intrusive Bypass Diode Thermal	Not performed.

5.7 TEST SEQUENCE B (United Solar test sequence specifically for j-box design qualification)**

Thermal Cycle Test	Performed per IEEE-1262.
Termination Robustness	Performed per IEEE-1262. Only one sample was tested after the thermal cycle test.
Humidity-Freeze Cycle Test	Performed per IEEE-1262.
Termination Robustness	Performed per IEEE-1262. Both samples were tested.

5.8 TEST SEQUENCE F

Intrusive Bypass Diode Thermal	Not performed on these modules, but performed on a special test sample. The test was performed per IEEE-1262 except the ambient was 75°C rather than 45°C and solar cells were electrically isolated so that all the applied current was through the diode (more severe than IEEE-1262).
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5.9 FINAL TESTS AND INSPECTIONS

Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262, except the SSR-128 module was measured outdoors under natural sunlight.
Electrical Isolation (dry hi-pot)	Performed per IEEE-1262, except the SSR-128 module was measured with a 1000 volt megger.
Wet Insulation Resistance	This value is not directly measured, rather, it is based on a calculation using wet hi-pot data.
Electrical Isolation (wet hi-pot)	Performed per IEEE-1262.
Ground Continuity	Ground continuity testing is not performed due to the fact that there is only one continuous, exposed, metal part.
Visual Inspection	Performed per IEEE-1262.
Electrical Performance	Performed per IEEE-1262.

6. QUALIFICATION TEST RESULTS

Nine modules were used for BIPV qualification testing. Eight of the modules were custom, 3-cell type, modules, representative of the full-size SSR-128 module. Pairs of these modules were used for each of the 4 different test sequences, A, B, B*, and C. The ninth module was a full-size SSR-128 and was used for sequence D. In addition, two junction-box samples were used for test sequence B**. These samples are representative of the junction-box design used for the SSR-128 module. One special test sample was used for sequence F. The test results for each sequence are summarized below.

6.1 INITIAL TESTS AND INSPECTIONS

Baseline Visual Inspection: All 9 modules show no major defects.

Baseline Electrical Performance:	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)
	005	A	25	6.34	5.58	4.73	4.53	0.61	21.43
	006	A	25	6.33	5.52	4.70	4.57	0.61	21.47
	007	B	25	6.34	5.45	4.81	4.51	0.63	21.68
	008	B	25	6.31	5.49	4.69	4.56	0.62	21.38
	001	B*	23	6.35	5.57	4.81	4.58	0.62	22.04
	002	B*	23	6.38	5.51	4.79	4.55	0.62	21.78
	003	C	25	6.32	5.57	4.69	4.58	0.61	21.49
	004	C	25	6.33	5.51	4.60	4.65	0.61	21.41
	1320	D	-	43.50	5.95	30.97	5.34	0.64	166

Temperature measurement was not performed for module 1320.

Electrical Isolation (dry hi-pot):

The 8 small modules had less than 2 μ A of forward and reverse leakage current at 2200 volts DC. Pass criteria is 35 μ A. The SSR-128 module, serial number 1320, was tested with a 1000 volt megger and passed with greater than 500 megaohm resistance.

Electrical Isolation (wet hi-pot):

The 8 small test modules had less than 2 μ A of forward and reverse leakage current at 2200 volts DC. Pass criteria is 35 μ A. The SSR-128 module was not tested.

Visual Inspection:

All 9 modules show no additional defects.

Electrical Performance:

<u>Serial number</u>	<u>Test Sequence</u>	<u>Temp °C</u>	<u>Voc (V)</u>	<u>Isc (A)</u>	<u>Vmax (V)</u>	<u>Imax (A)</u>	<u>FF</u>	<u>Pmax (W)</u>	<u>Pmax %Δ</u>
005	A	23	6.40	5.59	4.85	4.43	0.60	21.51	+0.37
006	A	23	6.39	5.53	4.74	4.55	0.61	21.54	+0.32
007	B	25	6.33	5.49	4.87	4.44	0.62	21.63	-0.23
008	B	25	6.33	5.50	4.69	4.56	0.61	21.39	+0.04
001	B*	24	6.36	5.58	4.79	4.61	0.62	22.10	+0.27
002	B*	23	6.40	5.50	4.82	4.52	0.62	21.77	-0.04
003	C	25	6.33	5.52	4.79	4.48	0.62	21.47	-0.09
004	C	26	6.33	5.53	4.72	4.55	0.61	21.48	+0.32
1320	D	was not performed.							

All modules pass the %Δ criteria of greater than -10.

6.2 TEST SEQUENCE A

Thermal Cycle Test (200 cycles):

Two modules (005 and 006) are currently in test. Visual inspection and electrical performance has been performed after 150 cycles.

**Electrical Performance:
(after 150 cycles)**

<u>Serial number</u>	<u>Temp °C</u>	<u>Voc (V)</u>	<u>Isc (A)</u>	<u>Vmax (V)</u>	<u>Imax (A)</u>	<u>FF</u>	<u>Pmax (W)</u>	<u>Pmax %Δ</u>
005	26	6.36	5.52	4.70	4.55	0.61	21.39	-0.19
006	26	6.34	5.51	4.69	4.59	0.62	21.50	+0.14

Surface Cut Susceptibility:

Not performed yet. Modules are currently under test.

6.3 TEST SEQUENCE B

Thermal Cycle Test:

Completed 50 thermal cycles on two modules.

Electrical Performance:

<u>Serial number</u>	<u>Test Sequence</u>	<u>Temp °C</u>	<u>Voc (V)</u>	<u>Isc (A)</u>	<u>Vmax (V)</u>	<u>Imax (A)</u>	<u>FF</u>	<u>Pmax (W)</u>	<u>Pmax %Δ</u>
007	B	25	6.35	5.41	4.83	4.41	0.62	21.29	-1.79
008	B	25	6.34	5.48	4.75	4.49	0.62	21.37	-0.04

Both modules pass the %Δ criteria of greater than -10.

Humidity-Freeze Cycle Test: Completed 10 humidity-freeze cycles on the two modules.

Electrical Isolation (dry hi-pot): Both modules exhibited forward and reverse leakage currents of 2 μ A or less. Pass criteria is 35 μ A.

Electrical Performance:	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
	007	B	22	6.45	5.42	4.72	4.55	0.61	21.47	-0.96
	008	B	22	6.43	5.45	4.89	4.39	0.61	21.44	+0.28

Both modules pass the %Δ criteria of greater than -10.

Surface Cut Susceptibility: Surface cut was performed per IEEE-1262 on serial numbers 007 and 008. Both modules pass.

6.4 TEST SEQUENCE B*

Humidity-Freeze Cycle Test: Completed 10 humidity-freeze cycles on the two modules.

Electrical Performance:	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
	001	B*	24	6.38	5.58	4.88	4.50	0.62	21.95	-0.40
	002	B*	24	6.41	5.45	4.85	4.47	0.62	21.65	-0.59

All modules pass the %Δ criteria of greater than -10.

Electrical Isolation (dry hi-pot): Both modules exhibited forward and reverse leakage currents between 1 to 6 μ A. Pass criteria is 35 μ A.

Thermal Cycle Test: Completed 200 thermal cycles on the two modules.

Electrical Performance:	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
	001	B*	25	6.41	5.58	4.86	4.51	0.61	21.92	-0.54
	002	B*	24	6.41	5.46	4.97	4.34	0.62	21.59	-0.87

Both modules pass the %Δ criteria of greater than -10.

6.5 TEST SEQUENCE C

Damp Heat: Completed 1000 hours of damp heat exposure on two modules.

Electrical Isolation (dry hi-pot): Both modules exhibited forward and reverse leakage currents between 3 to 4 μ A. Pass criteria is 35 μ A.

Electrical Performance:	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
	003	C	24	6.43	5.42	4.85	4.41	0.61	21.39	-0.47
	004	C	24	6.43	5.43	4.91	4.39	0.62	21.54	+0.60

Both modules pass the %Δ criteria of greater than -10.

Hail Impact: Hail impact test was performed per IEEE-1262 on module 003.

6.6 TEST SEQUENCE D

Outdoor Exposure: One SSR-128 module underwent outdoor exposure in Troy, MI for 31 days between 8-14-97 and 9-15-97. Testing continues.

Electrical Isolation (dry hi-pot): Serial number 1320 passed the 1000 volt megger test at greater than 500 megaohm resistance.

6.7 TEST SEQUENCE B**

Thermal Cycle Test Completed 50 thermal cycles on two SSR junction-box samples.

Termination Robustness One sample was tested and passed.

Humidity-Freeze Cycle Test Completed 10 humidity-freeze cycles on two SSR junction-box samples.

Termination Robustness Both samples were tested and passed.

6.8 TEST SEQUENCE F

Intrusive Bypass Diode Thermal

The test sample was a 7" x 7" laminate containing two cells. The bypass diodes and interconnections were the same design as used in our roofing laminates. The test was performed per IEEE-1262 except the ambient was 75°C rather than 45°C (more severe than IEEE-1262). The bypass diode temperature at 5.6 amps forward current was measured to be 138°C which is under the manufacturer's rating of 150°C. No physical damage occurred during step d (IEEE-1262) performed at 7 amps forward current. Therefore, this diode configuration passes the requirements.

6.9 FINAL TESTS AND INSPECTIONS

Visual Inspection:

All 9 modules show no major defects.

Electrical Performance:

	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
after surface cut test	005	A		currently in test.						
after surface cut test	006	A		currently in test						
after surface cut test	007	B	26	6.36	5.42	4.80	4.47	0.62	21.48	-0.92
after surface cut test	008	B	26	6.35	5.52	4.84	4.42	0.61	21.41	+0.14
after surface cut test	001	B*	26	6.37	5.56	4.93	4.46	0.62	22.00	-0.18
after surface cut test	002	B*	26	6.39	5.46	4.89	4.43	0.62	21.66	-0.55
after hail impact test	003	C	26	6.41	5.44	4.80	4.46	0.61	21.41	-0.37
	004	C	24	6.43	5.43	4.91	4.39	0.62	21.54	+0.60
	1320	D	-	39.2	5.90	26.9	5.10	0.59	137	-17.5

Modules 001-004, 007, 008 pass the %Δ criteria of greater than -10.

Module 1320 passes the Pmax criteria of greater than 115.2 watts.

Electrical Isolation (dry hi-pot):

The 6 small modules which have completed sequences B, B*, and C had forward and reverse leakage currents in the 1 - 3 μ A range (at 2200 volts DC). Pass criteria is 35 μ A. The SSR-128 module was not tested again (see the results for test sequence D).

Electrical Isolation (wet hi-pot):

The 6 small modules which have completed sequences B, B*, and C had forward and reverse leakage currents in the 1 - 4 μ A range (at 2200 volts DC). Pass criteria is 35 μ A. The SSR-128 module was not tested (see the results for test sequence D).

Final Visual Inspection:

All 9 modules show no major defects.

Final Electrical Performance:

	Serial number	Test Sequence	Temp °C	Voc (V)	Isc (A)	Vmax (V)	Imax (A)	FF	Pmax (W)	Pmax %Δ
	005	A		currently in test						
	006	A		currently in test						
	007	B	25	6.38	5.46	4.88	4.42	0.62	21.56	-0.55
	008	B	24	6.40	5.48	4.79	4.48	0.61	21.49	+0.51
	001	B*	24	6.40	5.57	4.86	4.54	0.62	22.08	+0.18
	002	B*	24	6.43	5.46	4.77	4.57	0.62	21.81	+0.13
	003	C	24	6.44	5.48	4.75	4.56	0.61	21.67	+0.83
	004	C	25	6.45	5.46	4.84	4.47	0.62	21.64	+1.07

Modules 001-004, 007, 008 pass the %Δ criteria of greater than -10.

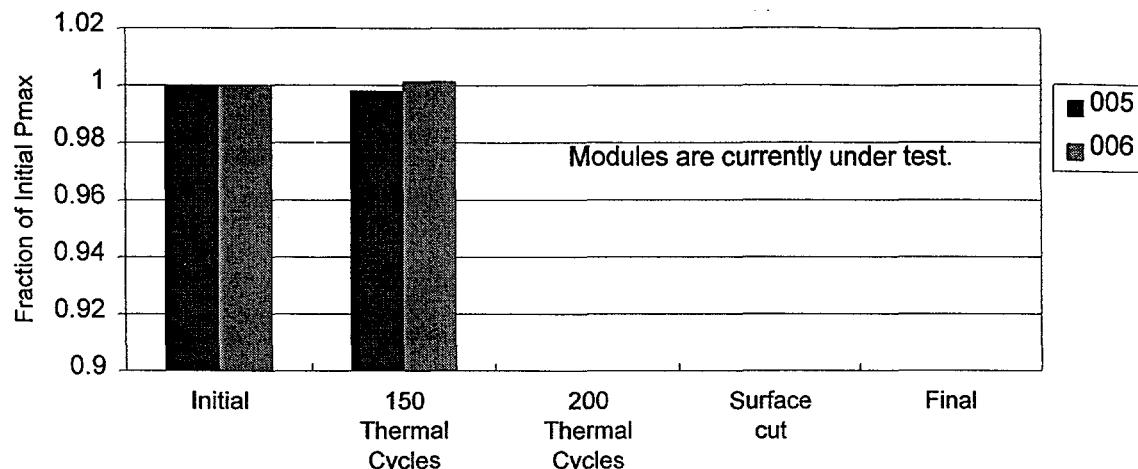


Figure 3: Results of electrical performance measurements on two roofing module samples during test sequence A.

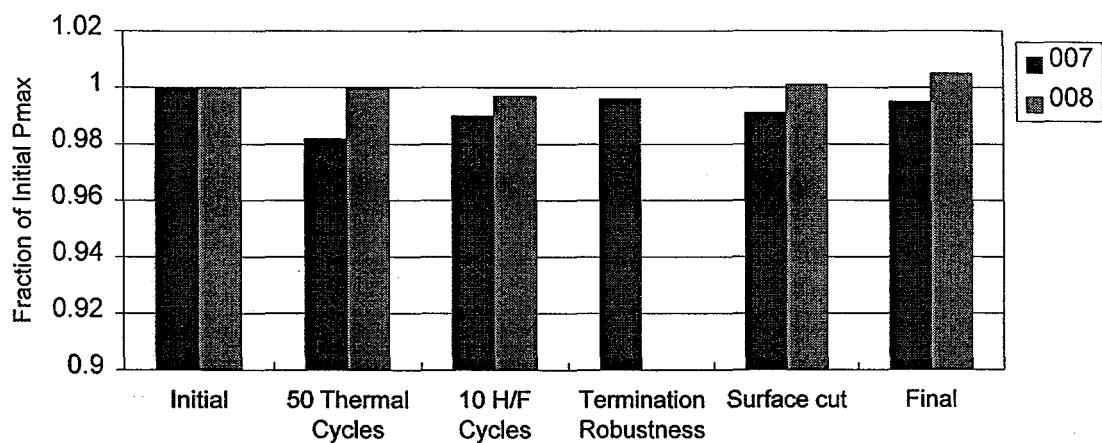


Figure 4: Results of electrical performance measurements on two roofing module samples during test sequence B.

