[redacted]

Technical Support Package

National Aeronautics and Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

A Survey Of Photovoltaic Systems

NASA Tech Briefs, Summer 1980
Vol. 5 No. 2, MFS-25397

TECHNOLOGY UTILIZATION OFFICE

MSFC - Cover 18 (March 1979)

Technical Support Package
For

A Survey Of Photovoltaic Systems

NASA Tech Briefs, Vol.5 , No.2

The information in this Technical Support Package comprises the documentation referenced in MFS-25397 of NASA Tech Briefs, Vol.5 , No. 2 . It is provided under the Technology Utilization Program of the National Aeronautics and Space Administration to make available the results of aerospace-related developments considered to have wider technological, scientific, or commercial applications.

Additional information regarding research and technology in this general area may be found in Scientific and Technical Aerospace Reports (STAR) which is a comprehensive abstracting and indexing journal covering worldwide report literature on the science and technology of space and aeronautics. STAR is available to the public on subscription from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO. DOE/NASA CR-150696	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
4. TITLE AND SUBTITLE A Survey of Photovoltaic Systems		5. REPORT DATE August 1979 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)		8. PERFORMING ORGANIZATION REPORT #
9. PERFORMING ORGANIZATION NAME AND ADDRESS The University of Alabama in Huntsville P. O. Box 1247 Huntsville, Alabama 35807		10. WORK UNIT NO. 11. CONTRACT OR GRANT NO. NAS8-31293
12. SPONSORING AGENCY NAME AND ADDRESS National Aeronautics and Space Administration Washington, D. C. 20546		13. TYPE OF REPORT & PERIOD COVERED Contractor Report 14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

This work was done under the technical monitorship of Mr. John Price, George C. Marshall Space Flight Center, Alabama.

16. ABSTRACT

In developing this survey of photovoltaic systems, the University of Alabama in Huntsville assembled a task team to perform an extensive telephone survey of all known photovoltaic manufacturers.

Three U. S. companies accounted for 77 per cent of the total domestic sales in 1978. They are Solarex Corporation, Solar Power Corporation, and ARCO Solar, Inc.

This survey of solar photovoltaic (P/V) manufacturers and suppliers consists of three parts: a catalog of suppliers arranged alphabetically, data sheets on specific products, and typical operating, installation, or maintenance instructions and procedures.

This report does not recommend or endorse any company product or information presented within as the results of this survey.

17. KEY WORDS	18. DISTRIBUTION STATEMENT UC-59c Unclassified-Unlimited WILLIAM A. BROOKSBANK, JR. Manager, Solar Energy Applications Projects

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	220	NTIS

MSFC - Form 3292 (Rev. December 1972)

For sale by National Technical Information Service, Springfield, Virginia 22151

TABLE OF CONTENTS

INTRODUCTION

Photovoltaics -- turning sunlight into electricity -- is a technology that saw its first practical application just over twenty years ago. Small photovoltaic cells were used to power one of the first U. S. satellites.

Since that time, photovoltaics have been intensively researched and tremendous amounts of time and money spent in attempting to make them attractive and practical for everyday use. As in other solar energies, cost has been the primary barrier; and it remains so.

However, in certain applications where electricity is unavailable or prohibitively expensive, photovoltaics (P/V) have become economical and practical. A number of firms have been attempting to develop and market home P/V systems, but not all have survived. Several U. S. manufacturers have recently discontinued their P/V marketing, while others have reverted to research and development.

The UAH task team performed an extensive telephone survey of all known photovoltaic manufacturers.

One firm reported that state regulations are limiting its marketing efforts. The California government wants the company to warrant its P/V products for 30 years. Lacking extensive test data and field experience, such a warranty would be impractical or impossible, the firm said.

Another company reported that there is little or no domestic market for the systems, but that there is quite an export demand. However, trade barriers are severely hampering exports. The export demand comes from countries where electricity costs are many times higher than in the U. S. and in applications where conventional electricity is unavailable, such as off-shore, or in underdeveloped countries.

Typical applications include off-shore navigational aids and petroleum platforms, television, telemetry and microwave transmitters and repeaters and irrigation pumps.

One manufacturer stated that he had sold several thousand units to recharge battery-operated television sets in week-end and summer cabins in Norway.