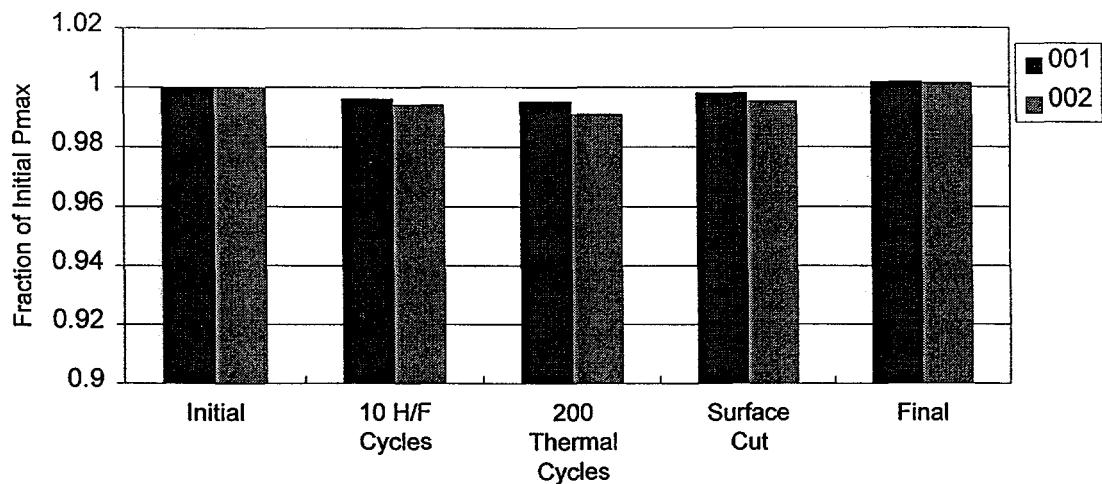


Figure 5: Results of electrical performance measurements on two roofing module samples during test sequence B*.

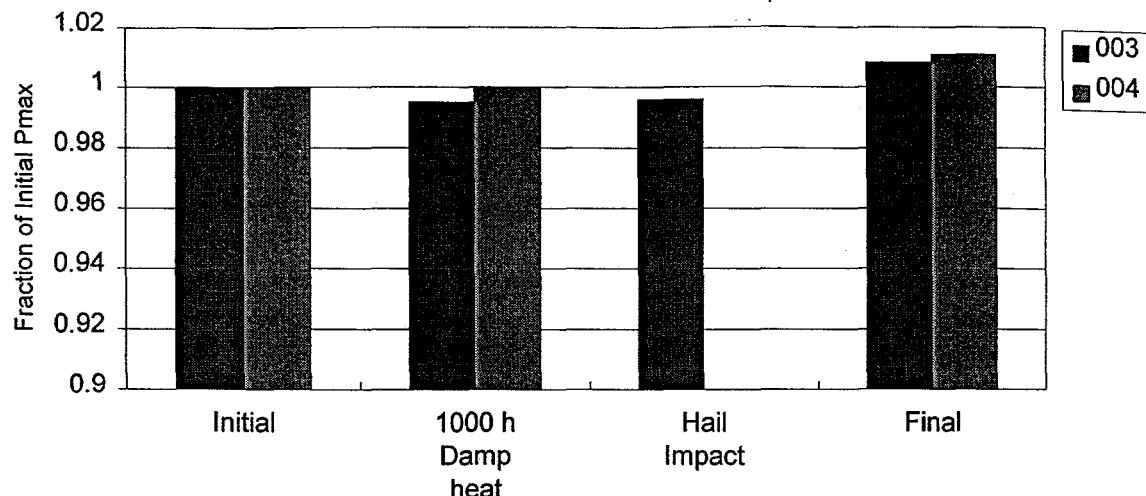


Figure 6: Results of electrical performance measurements on two roofing module samples during test sequence C.

7. CONCLUSIONS

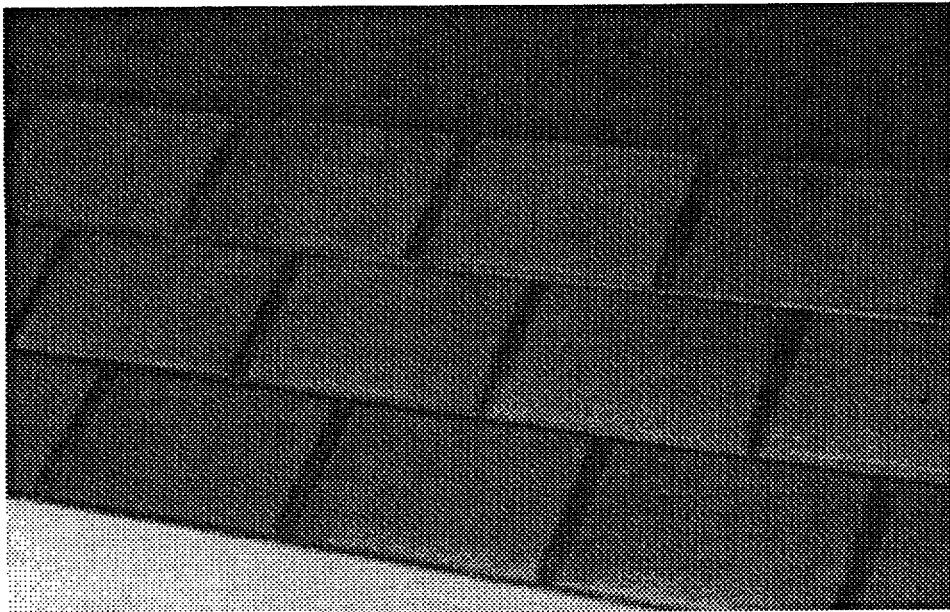
The metal roofing panel (SSR type) design has passed all United Solar qualification tests. Sequence A is incomplete at this time but it is expected from the results of sequence B* that the modules still in test will pass the requirements. Our design has passed the requirements of all other sequences outlined above. All tests were completed, including sequence A within sequence B*, and requirements met or exceeded. Only minor cosmetic changes were noted. It is our expressed opinion that our design meets IEEE Std 1262-1995 requirements.

APPENDIX IV
United Solar Shingle Module
Owner's Manual and Installation Guide



SHR-17 Solar Electric Roofing Shingle Owner's Manual & Installation Guide

12/18/97



SHR-17 solar electric shingles are intended for use with other electrical power components such as DC combiner boxes (for series and parallel connections) charge controllers, DC/AC inverters, and ground fault detection and interruption equipment. System design and component selections should comply with the National Electric Code and all state and local codes.

CAUTIONS

Solar electric (photovoltaic) roofing shingles produce DC electricity when exposed to light. The voltage from one individual shingle is not considered hazardous, however if connected in series to increase voltage and/or connected in parallel to increase current, the potential shock hazard increases. When installing or working around photovoltaic shingles, batteries and related electrical equipment, observe industry standards and practices as well as manufacturer's safety recommendations.

WARNINGS

- Photovoltaic (PV) shingles contain live electrical components enclosed and protected within. **Do not cut or trim PV shingles in any way.** Doing so can cause electric shock, may result in fire and will void the warranty.
- Cover the PV shingles with an opaque material before making wiring connections to reduce the risk of electric shock or sparks.
- Use insulated tools and wear electrical rubber gloves rated for maximum system voltage when wiring PV shingles.
- Observe safe electrical practices at all times. Make connections in well-ventilated areas free from flammable gas vapors.
- Observe proper polarity when connecting the PV shingles into an electrical circuit (see section on wiring). Reverse connection will damage the shingle, may result in fire and will void the warranty.
- Do not use any PV shingle without blocking diode protection to prevent

reverse current flow from a battery or from other solar shingles in the circuit.

- Do not attempt to concentrate sunlight on the PV shingles for increased output. Doing so may cause damage and will void the warranty.
- PV shingles are slippery, especially when wet. Use extreme caution and proper safety harness when working on or near PV shingles.
- Do not place equipment on PV shingles.
- Avoid dropping any sharp objects on PV shingles.
- Contact appropriate local authorities prior to installing any PV shingles to determine if permits and inspections are required for your particular area.
- Only qualified persons should install PV shingles. Contact a licensed roofer for installation of the PV shingles onto your structure and a licensed electrician for making any electrical connections.

DISCLAIMER OF LIABILITY

The information contained in this manual is based on United Solar's knowledge and experience, but such information and suggestions do not constitute a warranty expressed or implied. The methods of installation, use and maintenance of PV shingles are beyond the control of United Solar. United Solar assumes no responsibility and expressly disclaims liability for any loss, damage or expense associated with the use, installation or operation of the product. Any liability of United Solar is strictly limited to the Limited Warranty attached hereto. United Solar reserves the right to make changes to product specifications or to this manual without notice.

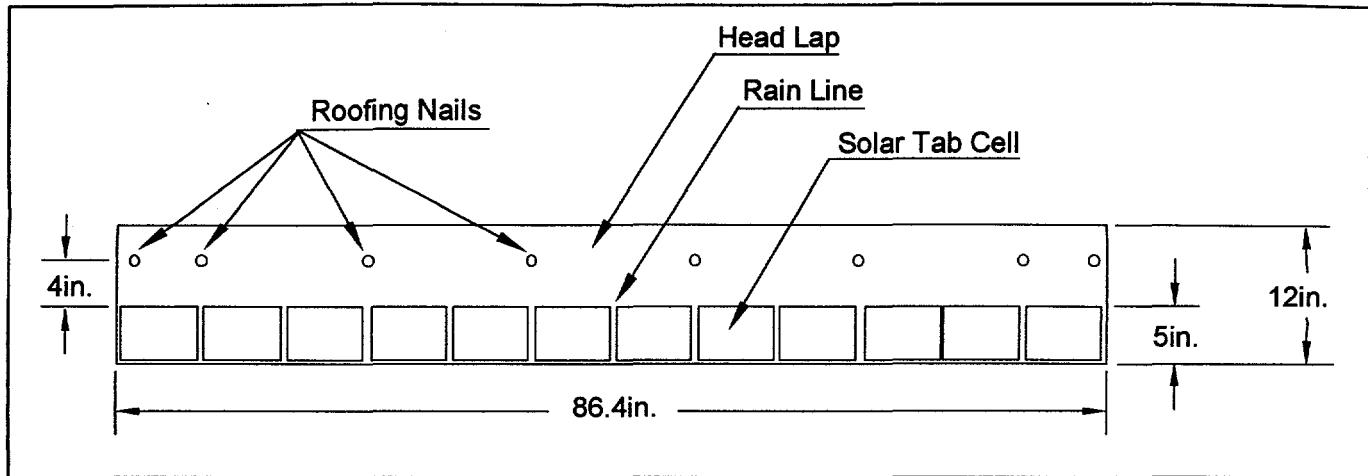


Figure 1

Table 1.
Specifications and Performance

Rated Power (Watts)	17
Operating Voltage (Volts)	8.6
Operating Current (Amps)	2.0
Open-Circuit Voltage (Volts)	12
Open-Circuit Voltage (Volts) at -10°C and 1250 W/m ²	13.8
Short-Circuit Current (Amps)	2.5
Short-Circuit Current (Amps)* at 75°C and 1250 W/m ²	3.3
Series Fuse Rating (Amps)	4
Min. Blocking Diode (Amps)	4
Weight (lbs/ft ²)	1.4

During the first 8-10 weeks of operation, the SHR-17 PV shingle has higher electrical output than that rated in table 1. Output power may be higher by 15%, operating voltage may be higher by 11% and operating current may be higher by 4%.

Electrical specifications ($\pm 10\%$) are based on measurements performed at standard test conditions of 1000 W/m² irradiance, Air Mass 1.5, and Cell Temperature of 25°C after long-term stabilization. Actual performance may vary up to 10% from rated power due to low temperature operation, spectral and other related effects.

Maximum system open-circuit voltage not to exceed 600 VDC.

Specifications subject to change with out notice.

* Refer to section 690-8 of the National Electric Code for an additional factor of 125% which may be applicable.

GENERAL INSTALLATION

This is a general installation guide. Detailed installation instructions are included in each box of 15 SHR-17 PV shingles.

Handling

UNI-SOLAR® PV shingles may be handled in a manner similar to asphalt shingles with a few exceptions:

- 1.) PV shingles may not be cut or trimmed in any way.
- 2.) Do not fold or crease the PV shingle. Avoid excessive bending that might crease or deform the active tabs, as they may not return to their original form.
- 3.) Avoid standing on shingles whenever possible. If unavoidable, use only clean rubber backed shoes when standing directly on PV shingles.

Placement

Pick a location on the roof deck with a maximum exposure to sunlight (free from shadows) that is devoid of vents, air conditioners or any other potential obstructions.

Installation

UNI-SOLAR® PV shingles are nailed in place in a manner similar to traditional asphalt shingles using common roofing nails on conventional roof decking (see figures 1 and 2). **Caution: Roofing nails are only to be driven 4 inches above the rain line as shown in figure 1 to avoid puncturing electrical components within the PV SHINGLE.** Use 30lb ungranulated asphalt saturated felt underlayment in a manner consistent with standard asphalt shingle installation practices. The use of 30lb felt will result in a flatter more uniform appearance of installed PV shingles. PV shingles are applied in consecutive overlapping courses. Lead wires on the backside of

each shingle head-lap pass through the roof deck to allow wiring connections to be made in the roof space underneath the deck. Each course bonds to the previous course as the sun warms the PV shingle forming a weather-resistant roof.

Wiring

Each PV shingle has two wires on the backside of the head-lap. Red is positive and black is negative. Wiring and all splices should be contained in an approved raceway suitable for the application and temperatures seen in the roof space (see figure 3).

Blocking Diodes

Proper use of suitable blocking diodes is recommended to prevent reverse current flow into a PV shingle from a battery, another parallel-connected solar shingle or other energy source. Use a single blocking diode of appropriate rating

in each series-connected string of PV shingles. Use an external termination box to mount blocking diodes (and heat sink if required). For assistance call United Solar or authorized dealer.

Bypass Diodes

Every SHR-17 PV shingle includes bypass diodes across each cell, resulting in superior shadow tolerance (reduced power loss under partial shadow conditions). When two or more solar shingles are connected in series a bypass diode can be installed across each shingle providing further shadow tolerance.

Charge Regulation

The use of a charge regulator is recommended in battery systems to prevent PV shingles from overcharging the battery. Follow the manufacturer's instructions for installation of the charge regulator.

High Voltage Systems

SHR-17 PV shingles are suitable for use in systems with system voltages up to 600 volts. **Do not use SHR-17 PV shingles in systems having an open circuit voltage greater than 600 volts dc.**

Wire Selection

PV shingles are to be spliced together in an UL listed raceway under the roof deck (see figure 3). Splices are to be made with all weather, heat-sealable butt splices or wire nuts. Do not use standard wire nuts or butt splices. All transition wiring should be chosen for maximum temperature, environment and application. Refer to National Electric Code article 690 and all other applicable codes and standards.

Grounding

SHR-17 PV shingles contain no exposed metal elements. Consequently, no ground points are provided and grounding of the SHR-17 PV shingle is not required.

Maintenance

Check wiring connections periodically for tightness and corrosion. Generally, a good rain is

sufficient to clean the PV shingles. However, in dusty arid locations the PV shingles can be cleaned with mild soap and water. **Do not use abrasive soaps or solvents.** Do not spray water directly at leading edge of the PV shingle. Use caution when cleaning the solar shingles, as the combination of water and electricity may present a shock hazard. Always wear electrical gloves, disconnect all energy sources (i.e. battery and/or utility) and short-circuit the output of the PV shingles or wash at night when cleaning.

WARRANTY

Limited Ten-Year Warranty

United Solar Systems Corp. warrants each UNI-SOLAR® SHR-17 Solar Electric Roofing Shingle against lost power output as follows: For a period of ten (10) years from the date of sale to the original purchaser, shingles which upon inspection by United Solar Systems or its appointed agent are determined to exhibit a power output of less than 90 % of the Rated Power specified at the time of sale due to defects in materials or workmanship will be repaired or replaced, or, at the option of United Solar Systems Corp., it will refund an amount equal to such lost power times the amount paid for the panels per watt of Rated Power. Lost power is the difference between exhibited power and 90% of the Rated Power.

What is not covered by the Warranty

This warranty does not apply to any shingle which in the judgement of United Solar Systems Corp. has been subject to misuse, neglect or accident or which has been damaged through abuse, alteration, improper installation or application, or negligence in use, storage, transportation or handling, or repaired by anyone other than United Solar Systems Corp. The warranty does not cover any transportation costs for return of shingle or for reshipment of any repaired or replaced shingle, or cost associated with installation, removal or reinstallation of shingles.

Warranty Limitations

United Solar Systems Corp. shall have no responsibility for damage to persons

or property or other loss or injury resulting from defect in the shingle or from improper use or installation. Under no circumstances will United Solar Systems Corp. be liable for any incidental or consequential damage. Any warranties implied by law, including those of merchantability and fitness for a particular purpose are hereby expressly disclaimed. The maximum liability of United Solar Systems Corp. is limited to the purchase price of the shingle. Such liability shall be limited in duration to twelve (12) months from the date of original purchase. This warranty is in lieu of all other warranties, expressed or implied. The purchaser's exclusive remedy shall be only as stated herein. Some states do not allow limitations on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusions may not apply to you.

Obtaining Warranty Performance

If you feel you have a claim under this warranty, first contact your United Solar Roofing agent who will give advice on handling the claim. If further assistance is required, contact United Solar Systems Corp. for instructions. The return of any module will not be accepted by the factory unless prior written authorization has been given by United Solar Systems Corp. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

United Solar Systems Corp.
Corporate Office
1100 West Maple Road
Troy, MI 48084
(248) 362-4170
Fax (248) 362-4442

United Solar Systems Corp.
Sales Office
9235 Brown Deer Road
San Diego, CA 92121-2268
(800) 397-2083
(619) 625-2080
Fax (619) 625-2083

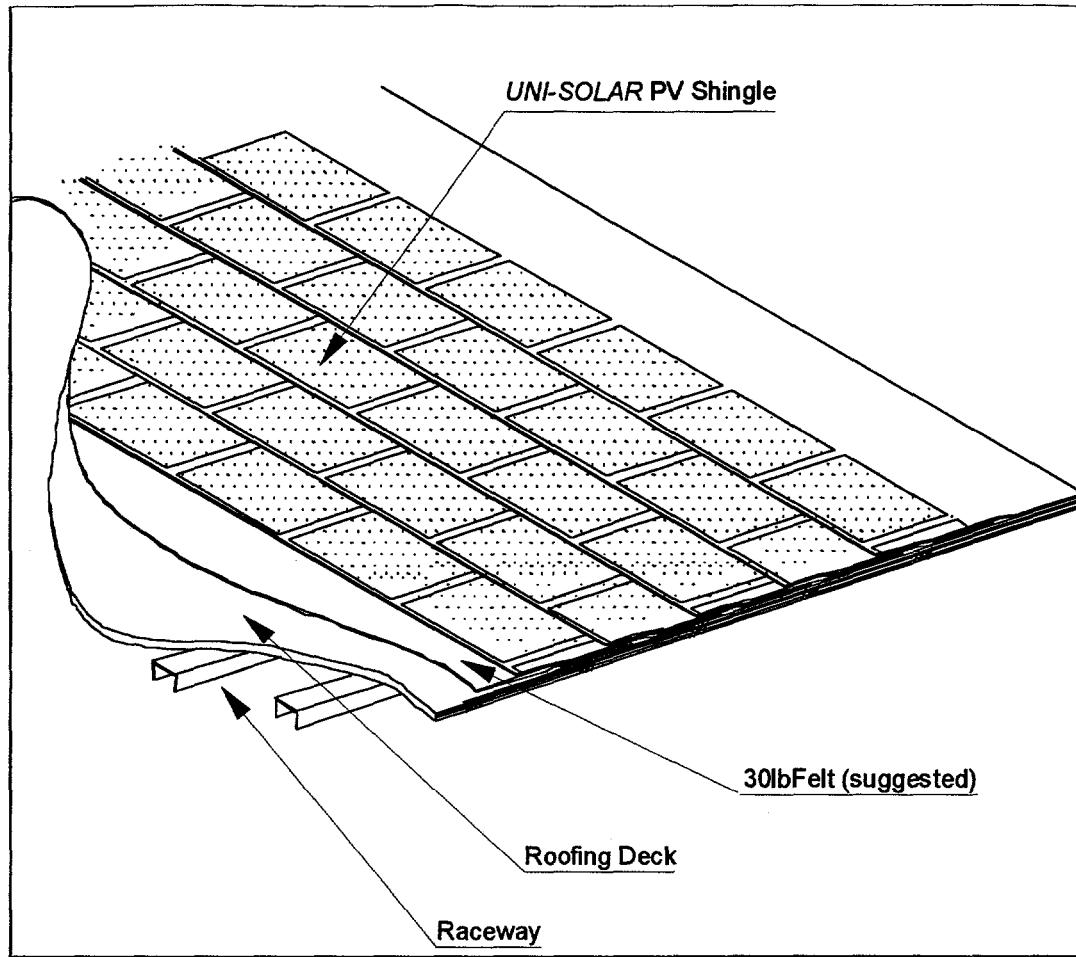


Figure 2

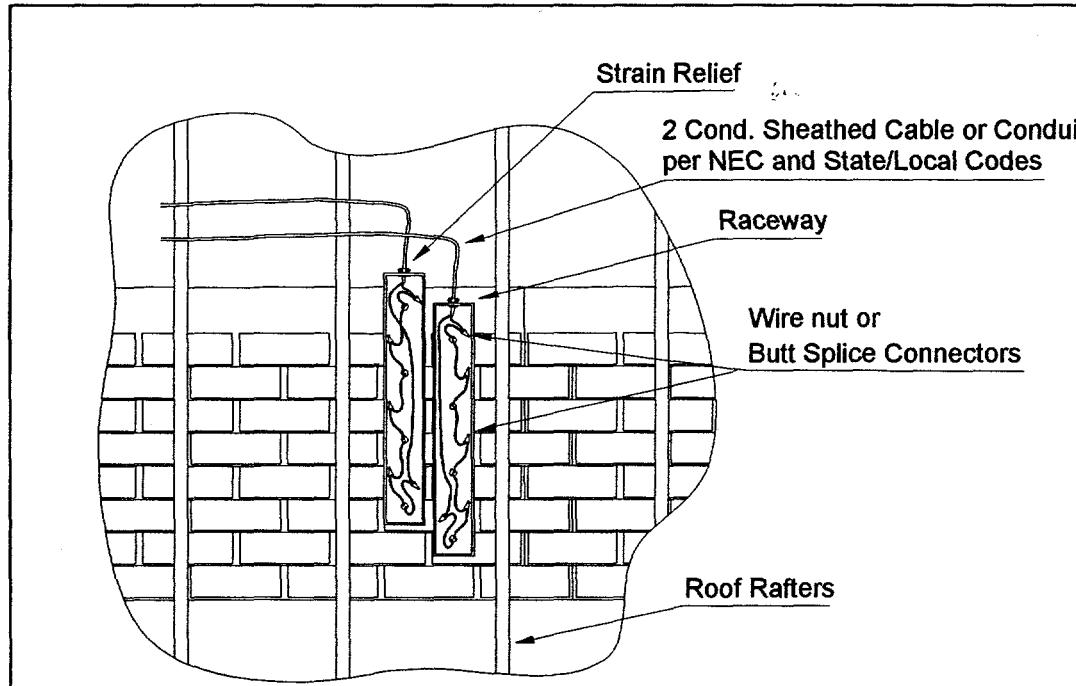


Figure 3

APPENDIX V

Shingle Module Installation Instructions

INSTALLATION INSTRUCTIONS
UNI-SOLAR SHR-17 Solar Electric Shingle
— Draft 1.0 —

General Precautions

PV shingles are flexible solar electric devices. They may be handled in a manner similar to asphalt shingles with a few exceptions. The first exception is that the PV shingle may not be cut or trimmed in any way. This is due to live electrical components enclosed and protected within the package. The second is that, although they are flexible, the active tabs must not be creased, as they will not return to their original form. When standing directly on the PV shingle material use only a clean rubber backed shoe. PV shingles are slippery, especially when wet.

Tools Needed

Drill, $\frac{3}{4}$ " drill bit, chalk line, template, hammer, roofing nails, template.

1.0 Deck Preparation

Reference figures 1 through 3 for steps 1.1 through 1.6.

1.1 Layout 30 lb, ungranulated, felt paper over entire deck. Deck must be flat, with no sagging or buckling of plywood and free of protrusions such as high fasteners, plywood splinters etc.

1.2 Determine the starting position of the first PV shingle. Place a mark on the deck at the lower left corner of where the first PV shingle will be (no shingles are to be installed at this time). This position should be a multiple of 5" from the bottom edge of the first row of asphalt shingles (see figure 1).

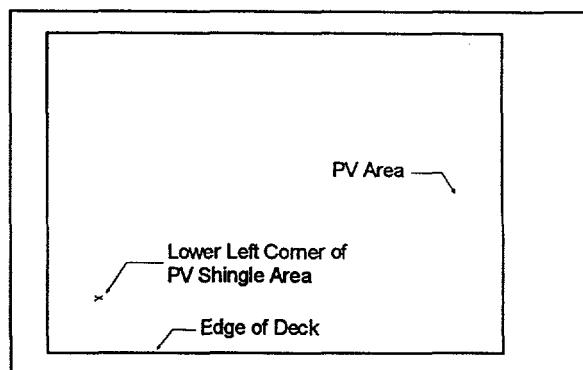


Figure 1

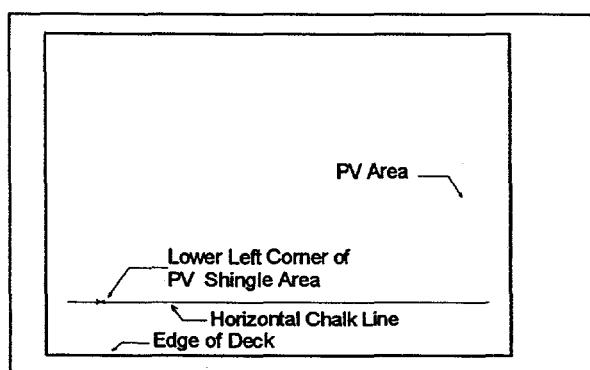


Figure 2

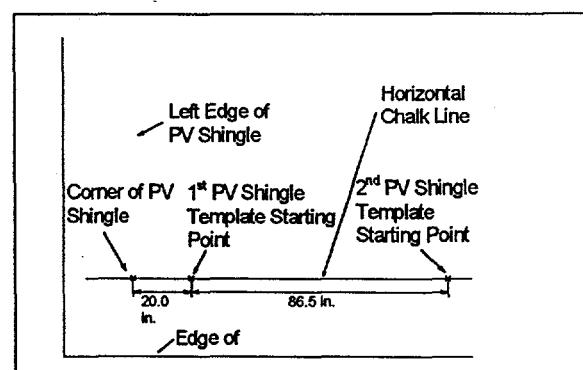


Figure 3

- 1.3 Using the mark in step 1.2 snap a horizontal chalk line along the length of the PV section of the deck (see figure 2).
- 1.4 To establish template starting point, measure 20" (508mm) from left corner point along horizontal line and mark position (see figure 3).
- 1.5 For every PV shingle on first row measure an additional 86½ inches (2195mm) along horizontal line and mark position (see figure 3).
- 1.6 At each marked position on horizontal line snap a vertical chalk line sufficiently long to mark all rows of PV shingles (see figure 4).

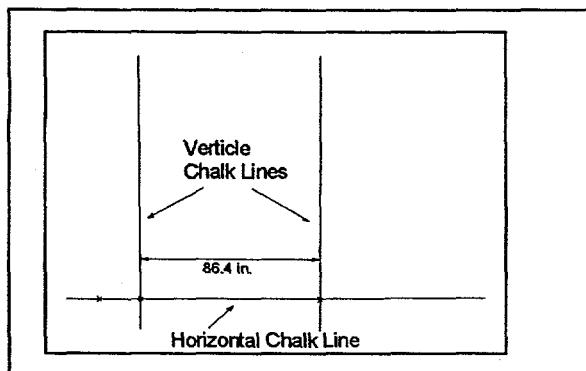


Figure 4

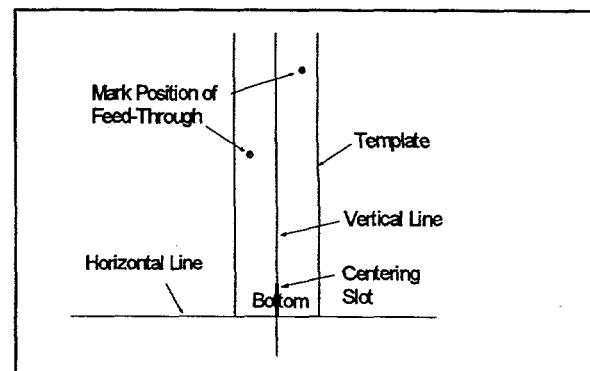


Figure 5

2.0 Positioning and Drilling of Feed-through Holes

Reference figures 4 and 5 for steps 2.1 and 2.2.

- 2.1 Lay template face up and centered (using centering slots) on first vertical line with the bottom edge along the horizontal line as shown in figure 5. [Cardboard template included in each carton of PV shingles.]
- 2.2 While holding template firmly in place mark position of feed-through holes, using holes in template, for as many rows of PV shingles as will be installed.
- 2.3 To mark additional PV shingle feed through holes move the template up on the deck such that the template is still centered on the vertical line with at least two holes of the template overlapping and centered on the previous marked position.
- 2.4 Continue marking feed-through holes on the same vertical line until there are as many feed-through holes as there are rows of PV shingles.
- 2.5 Repeat steps 2.2 and 2.3 for each vertical line made in step 1.6.