A number of large-scale, P/V demonstration projects are underway. One is in the Indian village of Schuchuli, AZ, where a 768-square-foot array provides 3.5-kW peak power, or 2,380 amp-hr of battery storage, to power the village water pump, home lighting and domestic appliances.

A remote village in Upper Volta, West Africa, has a 1.8-kW power supply which is used to drive a 1,200-gallon-per-hour water pump.

Recent studies indicate that the P/V market, and hence the industry, should stabilize within the next three or four years. The market has been estimated to be between $500 and $700 million by 1990. Total sales in 1977 were $8.1 million and rose to $12.3 million in 1978. Estimated sales for this year are $13.75 million.

Three U. S. companies accounted for 77 per cent of the total domestic sales in 1978. They are Solarex Corp., Solar Power Corp., and ARCO Solar, Inc.

This survey of solar P/V manufacturers and suppliers consists of three parts: a catalog of suppliers arranged alphabetically, data sheets on specific products, and typical operating, installation or maintenance instructions and procedures.

Pricing information was difficult to obtain because most manufacturers work on a quotation basis rather than fixed-prices for components. Practically all of the available hardware was in the form of modules of various sizes and performance. Complete systems are not readily available as most applications at this time are custom designed, due to climatic and load variations.

SELECTED BIBLIOGRAPHY

"Application and System Design Study For Cost-Effective Solar Photovoltaic Systems at Federal Installations, Final Report to the U. S. Congress," No. HCP/M2522-01. Washington, D.C.: U. S. Department of Energy, March 1979.

Buerger, E. J., et al., "Regional Conceptual Design and Analysis Studies for Residential Photovoltaic Systems, Executive Summary (Volume 1), Technical Volume (Volume 2)," No. SAND78-7039. Washington, D.C.: U. S. Department of Energy, January 1979.

Costello, D., et al., "Photovoltaic Venture Analysis, Final Report, Executive Summary," No. SERI/TR-52-040. Golden, CO: Solar Energy Research Institute, July 1978.

"Criteria for an Ideal Solar Photovoltaic Powered Industry," No. HCP/T5433-01. Washington, D.C.: U. S. Department of Energy, June 1979.

"Technology Assessment of Solar Energy: Decentralized Solar Photovoltaic Energy Systems," No. LA-7866-TASE. Los Alamos, NM: University of California Los Alamos Scientific Laboratory, June 1979.

"Export Potential for Photovoltaic Systems," No. DOE/CS-0078. Washington, D.C.: U. S. Department of Energy, April 1979.

"Photovoltaic Power Systems Market Identification and Analysis: Volume 1 (Executive Summary and Main Report), Volume 2," No. HCP/M2533-01/2. Washington, D.C.: U. S. Department of Energy, November 1978.

"Photovoltaic Power Systems Market Identification and Analysis," Final Report, No. HCP/T4022-01. Washington, D.C.: U. S. Department of Energy, May 1979.

"Policy Strategies for The International Marketing of U. S. Photovoltaics, Final Report (Volume 1), Final Report - Appendix (Volume 2)," Pasadena, CA: Jet Propulsion Laboratory, California Institute of Technology, August 1979.

Rattin, E. J., "Overview of Photovoltaic Market Studies," SAN-1101/PA8-10. Washington, D.C.: U. S. Department of Energy, May 1978.

"System Tests and Applications Photovoltaic Program," No. HCP/T4024-01/15. Washington, D.C.: U. S. Department of Energy, May 1979.

Turfler, R. M., et al., "Design Guidelines for Large Photovoltaic Arrays," No. SAND79-7001. Washington, D.C.: U. S. Department of Energy, January 1979.

SOLAR PHOTOVOLTAIC SUPPLIERS

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: ACUREX Corporation
Aerotherm Group

ADDRESS: 485 Clyde Avenue
Mountain View, CA 94042

PHONE: (415) 964-3200

CONTACT: Jorgen O. Vindum

PHOTOVOLTAIC PRODUCTS: Parabolic-trough concentrating collector for P/V.

DATA SHEETS: See Appendix A

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: AMB Flexhose

ADDRESS: 1257 24th Street
Oakland, CA

PHONE: (415) 836-4111

CONTACT: Rob Bostock

PHOTOVOLTAIC PRODUCTS:

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Ametek, Inc.
Applied Materials Div.