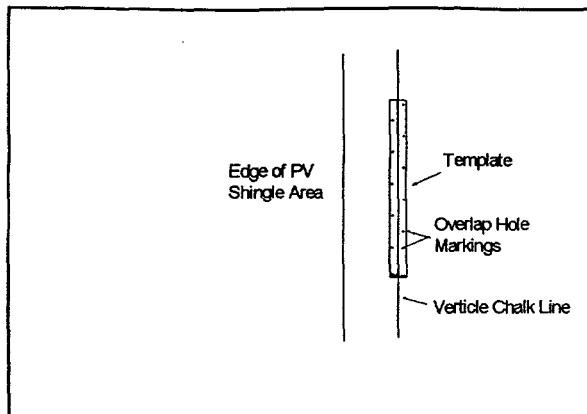


Figure 6

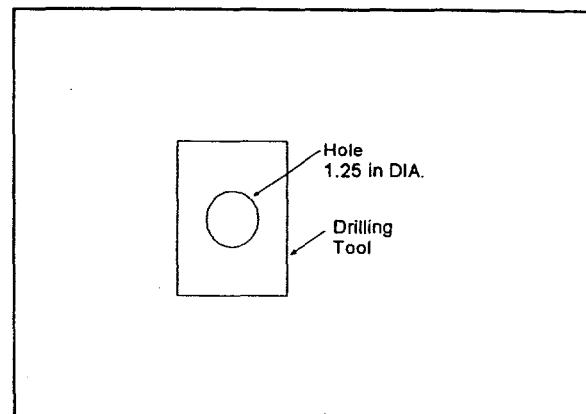


Figure 7

2.6 Position the drilling tool shown in figure 7 over the center of the mark made in steps 2.1 through 2.5. Drill a $\frac{1}{4}$ inch (19mm) wire feed through hole while holding the tool firmly to the felt so that no wood shavings get underneath the felt paper. **Note: It is best to avoid rafters under deck if possible. If this is unavoidable, drill through the rafter at an angle so as to clear the rafter for the feedthrough wires.**

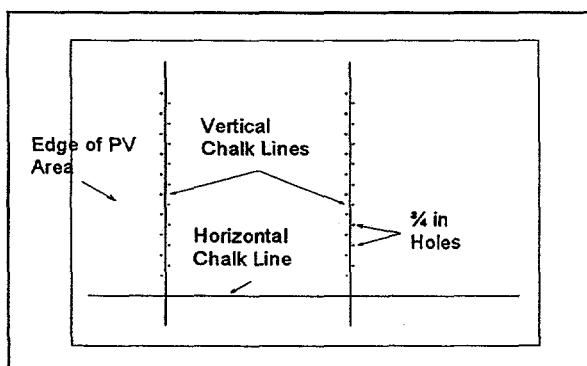


Figure 8

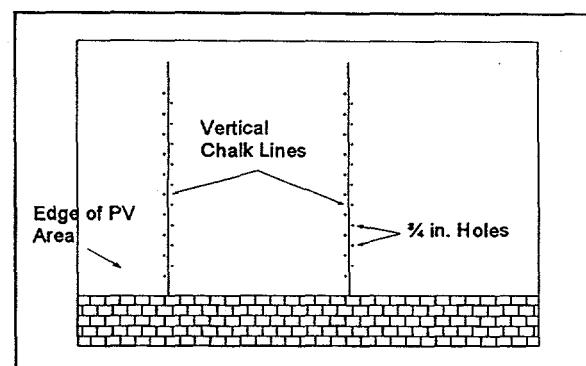


Figure 9

2.7 Repeat step 2.6 for all remaining marks made in steps 2.1 through 2.5 as shown in figure 8.

2.8 Sweep away all shavings produced from drilling in step 2.6 and 2.7.

2.9 Layout and install the first asphalt shingles up to the horizontal chalk line as shown in figure 9.

3.0 Mounting of Under Deck Raceway

3.1 From under the deck place bottom part of raceway over the drilled holes and mount to the underside of the decking using 7/16" wood screws (see figure 10). **CAUTION: be sure that the wood screws are not protruding through the roof as the SHR-17 PV shingle may be damaged, resulting in a potential shock hazard.**

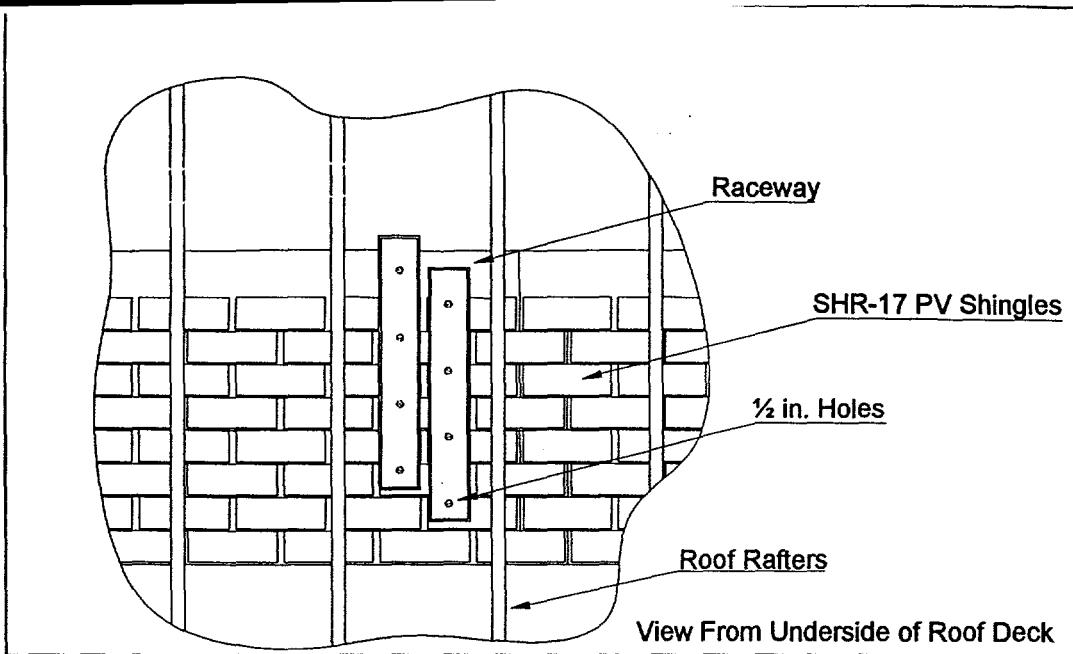


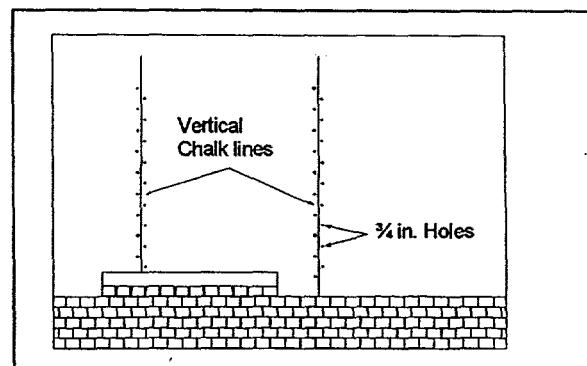
Figure 10.

3.2 From the top side of the roof deck, using the existing $\frac{3}{4}$ " holes previously drilled in the roof deck as a template, drill $\frac{1}{2}$ " diameter holes through the raceway for shingle wiring. Figure 10 shows installed raceway with $\frac{1}{2}$ " holes for shingle wiring.

4.0 Mounting of PV shingles

4.1 Remove the release paper on the back of the PV shingle near the output wires and the long strip at the bottom of the PV shingle.

4.2 Position the first PV shingle in the first row feeding the wires through the hole as the shingle is placed on the deck (see figure 11).



Note: It is very important for the base of the wire (where it goes into the PV shingle) to be completely within the hole so that the PV shingle will lay flat on the deck.

4.3 Align the bottom of the PV shingle with the top of the 5 inch (127mm) exposure of the previous row of asphalt or PV shingle as shown in figure 11 (if there is no earlier row align with edge of deck).

4.4 Fasten PV shingle using $1\frac{1}{4}$ inch (32mm) roofing nails 2 rain lines apart and 4 inches (102mm) directly above the rain line as shown in figure 12. Note: It is important to fasten PV shingle in this area to avoid puncturing electrical components inside the package (see figure 12).

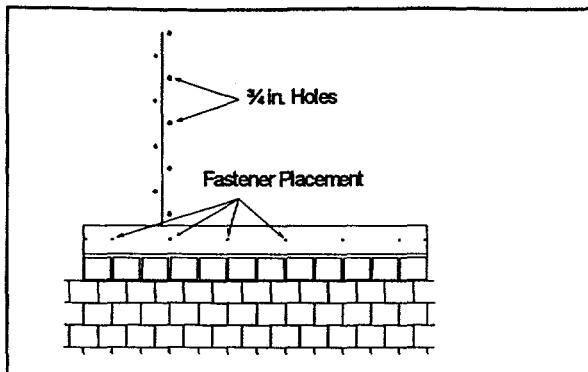


Figure 12

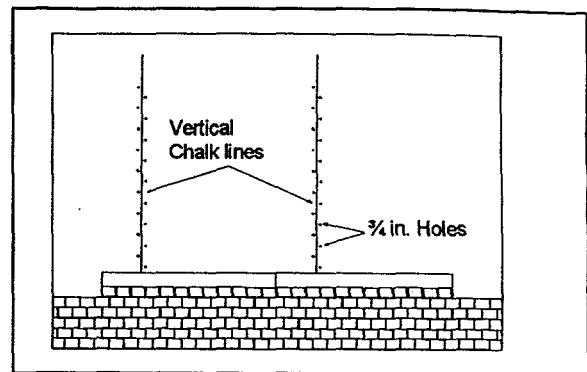


Figure 13

- 4.5 Repeat steps 4.2 through 4.4 for all remaining PV shingles in first row as shown in figure 13.
- 4.6 Finish first row with asphalt shingles installing them in the usual fashion, butting the asphalt to the PV shingle, edge to edge as shown in figure 14.

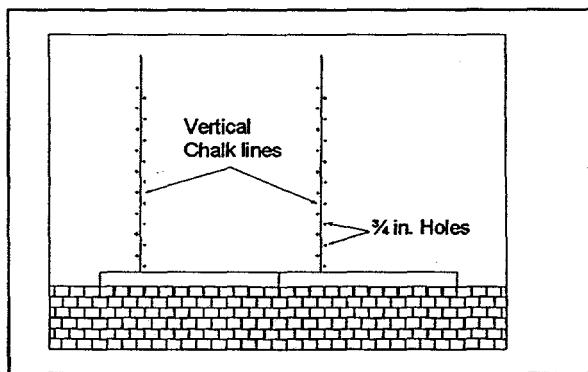


Figure 14

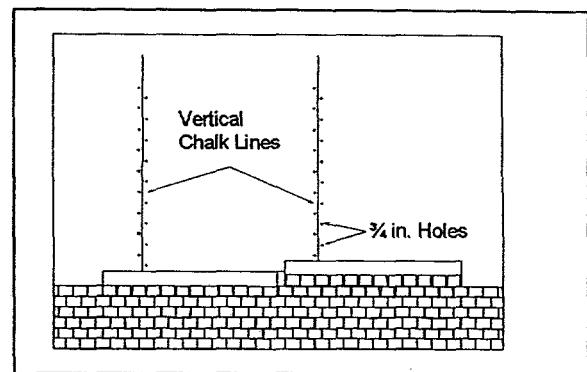


Figure 15

- 4.7 As in steps 4.2 through 4.4 install first PV shingle in second row with the rain lines staggered by half of a tab on the previous row (see figure 15).
- 4.8 Repeat steps 4.2 through 4.4 for all remaining PV shingles in the second row as shown in figure 16.
- 4.9 As in step 4.6 complete the second row with asphalt shingles.
- 4.10 On one end of each row, starting with the second row, the asphalt will overlap the PV shingle by about $3\frac{1}{2}$ ". Where this occurs run a bead of plastic cement onto the PV shingle just above the glossy line (about 1" above exposed area).

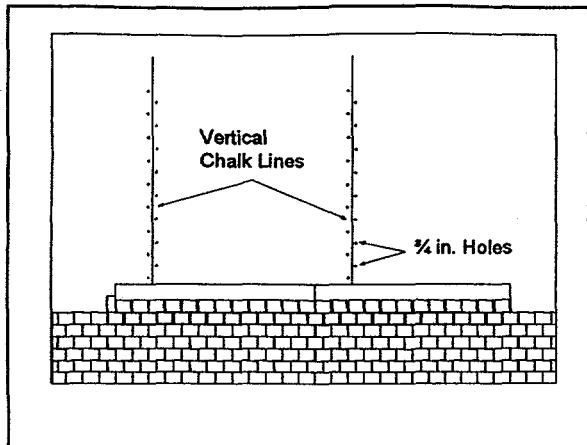


Figure 16

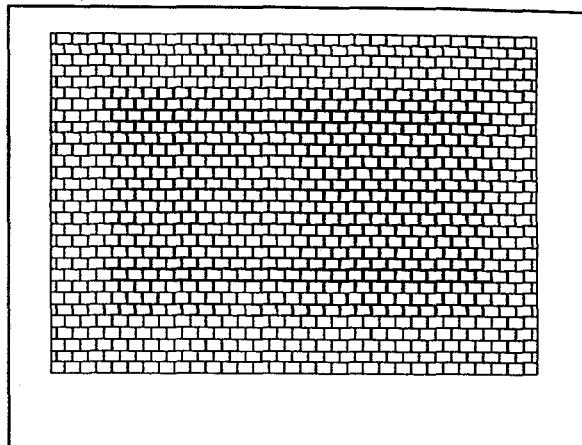


Figure 17

Finishing Deck with Asphalt Shingles

- 4.12 Install asphalt shingles above the PV shingle array in the normal fashion (see figure 17).
- 4.13 In the first row of asphalt shingles above the PV shingles use plastic cement as in step 4.10 to adhere asphalt to the PV shingles.

5.0 WIRING SHR-17

General Information

The PV Shingle is an active electrical power source in sunlight. Consider all electric leads to be “live”, nominally as 12 volts DC and 2.5 amps (in short circuit).

Each PV shingle has two wires - red is positive and black is negative. Wiring of the shingles to form a complete solar electric “array” involves connecting shingles in series to form “string” circuits that are combined in a separate junction box. No parallel wiring of shingles occurs in the raceway beneath the shingles.

Tools Needed

Stripper, Crimp tool (for butt splice connectors), heat gun (for sealing all-weather type wire nuts or butt splice connectors)

- 5.1 From under the deck, connect shingles in series (2, 4 or 7 typical) for the desired circuit voltage (see table 1) and system design. Black is connected to red using a “butt splice connector” and high quality crimp tool. Figure 18 shows two strings of four PV shingles connected in series that transitions to standard building wire.

Table 1

Nominal System Voltage	Number of SHR-17 in Series	Open Circuit Voltage	SHR-17 Operating Voltage
12	2	24	17
24	4	48	34
48	7	84	68

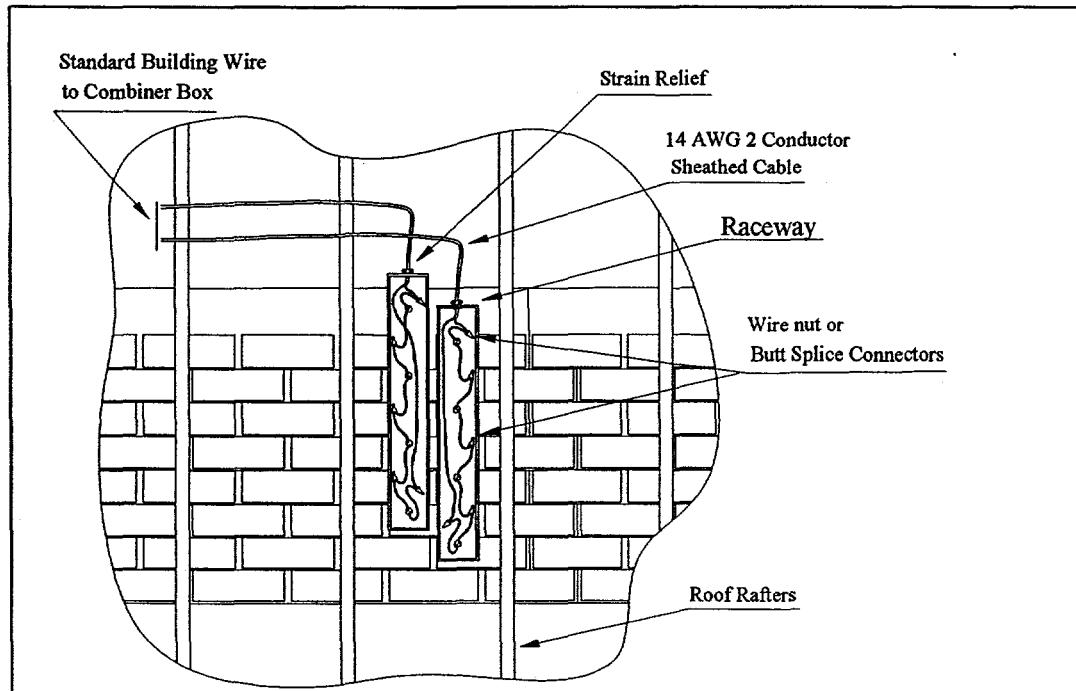


Figure 18

APPENDIX VI – VII
Metal Roofing Owner's Manual & Installation Guide



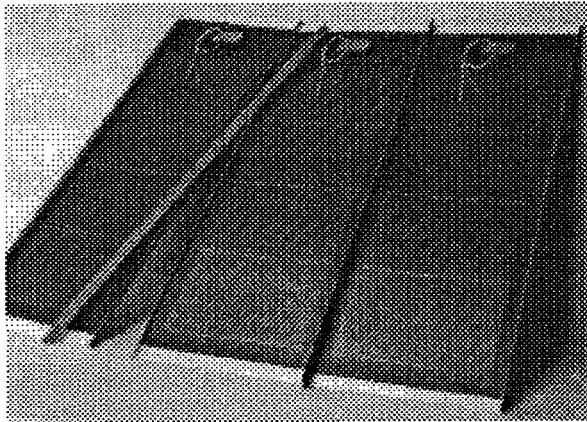
Solar Electric Metal Roofing Panel

ASR-64, ASR-128 Architectural Standing Seam

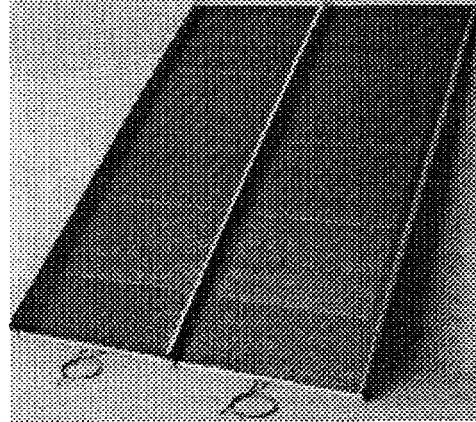
SSR-64, SSR-128 (SSR-64J, SSR-128J) Structural Standing Seam

Owner's Manual & Installation Guide

1/12/98



Architectural Standing Seam
(Shown with potted top termination)



Structural Standing Seam
(Shown with potted bottom termination)

UNI-SOLAR® Solar Electric Metal Roofing Panels (photovoltaic roofing panels) are building integrated photovoltaic products. They are integrated into the roof following the specifications of conventional metal roofing panels. Photovoltaic roofing panels are intended for use with other electrical power components such as DC combiner boxes (for series and parallel connections) charge controllers, DC/AC inverters, and ground fault detection and interruption equipment. System design and component selections should comply with the National Electric Code (NEC) and all state and local codes.

These installation instructions cover **UNI-SOLAR®** Architectural and Structural Metal Roofing Products. Refer to metal roofing supplier's installation instructions and practices and note the following cautions:

CAUTIONS

Photovoltaic (PV) roofing panels produce DC electricity when exposed to light. The voltage from

one individual panel is not considered hazardous, however if connected in series to increase voltage and/or connected in parallel to increase current, the potential shock hazard increases. When installing or working around PV roofing panels, batteries and related electrical equipment, observe industry standards and practices as well as manufacturer's safety procedures.

WARNINGS

- PV roofing panels contain live electrical components enclosed and protected within. Do not cut or trim the panels in any way. Do not drive screws into or through any portion of the laminate area of the panel. Doing so can cause electric shock, may result in fire and will void the warranty.
- Cover PV roofing panels with an opaque material before making wiring connections to reduce the risk of electric shock or sparks.
- Use insulated tools and wear electrical rubber gloves rated for maximum system voltage when wiring PV roofing panels.

- Observe safe electrical practices at all times. Make connections in well-ventilated areas free from flammable gas vapors.
- Observe proper polarity when connecting the PV roofing panels into an electrical circuit (see section on wiring). Reverse connection will damage the roofing panels, may result in fire and will void the warranty.
- Do not use any PV roofing panels without blocking diode protection to prevent reverse current flow from a battery or from other panels in the circuit.
- Do not attempt to concentrate sunlight on the PV roofing panels for increased output. Doing so may cause damage and will void the warranty.
- PV roofing panels are slippery, especially when wet. Use extreme caution and proper safety harness when working on or near PV roofing panels.
- Do not place equipment on PV roofing panels.
- Avoid dropping any sharp objects on PV roofing panels.
- Contact appropriate local authorities prior to installing any PV

roofing panels to determine if permits and inspections are required for your particular area.

- Only qualified persons should install PV roofing panels. Contact a licensed roofer for installation of the panels onto your structure and a licensed electrician for making electrical connections.

DISCLAIMER OF LIABILITY

The information contained in this manual is based on United Solar's knowledge and experience, but such information and suggestions do not constitute a warranty expressed or implied. The methods of installation, use and maintenance of PV roofing panels are beyond the control of United Solar. United Solar assumes no responsibility and

expressly disclaims liability for any loss, damage or expense associated with the use, installation or operation of the product. Any liability of United Solar is strictly limited to the Limited Warranty attached hereto. United Solar reserves the right to make changes to product specifications or to this manual without notice.

Table 1. Specifications and Performance

	ASR-64	ASR-128	SSR-64(J)	SSR-128(J)
Rated Power (Watts)	64	128	64	128
Operating Voltage (Volts)	16.5	33	16.5	33
Operating Current (Amps)	3.6	3.6	3.6	3.6
Open-Circuit Voltage (Volts)	47.6	23.8	47.6	23.8
Open-Circuit Voltage (Volts) At -10°C and 1250 W/m ²	54.2	27.1	54.2	27.1
Short-Circuit Current (Amps)	4.5	4.5	4.5	4.5
Short-Circuit Current (Amps) At 75°C and 1250 W/m ²	5.9	5.9	5.9	5.9
Series Fuse Rating (Amps)	8	8	8	8
Min. Blocking Diode (Amps)	8	8	8	8
Weight (lbs/ft ²)	2	2	2	2

During the first 8-10 weeks of operation, *UNI-SOLAR®* Solar Electric Metal Roofing Panels have higher electrical output than that rated in table 1. Output

power may be higher by 15%, operating voltage may be higher by 11% and operating current may be higher by 4%.

Electrical specifications ($\pm 10\%$) are based on measurements performed at standard test conditions of 1000 W/m² irradiance, Air Mass 1.5, and Cell Temperature of 25°C after long-term stabilization. Actual performance may vary up to 10% from rated power due to low temperature operation, spectral and other related effects.

Maximum system open-circuit voltage not to exceed 600 VDC. Specifications subject to change with out notice.

* Refer to section 690-8 of the National Electric Code for an additional factor of 125%, which may be applicable.

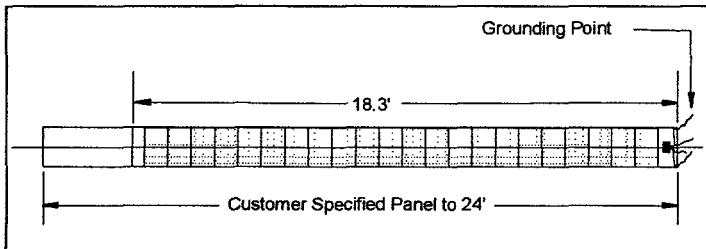


Figure 1. ASR-128 top view

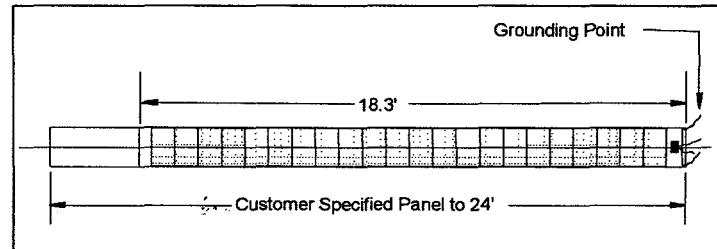


Figure 4. SSR-128 top view

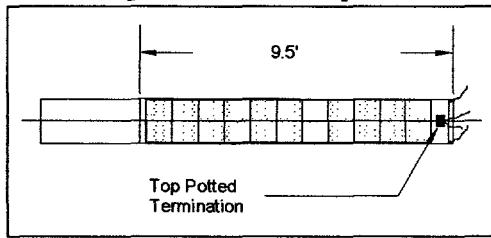


Figure 2. ASR-64 top view

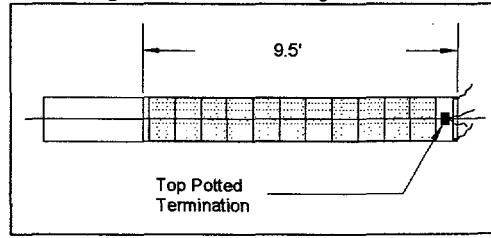


Figure 5. SSR-64 top view

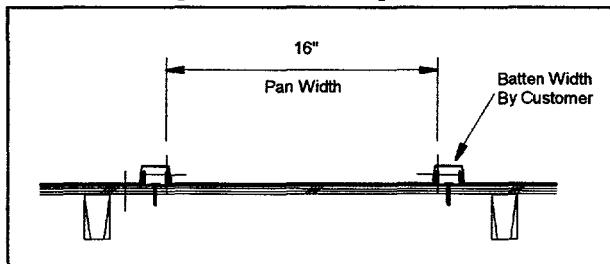


Figure 3. ASR side view

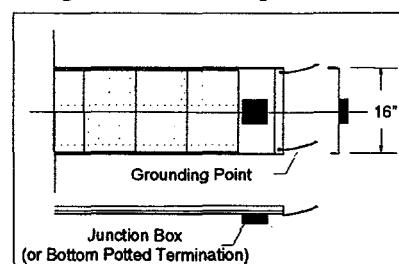


Figure 6. SSRJ detail

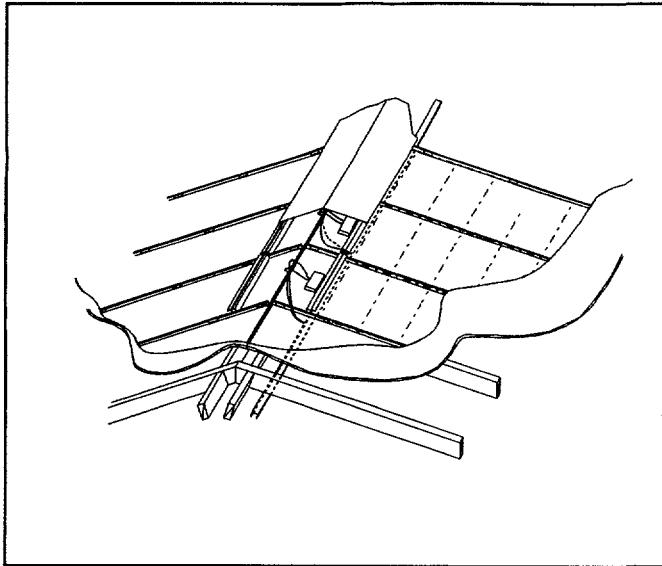


Figure 7. ASR installation detail

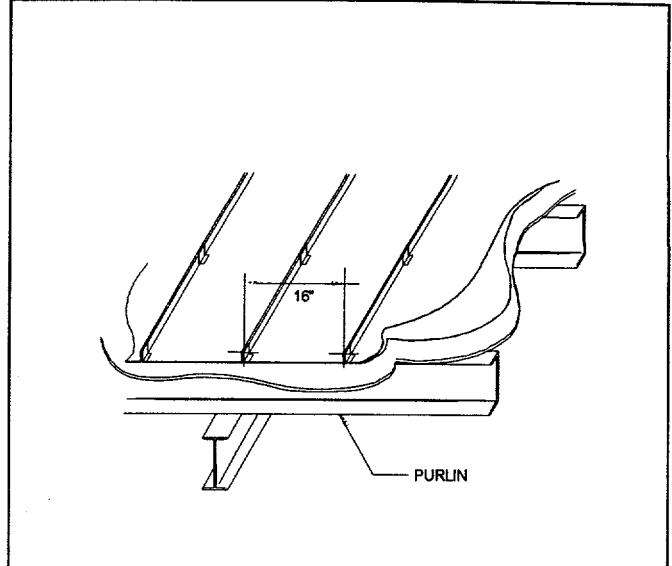


Figure 8. SSR installation detail

GENERAL INSTALLATION

This general installation guide covers the unique installation practices required when handling and installing *UNI-SOLAR®* PV Metal Roofing Panels. Contact roofing panel manufacturer for detailed installation instructions of roofing panel.

Handling

UNI-SOLAR® PV roofing panels may be handled in a manner similar to current commercially available metal roofing panels with a few exceptions:

- 1.) PV roofing panels may not be cut or trimmed in any way.
- 2.) Avoid standing on PV roofing panels whenever possible. If unavoidable, wear only clean rubber backed shoes and use an approved safety harness when standing directly on PV roofing panels.
- 3.) Do not bend, scrape or abrade PV roofing panel surfaces.
- 4.) Never puncture or penetrate the solar laminate.

Placement

Pick a location on the roof deck with a maximum exposure to sunlight (free from shadows) that is devoid of vents, air conditioners or any other potential obstructions. Figures 1 through 6 show plan views for both the ASR and SSR PV roofing panels.

Installation

UNI-SOLAR® PV roofing panels are secured in place in a manner similar to traditional metal roofing panels using standard anchor panel clips and fasteners (available from metal roofing panel manufacturer). Figures 7 and 8 show detail for both ASR and SSR installations (respectively). Refer to roofing panel manufacturer for detailed installation instructions and flashing details.

Wiring

Each PV roofing panel has one positive and one negative termination point. ASR-64 and ASR-128 PV roofing panels offer a potted top termination with one red and one black output wire. Red is positive and black is negative.

SSR-64 and SSR-128 PV roofing panels can be offer either a top or bottom potted termination each with one red and one black output wire (see figures 4 and 5).

SSR-64J and SSR-128J PV roofing panels come equipped with a junction box on the bottom of the panel (see figures 6 and 9).

Wiring and all splices should be contained in an approved junction box or raceway suitable for the application and temperatures seen on top of or in the roof space.

Blocking Diodes

Proper use of suitable blocking diodes is recommended to prevent reverse current flow into a PV roofing panel from a battery, another parallel-connected PV roofing panel or other energy source. Use a single blocking diode of appropriate rating in each series-connected string of PV roofing panels. Use an external termination box to mount blocking diodes (and heat sink if required). For assistance call United Solar or authorized dealer.

Bypass Diodes

Every PV roofing panel includes bypass diodes across each cell, resulting in superior shadow tolerance (reduced power loss under partial shadow conditions). When two or more PV roofing panels are connected in series a bypass diode can be installed across each PV roofing panel providing further shadow tolerance.