ADDRESS: 1 Spring Ave.
Hatfield, PA 19440

PHONE: (215) 257-6531

CONTACT: Dr. Frank Schmitt

PHOTOVOLTAIC PRODUCTS:

Solar P/V cells. NOTE: Discontinued production because of lack of market and high technology required for solar P/V applications.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: ARCO Solar, Inc.

ADDRESS: 20554 Plummer Street
Chatsworth, CA 91311

PHONE: (213) 998-0667

CONTACT: Ken Ude

PHOTOVOLTAIC PRODUCTS:

Power modules (3 series, Models 500, 1,000, 2,000).

DATA SHEETS: See Appendix B

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Automatic Power, Inc.

ADDRESS: 205 Hutcheson Street
Houston, TX 77203

PHONE: (713) 228-5208

CONTACT: Sid Sitkaroff

PHOTOVOLTAIC PRODUCTS:

Silicon cell panels

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: CSI Inc.
Solar Systems Div.

ADDRESS: 12400 49th Street
Clearwater, FL 33520

PHONE: (813) 577-4228/4489

CONTACT: Roy Sallin

PHOTOVOLTAIC PRODUCTS:

Solar P/V panels custom-built systems in sizes to provide 400W to 2000 kW-hr/mo. Primarily power generation for custom-designed commercial and industrial installations. P/V systems for providing electric power for pumps and controls of solar thermal heating and cooling systems.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Delavan Electronics, Inc.

ADDRESS: 14605 No. 73rd Street
Scottsdale, AZ 85260

PHONE: (602) 948-6350

CONTACT: John Frantz

PHOTOVOLTAIC PRODUCTS:

Solar tracker for P/V systems.

NOTE: Company is phasing out of solar products. Effort takes too much time and manpower. Many units in field, and sales were good on domestic market.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Energy Savings Systems

ADDRESS: Holmes Industrial Park
Holmes, PA 19043

PHONE: (215) 583-4780

CONTACT: Richard Corrill

PHOTOVOLTAIC PRODUCTS:

Solar P/V modules. Primary application is power supply for boats and yachts, but applicable for any remote site where power is required.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Ergenics, Inc.

ADDRESS: Lawkins Road
Waldwick, NJ 07463

PHONE: (201) 891-7911

CONTACT: Ed Snate

PHOTOVOLTAIC PRODUCTS:

Controls and storage systems for solar P/V power supplies.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: McGraw Edison Co.
Power System Div.

ADDRESS: 75 Belmont Ave.
P.O. Box 28
Bloomfield, NJ 07003

PHONE: (201) 751-3700

CONTACT: Bob Hammond

PHOTOVOLTAIC PRODUCTS:

P.V modules. NOTE: Manufacturing discontinued, but components in field.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Mobil Tyco Solar Energy Corp.

ADDRESS: 16 Hickory Drv.
Waltham, MA 02154

PHONE: (617) 890-0909

CONTACT: Ms. Linda Lucier

PHOTOVOLTAIC PRODUCTS:

Advanced solar P/V panel. Company hopes to be on commercial market in 1980.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Motorola, Inc.
Semi conductor Group

ADDRESS: 5005 East McDowell Rd.
Phoenix, AZ 85008

PHONE: (602) 244-6900 Ext. 5459

CONTACT: Marilyn Haas

PHOTOVOLTAIC PRODUCTS:

Systems, high density solar modules, 36- and 48-cell solar modules, voltage regulators, support structures.

DATA SHEETS: See Appendix C

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: National Semi conductors Ltd.

ADDRESS: 331 Cornelia Street
Plattsburgh, NY 12901

PHONE: (518) 561-3160

CONTACT: Duncan Clifton

PHOTOVOLTAIC PRODUCTS: Solar P/V modules

DATA SHEETS: See Appendix D

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Optical Coating Laboratories, Inc.

ADDRESS: 15251 E. Don Julian Rd.
City of Industry, CA 91746

PHONE: (213) 882-4100

CONTACT: George Holmes

PHOTOVOLTAIC PRODUCTS:

Silicon cells and panels

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solectro-Thermo Inc.