Charge Regulation

The use of a charge regulator is recommended in battery systems to prevent PV roofing panels from overcharging the battery. Follow the manufacturer's instructions for installation of the charge regulator.

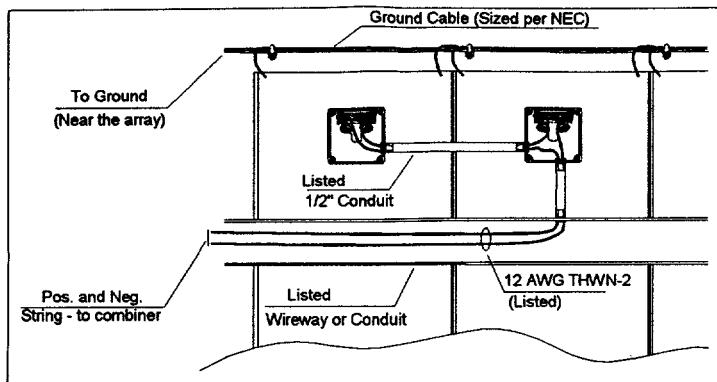


Figure 9 SSR-64J/128J wiring detail

High Voltage Systems

UNI-SOLAR® PV roofing panels are suitable for use in systems with system voltages up to 600 volts. **Do not use ASR or SSR PV roofing panels in systems having a maximum open circuit voltage greater than 600 volts DC.**

Wire Selection

PV roofing panel wiring connections are to be made in a listed raceway under the roof deck (see figure 3). Splices should be made with listed, all weather heat-sealable butt splices or wire nuts. All transition wiring should be chosen for maximum temperature, environment and application. Refer to National Electric Code article 690 and all other applicable codes and standards.

Grounding

PV roofing panels have two ground points located on the underside of the panel at the two upper corners. These points should be physically tied to an appropriate ground cable (sized per NEC) that is in turn tied to an earth ground (see figure 9).

Maintenance

Periodically check wiring connections for tightness and corrosion. Generally, a good rain is sufficient to clean the PV roofing panels. However, in dusty arid locations the PV roofing panels can be cleaned with mild soap and water. **Do not use abrasive soaps or solvents.** Do not spray water directly at leading edge of the PV roofing panel. Use caution when cleaning PV roofing panels, as the combination of water and electricity may present a shock hazard. Always wear electrical gloves, disconnect all energy sources (i.e. battery and/or

utility) and short-circuit the output of the PV roofing panels or wash at night when cleaning.

WARRANTY

Limited Ten-Year Warranty

United Solar Systems Corp. warrants each UNI-SOLAR® ASR-64, ASR-128, SSR-64 and SSR-128 Solar Electric Metal Roofing Panel against lost power output as follows: For a period of ten (10) years from the date of sale to the original purchaser, PV roofing panels which upon inspection by United Solar Systems or its appointed agent are determined to exhibit a power output of less than 90 % of the Rated Power specified at the time of sale due to defects in materials or workmanship will be repaired or replaced, or, at the option of United Solar Systems Corp., it will refund an amount equal to such lost power times the amount paid for the panels per watt of Rated Power. Lost power is the difference between exhibited power and 90% of the Rated Power.

What is not covered by the Warranty

This warranty does not apply to any PV roofing panel which in the judgement of United Solar Systems Corp. has been subject to misuse, neglect or accident or which has been damaged through abuse, alteration, improper installation or application, or negligence in use, storage, transportation or handling, or repaired by anyone other than United Solar Systems Corp. The warranty does not cover any transportation costs for return of PV roofing panel or for reshipment of any repaired or replaced PV roofing panel, or cost associated with installation, removal or reinstallation of PV roofing panels.

Warranty Limitations

United Solar Systems Corp. shall have no responsibility for damage to persons or property or other loss or injury resulting from defect in the PV roofing panel or from improper use or installation. Under no circumstances will United Solar Systems Corp. be liable for any incidental or consequential damage. Any warranties implied by law, including those of merchantability and fitness for a particular purpose are hereby expressly disclaimed. The maximum liability of United Solar Systems Corp. is limited to the purchase price of the PV roofing panel. Such liability shall be limited in duration to twelve (12) months from the date of original purchase. This warranty is in lieu of all other warranties, expressed or implied. The purchaser's exclusive remedy shall be only as stated herein. Some states do not allow limitations on how long an implied warranty lasts or the exclusion or limitation of incidental or consequential damages, so the above limitations or exclusions may not apply to you.

Obtaining Warranty Performance

If you feel you have a claim under this warranty, first contact your United Solar Roofing agent who will give advice on handling the claim. If further assistance is required, contact United Solar Systems Corp. for instructions. The factory will not accept the return of any PV roofing panel unless prior written authorization has been given by United Solar Systems Corp. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

United Solar Systems Corp.

Corporate Office
1100 West Maple Road
Troy, MI 48084
(248) 362-4170
Fax (248) 362-4442

Sales Office
9235 Brown Deer Road
San Diego, CA 92121-2268
(800) 397-2083
(619) 625-2080
Fax (619) 625-2083
<http://ovonic.com/unisolar.html>

APPENDIX VIII
Uni-Solar BIPV Sales Brochures



UNITED SOLAR SYSTEMS CORP.

HOME OFFICE:
1100 West Maple Road
Troy, MI 48084

Telephone: 248/362-4170
Fax: 248/362-4442
1-800-843-3892

January 1997

Thank you for your inquiry about *UNI-SOLAR* Roofing.

United Solar Systems Corp. has developed and will bring to market in 1997 innovative solar electric roofing systems designed as shingles and metal roofing. These *UNI-SOLAR* Roofing modules are durable photovoltaic (PV) roofing materials that replace conventional roofing materials. They offer the same levels of protection and aesthetics as premium roofing and generate clean solar electricity to power homes and commercial buildings.

UNI-SOLAR Architectural Standing Seam, Structural Standing Seam and PV shingle modules are made from thin, flexible and lightweight amorphous silicon solar cells laminated in advanced polymers - no glass is used. *UNI-SOLAR* Roofing modules are installed alongside standard shingles or metal roofing using the same tools and methods. Supplementary roofing materials or structural additions to the standard roof deck are not needed. United Solar's thin film technology lets you uniformly cover a roof with PV at half the price per square foot of traditional crystalline PV products. Also, under partially covered or shaded conditions, *UNI-SOLAR* Roofing modules continue to generate significant power where crystalline modules can lose up to 80% of their output. These unique features of our *UNI-SOLAR* Roofing systems provide a combination of benefits that cannot be matched by any other solar electric product. The reality of photovoltaics as a roofing material has arrived with the development of *UNI-SOLAR* Roofing.

UNI-SOLAR Roofing products will use new high-efficiency Triple Junction cells from our advanced 5 megawatt production machine. Enclosed in this package is information on United Solar Systems Corp. and our new innovative *UNI-SOLAR* products.

Building integrated photovoltaics is cost effective today for many "off-grid" locations because it is less expensive than power line extension or operating engine-generators. For customers whose homes or buildings are grid-connected, the environmental and social benefits of *UNI-SOLAR* Roofing systems offer a valuable way to distinguish and enhance their properties.

Thank you again for your interest in United Solar. We look forward to working with you.

Lawrence T. Slominski
Manager, New Business Development

San Diego, CA

UNI-SOLAR[®] ROOFING SYSTEMS

UNIQUE SOLAR ELECTRIC TECHNOLOGY:

Structural Metal Roofing

Architectural Metal Roofing

Shingles

Corporate Office
1100 W. Maple Rd.
Troy, Michigan 48084
Telephone: (248) 362-4170

Sales Office
9235 Brown Deer Road
San Diego, CA 92121
Telephone: (619) 625-2080

Internet
<http://ovonic.com/unisolar.html>

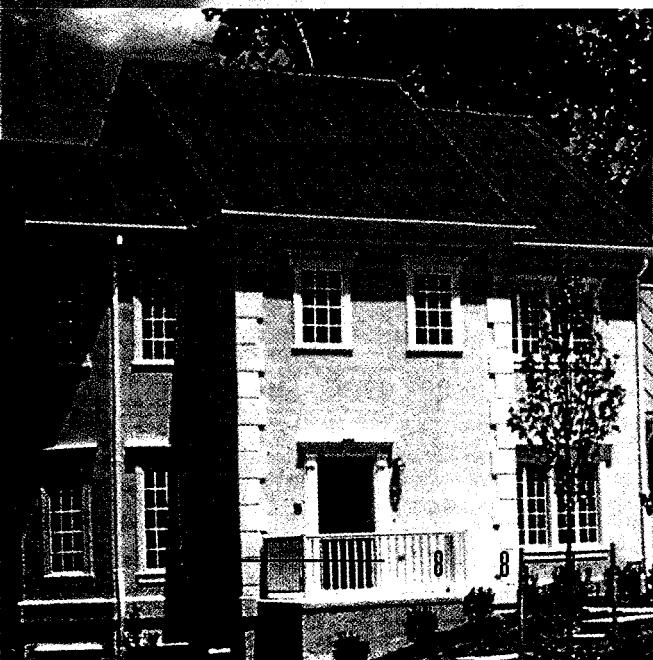
UNI-SOLAR is a Registered Trademark of United Solar Systems Corp.

8 8 8 - U N I - S O L A R

United Solar Systems Corp.,

The leader in thin-film amorphous silicon photovoltaics (PV) offers a revolutionary new line of solar-electric roofing panels. Unlike other photovoltaic technologies that use heavy, glass modules, United Solar System Corp.'s panels are flexible, lightweight, and architecturally attractive. These rooftop solar systems emulate conventional roofing materials in design, construction, function, and installation.

United Solar Systems Corp. is a joint venture of two of the world's most respected technology companies: Energy Conversion Devices, Inc. (ECD) and Canon Inc. ECD has gained international renown for its research and development in a variety of fields, including energy storage, information technology, and energy generation. Canon is a pre-eminent manufacturer of office equipment, photographic products, and optical systems. ECD and Canon formed United Solar in 1990 after working as partners in the successful development of amorphous-silicon deposition for copier drums.

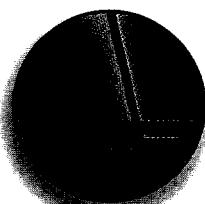


Photovoltaics

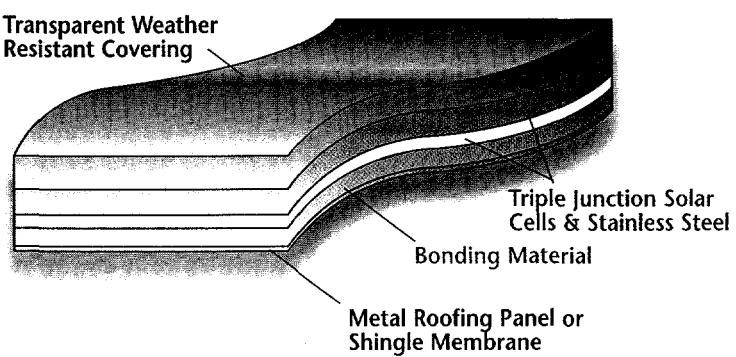
Originally developed as a source of energy for satellites, photovoltaic technology is changing the energy-source paradigm around the world. Solar power is produced silently with no pollution and no depletion of resources. It is easily integrated into commercial and residential building architecture. Whether for use in a remote location (off-grid), as an upgrade to existing utility power, or as an environmentally superior alternative to conventional grid-supplied electricity, United Solar roofing products combine solar power generation with standard roofing applications.

Technology

United Solar's Triple Junction technology provides unprecedented levels of efficiency for amorphous-silicon solar cells. By combining this advanced technology with a proprietary roll-to-roll solar cell-deposition process United Solar is able to fabricate flexible, lightweight solar electric laminates for building-integrated photovoltaics (BIPV).



Triple Junction Technology



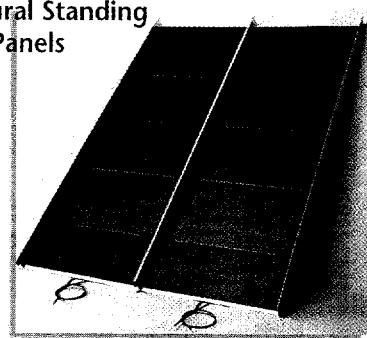
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The solar cell, consisting of amorphous-silicon on a 5-mil-thick stainless steel substrate, is encapsulated in TEFZEL® elastomer and other weather-resistant polymers.

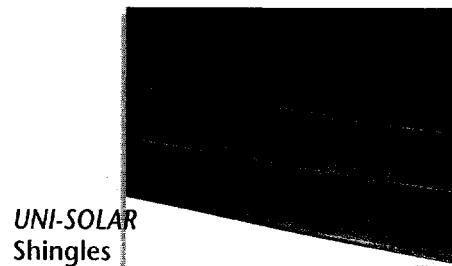
Roofing Products

The resulting solar electric laminate is bonded to conventional roofing panels or fabricated into roofing shingles. Three solar electric roofing products are available:

UNI-SOLAR
Structural Standing
Seam Panels



UNI-SOLAR
Architectural Standing
Seam Panels



UNI-SOLAR
Shingles

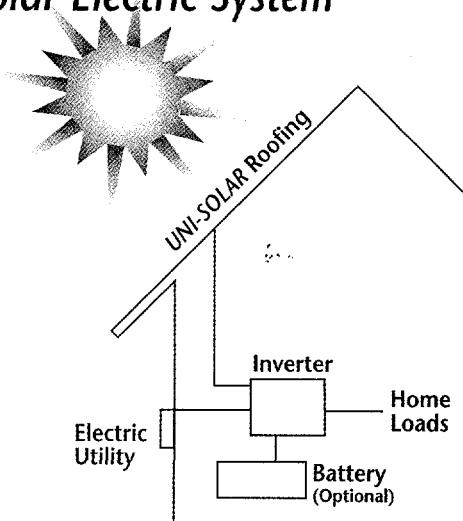
Systems

UNI-SOLAR roofing products are the key components of a total solar electric system.

The system integrates the solar electric roofing panel or shingle with the necessary combiner boxes, inverter, and wiring to convert sunlight into electric energy and distribute it directly to the building.

The solar electric roofing products are configured in series or parallel on the roof deck to form an array. The array is used in combination with conventional roofing products.

Solar Electric System



UNI-SOLAR design services provide assistance in configuring these solar electric roofing products to meet the specific user needs. For more information, please call: 888-UNI-SOLAR.

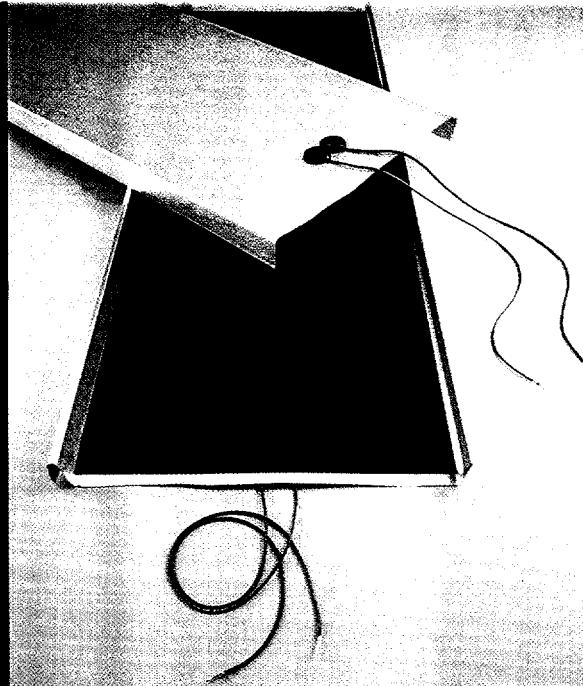
UNI-SOLAR is a Registered Trademark of United Solar Systems Corp.

TEFZEL is a Registered Trademark of DuPont Co.

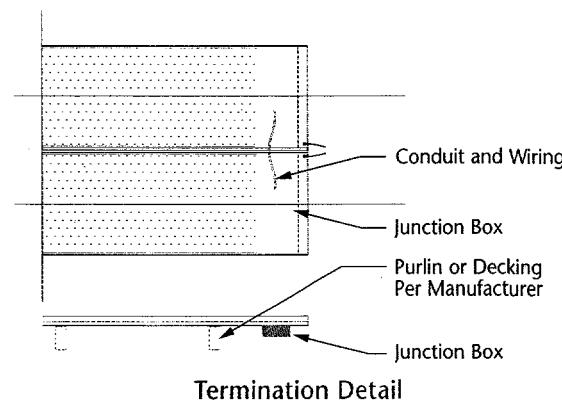
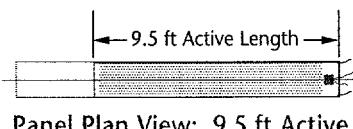
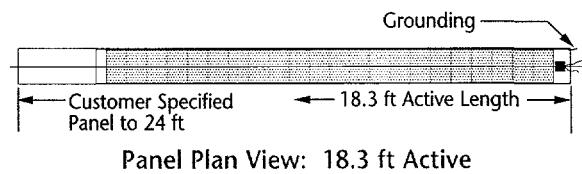
UNI-SOLAR®

Structural Standing Seam

*Unlimited Applications for Commercial Buildings;
Dependable, Environmentally Safe*



UNI-SOLAR Structural Standing Seam Metal Panels are designed with the electrical terminations at the bottom of the panel.



UNI-SOLAR Structural Metal Panels combine the appeal of a structural roofing product with the solar electric capabilities of PV. Designed for ease of installation, this solar panel is integrated into the roof following the specifications of conventional structural standing seam panels. System design and installation are made based on user needs.

- **Standard Panel Length:** 9.5 ft or 18.3 ft, active solar laminate bonded to conventional flat metal roof panel.
- **Laminate Width:** 15.75 in.
- **Metal Panel:** GALVALUME® steel, painted or unpainted.
- **Pan Width:** 16 in. (In-situ width 16 in.).
- **Customer Specified Panels:** From 9.5 ft to 24 ft.
- **Span and Allowable Loads:** Per panel supplier's specifications.
- **Electrical Connections:** Standard-junction box termination; optional-potted bottom or top termination.
- **Roof Slope:** Minimum 1:12 slope.
- **Installation:** Per panel supplier's specification.
- **Ideal Roof Orientation:** Open southern exposure.
- **Wind Load:** Per panel supplier's specification.
- **Array:** Size dependent on power demands. See table below.
- **System:** Typical systems range from 4 kW to 20 kW.

Specification & Performance

Product	Rated Power (W)	Voltage (V _{op})	Current (I _{op})	Voltage (V _{oc})	Current (I _{sc})	Length (ft)	Width (in.)	Weight (lbs/ft ²)	Area (ft ²)	Energy Per Day (Wh/ft ²)
SSR-60	60	16.5	3.6	23.8	4.5	9.5	16	2	12	20-30
SSR-64	64	16.5	3.9	23.8	4.8	9.5	16	2	12	20-30
SSR-120	120	33	3.6	47.6	4.5	18.3	16	2	23	20-30
SSR-128	128	33	3.9	47.6	4.8	18.3	16	2	23	20-30

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Typical Structural Metal-Panel Applications Include:

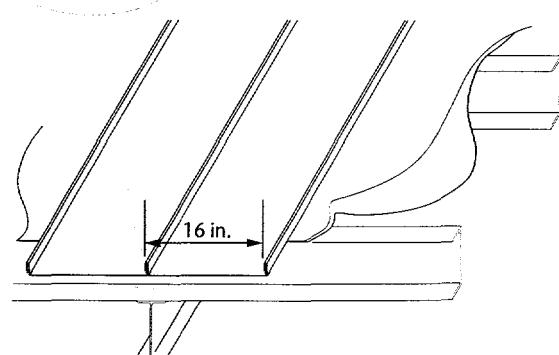
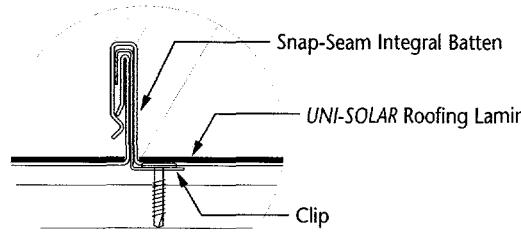


Southwestern Electric Power Company (SWEPCO)
Longview, Texas

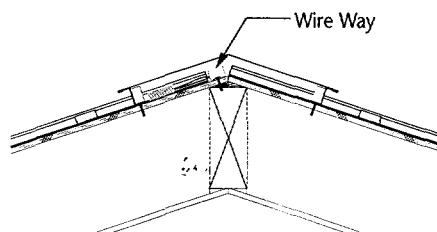
- PV Covered Parking
- EV Charging Stations
- Park Shelters
- Covered Spaces
- Commercial Buildings

Forty-two (42) UNI-SOLAR Standing Seam Roofing Modules (SSR-128) form the roof of the 4.2 kW Covered Parking System at SWEPCO, Longview, Texas. This turnkey project was developed by United Solar Systems Corp. for Central and Southwest Service, Inc. This utility-connected system uses a 5.5 kW inverter to supply AC power to the utility grid and is capable of being remotely monitored. As a renewable distributed generation resource, the PV Covered Parking System provides peak demand reduction on feeder lines to the site.

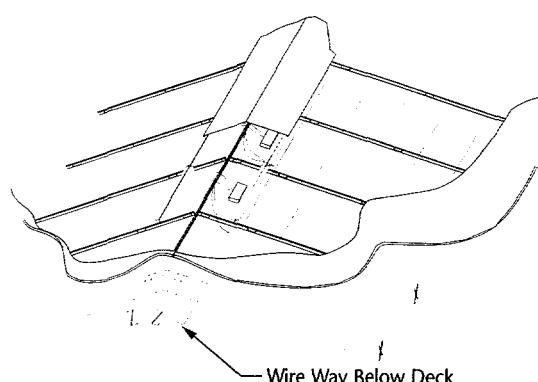
Batten Detail: Snap-Seam Integral Batten



Section View: Panel Attached to Purlin



Ridge Cap Detail
(Potted-Top Termination with ASR)

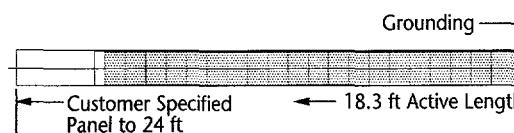


Wiring Detail
(Potted-Top Termination with ASR)

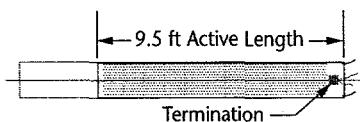
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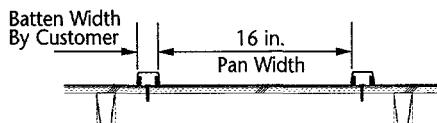
A 1.5 kW DC system was installed on a National Association of Home Builders (NAHB) 21st Century Townhouse in Maryland. The 18-panel system is grid connected. It has a 16-kWh battery backup.



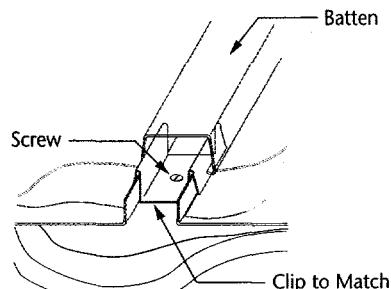
Panel Plan View: 18.3 ft Active



Panel Plan View: 9.5 ft Active



Panel Section



Batten Seam Detail

UNI-SOLAR®

Architectural Standing Seam

For Residential and Commercial Solar Power Systems

UNI-SOLAR Architectural Metal Panels are building-integrated photovoltaic panels. They are reliable, attractive, and cost-effective design options for creating sustainable and energy self-sufficient buildings.

Aesthetically-pleasing, solar architectural roofing panels are integrated into the roof following the specifications of conventional architectural standing seam panels. Solar electric power is collected through terminations located on top of the panel under the ridge cap. No deck penetrations are required.

- **Standard Laminate Length:** 9.5 ft or 18.3 ft, active solar length bonded to conventional flat metal roof panel.
- **Laminate Width:** 15.75 in.
- **Metal Panel:** GALVALUME® steel, painted or unpainted.
- **Pan Width:** 16 in. (In-situ width per batten size).
- **Customer Specified Panels:** From 9.5 ft to 24 ft.
- **Electrical Connections:** Standard-potted top termination, hidden and protected by ridge cap (see previous page).
- **Roof Slope:** Minimum 3:12 slope.
- **Installation:** Per panel supplier's specification.
- **Ideal Roof Orientation:** Open southern exposure.
- **Wind Load:** Per panel supplier's specification.
- **Array:** Size dependent on power demands. See table below.
- **System:** Typical systems range from 1 kW to 10 kW.

Specification & Performance

Product	Rated Power (W)	Voltage (V _{op})	Current (I _{op})	Voltage (V _{oc})	Current (I _{sc})	Length (ft)	Width (in.)	Weight (lbs/ft ²)	Area (ft ²)	Energy Per Day (Wh/ft ²)
ASR-60	60	16.5	3.6	23.8	4.5	9.5	16	2	12	20-30
ASR-64	64	16.5	3.9	23.8	4.8	9.5	16	2	12	20-30
ASR-120	120	33	3.6	47.6	4.5	18.3	16	2	23	20-30
ASR-128	128	33	3.9	47.6	4.8	18.3	16	2	23	20-30

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8 8 8 - U N | - S 0 L A R



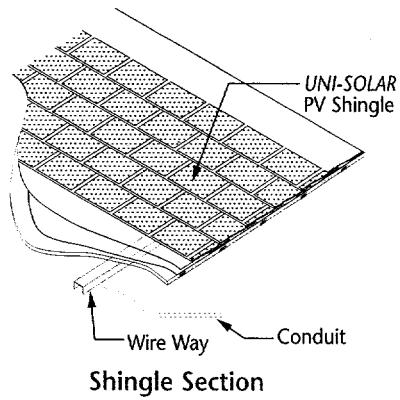
A 2.0 kilowatt DC grid-connected system operating at the Southface Energy & Environmental Resource Center in Atlanta, Georgia. The grid-connected system is configured at 48 volts DC using a 4,000 watt inverter.

UNI-SOLAR®

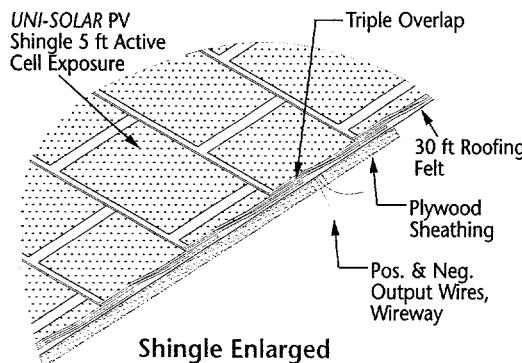
PV Shingles

Indistinguishable at a Distance from Traditional Shingles for Residential and Commercial Buildings

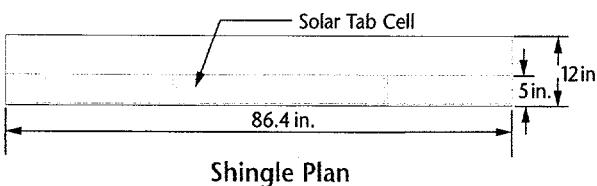
UNI-SOLAR shingles are unique and have been honored with the prestigious *Popular Science* Grand Award, "Best of What's New (Environmental Technology)," and *Discover* magazine's "Technological Innovation Award" for best innovation (Environment). The new PV shingle permits roofs of commercial and residential buildings to evolve from mere protection from the weather to a source of electric power. The flexible, thin-film solar cell shingle blends into a roofing pattern of traditional asphalt shingles.



Shingle Section



Shingle Enlarged



Shingle Plan

- **Appearance:** The surface is textured to blend and complement the granular surface of the surrounding conventional shingles.
- **Shingle Size:** 86.4 in. x 12 in.
- **Exposure:** 5 in. (12 – 7 in. Tabs per shingle).
- **Electrical connections:** Two 12 in-long, 18-gauge lead wires exiting from underside of each shingle.
- **Installation:** Nailed in place using common roofing nails on conventional roof decking over 30-lb felt underlayment.

Applied in consecutive overlapping layers.

Lead wires on back side of the head-lap pass through the roof deck to allow wiring connections to be made in the roof space.

- **Seal:** Sun warms the solar electric shingle providing a bond that forms a weather-resistant roof covering.

■ **Wind Load:** Independently tested up to 60 mph.

■ **Weight:** 140 lbs/sq.

■ **Array:** Size dependent on power demands. See table below.

■ **System:** Typical systems range from 1 kW to 4 kW.

Specification & Performance

Product	Rated Power (W)	Voltage (V _{op})	Current (I _{op})	Voltage (V _{oc})	Current (I _{sc})	Width (in.)	Height (in.)	Weight (lbs/ft ²)	Exposed Area (ft ²)	Energy Per Day (Wh/ft ²)
SHR-17	17	8.6	2.0	12	2.5	86.4	12	1.4	3	23-32
	8	8	8	-	11	11	11	11	11	11

SHORT FORM GUIDE SPECIFICATIONS

SECTION 13650

PHOTOVOLTAIC ROOFING SYSTEMS

PART 1 GENERAL

1.1 SCOPE

Select and edit one of the following two paragraphs:

A. Furnish [and install] solar electric [metal panel] [shingle] roofing array products, array mounting hardware, and array wiring components.

OR A. Furnish [and install] complete solar electric roofing system consisting of solar electric roofing array, combiner box, [inverter], [charge controller], [battery bank], [battery case], DC/AC disconnects, [data acquisition system], and wiring.
B. Array to cover [] square foot roof area with layout [] feet by [] feet. [Array] [System] to provide peak kilowatts of [] kWdc [] kWac at Standard Test Conditions.
C. Coordinate specification, procurement and installation of [array] [system] with manufacturer's authorized representative or system integrator.

1.2 WARRANTY

A. Solar electric roofing products. Manufacturer's standard 10-year warranty from date of sale to original purchaser to exhibit a power output of not less than 90% of Rated Power.

PART 2. PRODUCTS

2.1 MANUFACTURER

A. United Solar Systems Corp., Troy, Michigan.

2.2 MANUFACTURED UNITS

Select one of the following two paragraphs:

A. Photovoltaic (PV) standing seam metal panel, composed of flexible PV cells laminated together in weather-resistant polymers and bonded to a preformed metal roofing panel.

OR A. Photovoltaic (PV) shingle composed of flexible PV "tab cells" laminated in weather-resistant polymers in a shingle configuration providing 5-inch exposure.

B. Photovoltaic Cell: Thin-film, triple-junction, amorphous silicon alloy PV materials, manufactured by depositing multiple layers of a-Si material onto a flexible stainless steel substrate in a roll-to-roll production process.

C. Electrical Capacity

1. Rated Power (Wp): [60] [64] [120] [128]
1.4 watts
2. Operating Voltage (Vop): [16.5] [13.1]
13.6 volts
3. Operating Current (Iop): [1.6] [1.9]
1.9 amperes
4. Open Circuit Voltage (Voc): [24.8] [27.6]
27.6 volts
5. Short Circuit Current (Is): [4.5] [4.8]

Select one of the following three paragraphs:

D. Architectural Standing Seam Panel

1. 16-inch pan width by [9.5] [18.3] feet nominal [Customer specified length] [] (up to 24 feet)
2. Color: [None] [per metal panel]
Manufacturer's standard colors
3. Weight: 2 pounds per square foot, nominal
4. Acceptable Product: UNI-SOLAR ASR- [60]
[64] [120] [128] [with Customer specified metal panel] as manufactured by United Solar Systems Corp.

OR D. Structural Standing Seam Panel

1. 16-inch pan width by [9.5] [18.3] feet nominal [Customer specified length] [] (up to 24 feet)
2. Color: [None] [per metal panel]
Manufacturer's standard colors
3. Termination: [Junction box-bottom]
[Potted - top] [Potted - bottom]
4. Weight: 2 pounds per square foot.
5. Acceptable Product: UNI-SOLAR SSR- [60]
[64] [120] [128] [with Customer specified metal panel] as manufactured by United Solar Systems Corp.

D. Shingle

1. Dimensions: 86.4 inches long by 1.2 inches wide with 5 inch exposure.
2. Weight: 1.4 pounds per square foot.
3. Acceptable Product: UNI-SOLAR PV Shingle SHR-17 as manufactured by United Solar Systems Corp.

PART 3 EXECUTION

3.1 ROOFING ARRAY INSTALLATION

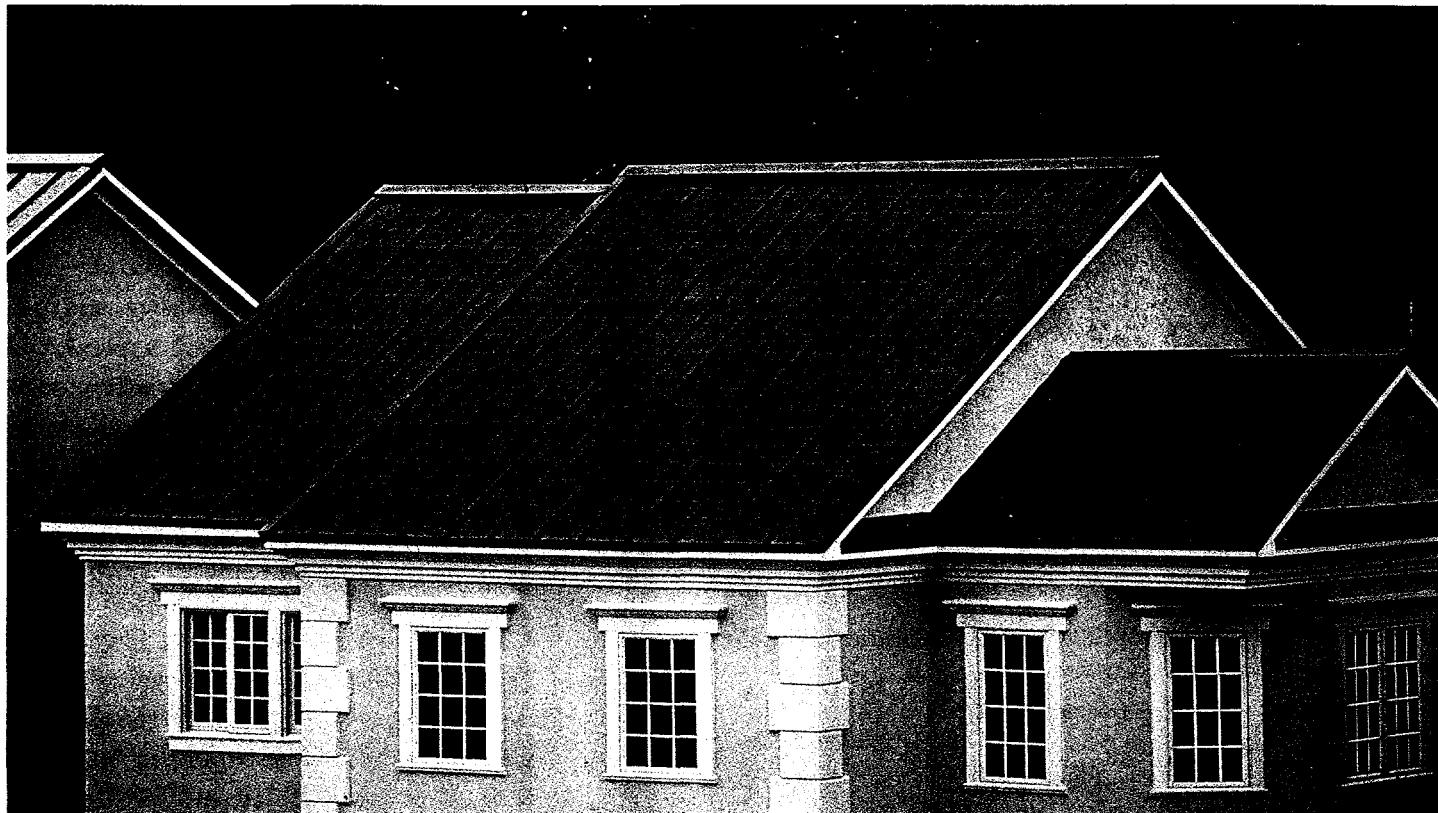
A. Install PV array and balance of electrical components in strict accordance with local and national electrical codes (NEC), and manufacturer's installation instructions and recommendations.

UNI-SOLAR® Roofing

Application Notes

Commercial Roofing
Residential Roofing

Covered Parking
Remote Power



Solar Electric Metal Roofing

SITE LOCATION: National Association of Home Builders
National Research Home Park
21st Century Townhouses
Bowie, MD

OWNER: NAHB Research Center

DATE ON LINE: April, 1996

CAPACITY: 1.5 kilowatts DC

DESIGN: Grid-connected system configured at 48 volts DC using a 4,000 watt inverter. A 16 kilowatt hour battery back-up is included.

APPLICATION: The system provides power to the townhouses in the Home Park, which feature alternative construction and advanced energy efficient materials and systems.

United Solar's architectural standing seam photovoltaic roofing provides an exciting way for architects and building owners to differentiate their properties using an innovative new renewable energy technology. This energy efficient townhouse in Bowie, Maryland demonstrates the new roofing material, highlighting the appealing aesthetics of the product.

The roofing system uses an architectural standing seam metal roof designed by ATAS International. The flexible solar cells are laminated directly onto 19-foot metal roofing panels. The solar panels closely match the look of the standard metal roofing panels, preserving a consistent, attractive appearance.

Remote Power for Parks & Recreation



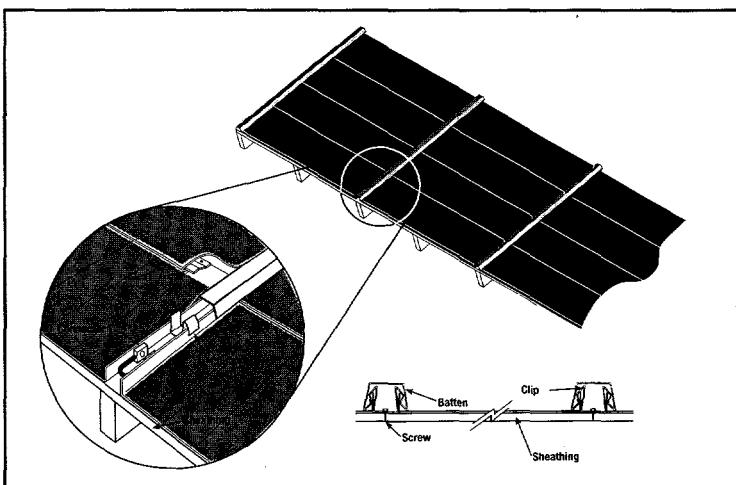
SITE LOCATION:	South Cardiff Beach State Park Cardiff-by-the-Sea, California
OWNER:	San Diego Gas & Electric (Enova Corp.)
DATE ON LINE:	December, 1995
CAPACITY:	2.4 kilowatts DC
DESIGN:	Stand-alone system configured at 24 volts, 4000 watt sine wave inverter, integrated power center, 1,600 amp hours of battery storage.
APPLICATION:	The system provides power to 2 rest room facilities, a contact station and parking lot area lights. Located in an undeveloped urban area, the <i>UNI-SOLAR</i> roofing system was more cost-effective than a line extension to bring utility power into the site.

United Solar's photovoltaic roofing systems are now making solar electricity a viable option for remote buildings at parks around the nation. In the past, the threat of vandalism and theft often precluded the use of conventional glass solar panels, considered too vulnerable to thieves and vandals throwing rocks.

UNI-SOLAR roofing contains no glass. It replaces conventional roofing, effectively disappearing as a photovoltaic array. Three designs suitable for remote park facilities are in development: architectural standing seam, shingles and horizontal batten and seam.

In a recent project, officials at South Cardiff Beach State Park in Cardiff-by-the-Sea, California were faced with a \$130,000 line extension to bring electricity to 2 rest rooms, a contact station and a parking lot. Conventional solar panels were ruled out as an alternative because of the threat of vandalism. Instead, a *UNI-SOLAR* batten & seam roof was installed on one of the comfort stations, along with a power control center, inverter and batteries. The power is used to operate lights in the rest rooms, contact station and area lights around the parking lot.

The *UNI-SOLAR* roofing system saved \$83,000 over the line extension. San Diego Gas & Electric specified and financed the project and retains ownership of the system. Eventually it will be sold to the California Parks & Recreation Department.



UNI-SOLAR®

United Solar will introduce in 1997 a solar electric shingle that can be laid out and nailed on, just like conventional shingles. This new roofing product will provide protection from the weather while simultaneously generating silent, pollution-free electricity.

Most homes use shingles. They are reliable, cost effective and attractive. Until now, people who wanted solar electric systems for their homes had to settle for bolting solar panels made from sheets of glass to their roof. The solar panels did the job, but they were unattractive and expensive. Working with a leading shingle manufacturer, *UNI-SOLAR* shingles are designed to look like conventional shingles. They are attractive and result in a lower cost system.

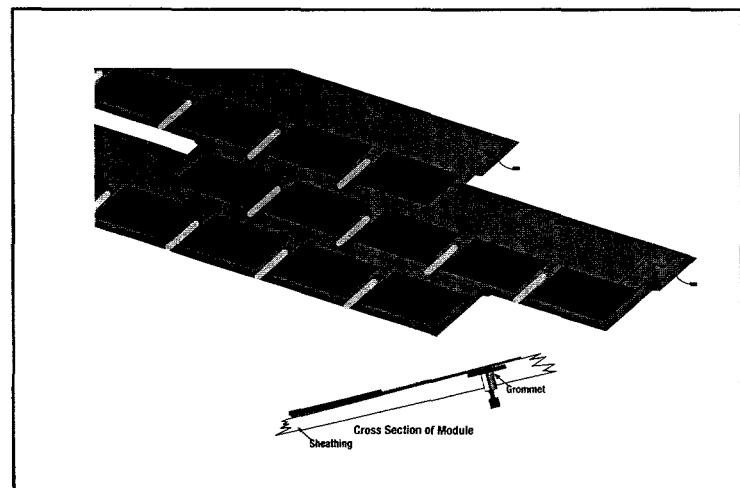
UNI-SOLAR shingles are ideal for remote site applications, where theft or vandalism are concerns. Since they look just like ordinary shingle roofs, they draw little attention. Only the owner knows that the home's power is coming from the sun.

The Southface Energy and Environmental Resource Center is a showcase for energy efficient technologies. A portion of the roof is covered in *UNI-SOLAR* shingles, which blend with the composition shingles. The system contributes to the overall power consumption of the house, reducing the electricity bill.



Popular Science

Residential Solar Electric Shingle Roofing System



SITE LOCATION:

Southface Energy & Environmental Resource Center
Atlanta, Georgia

OWNER:

Southface Energy Institute

DATE ON LINE:

July, 1996

CAPACITY:

2.0 kilowatts DC.

DESIGN:

Grid-connected system configured at 48 volts DC, using a 4,000 watt inverter.

APPLICATION:

The system provides power to the demonstration home and office for Southface Energy Institute. The project showcases energy and environmental products and building design. Educational, training and research programs will be conducted on-site.

UNI-SOLAR®

Solar Electric Covered Parking



SITE LOCATION: U.S. Army, Yuma Proving Ground
Yuma, Arizona

OWNER: U.S. Army

DATE ON LINE: July, 1996

CAPACITY: 10 kilowatts AC

DESIGN: Grid-connected system of *UNI-SOLAR* batten & seam roofing modules using two 6000 watt inverters.

APPLICATION: Solar electric covered parking providing power for electric vehicle charging and building electricity peak demand reduction.

United Solar's batten and seam roofing material is now providing shade to U.S. Army vehicles under the blazing sun of Yuma Proving Ground (YPG) in Arizona.

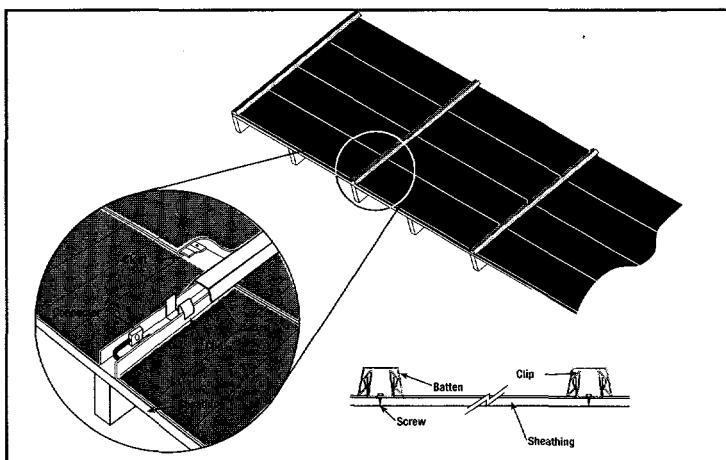
UNI-SOLAR roofing serves a dual function as covered parking, providing both shade and electricity. In this grid-connected system, the power from the roof is used to reduce the mid-day peak power consumption of the site.

Shaded parking has its own significant value, particularly under the harsh desert sun. The cost of shaded parking in Arizona is about \$5.00 per square foot, which effectively reduces the cost of the photovoltaic system.

Solar electric covered parking systems are of particular interest to the Army in meeting their need for off-grid, remote site power in hot climate locations.

Just over 600 modules, connected to the utility grid through a pair of inverters, generates about 10kW of power. The project was completed in support of a Cooperative Research & Development Agreement between YPG and Arizona Public Service.

The Yuma site demonstrates the durability of *UNI-SOLAR* roofing panels. Ambient air temperatures can soar to 120° F (49° C) in the summer, with array temperatures approaching 167° F (75° C).



UNI-SOLAR®

United Solar Systems Corp.

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