ADDRESS: 1934 Lakeview Ave.
Dracut, MA 01826

PHONE: (617) 957-0028

CONTACT: Arthur J. Manelas

PHOTOVOLTAIC PRODUCTS:

Hybrid electric/thermal solar system. Modules 4 ft. X 4 ft. each containing 33 P/V cells in concentrating reflectors. Modules are also solar thermal (air) collectors for space heating and DWH.

DATA SHEETS: See Appendix E

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Sensor Technology, Inc.

ADDRESS: 21012 Lassen Street
Chatsworth, CA 91311

PHONE: (213) 882-4100

CONTACT: Sanjeez Chitre

PHOTOVOLTAIC PRODUCTS:

Solar P/V Panel

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: SES, Inc.

ADDRESS: 3 Relee, Industrial Park
Newark, DE 19711

PHONE: (302) 731-0990

CONTACT: Greg Love

PHOTOVOLTAIC PRODUCTS:

Solar P/V modules, 8 $in.^2$, 24 cells, output 6V, 1W. Custom designed power generating systems primarily for industrial applications.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Silicon Sensors, Inc.
Solar Systems, Inc., Div.

ADDRESS: Highway 18 East
Dodgeville, WI 53533

PHONE: (608) 935-2707

CONTACT: Pallas Dieter

PHOTOVOLTAIC PRODUCTS:

Silicon solar cells, solar power modules

DATA SHEETS: See Appendix F

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solar Energy Products

ADDRESS: 1208 NW 8th Avenue
Gainesville, FL 32601

PHONE: (904) 377-6527

CONTACT: Ward Wilson

PHOTOVOLTAIC PRODUCTS:

Silicon cell panels

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solarex Corporation

ADDRESS: 1335 Picard Drive
Rockville, MD 20850

PHONE: (301) 948-0202

CONTACT: Dr. Peter Baradi

PHOTOVOLTAIC PRODUCTS:

Solar P/V panels and systems

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solargenics, Incorporated

ADDRESS:
Chatsworth, CA

PHONE: (213) 998-0806

CONTACT: David Collins

PHOTOVOLTAIC PRODUCTS:

Mod. 79-6.5 Solar P/V Panel. Each is 36 in. x 78 in. x 4 in. and produces 16.5 V, 9 amps.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solar Power Corporation

ADDRESS: 20 Cabot Road
Woburn, MA 01801

PHONE: (617) 935-4600

CONTACT: Bill Schlosser

PHOTOVOLTAIC PRODUCTS:

Solar P/V systems for microwave power, transmission, water pumping, communications, navigational aids, cathodic protection, power generators, solar P/V voltage regulators

DATA SHEETS: See Appendix G

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solar Systems, Inc.

ADDRESS: 1011 S. Delthia
Park Ridge, IL

PHONE: (312) 823-3819

CONTACT:

PHOTOVOLTAIC PRODUCTS:

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solec International, Inc.

ADDRESS: 12533 Chadron Avenue
Hawthorne, CA 90250

PHONE: (213) 970-0065

CONTACT: Robert W. Craford

PHOTOVOLTAIC PRODUCTS:

Solar P/V panels

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Solenergy Corporation

ADDRESS: 23 North Avenue
Wakefield, MA 01860

PHONE: (617) 246-1855

CONTACT:

PHOTOVOLTAIC PRODUCTS:

Variety of solar P/V modules, about half for commercial export market.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Sollos, Inc.

ADDRESS: 2231 S. Camelina
Los Angeles, CA 90024

PHONE: (213) 820-5181

CONTACT: Dr. Milo Macha

PHOTOVOLTAIC PRODUCTS:

Solar P/V modules, 6 V and 12 V, mainly for export market

DATA SHEETS: See Appendix H

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Spectrolab, Inc.

ADDRESS: 12500 Gladstone Avenue
Sylmar, CA 91342

PHONE: (213) 365-4611

CONTACT: James Albeck

PHOTOVOLTAIC PRODUCTS:

10 Kw P/V concentrating solar system consisting of 8.6 ft. x 4.25 in. modules, each with 32 V, 250 W output. NOTE: No longer manufacturing components, but systems are in the field.

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Sun Trace Corporation

ADDRESS: 1674 S. Wolf Road
Wheeling, IL 60090

PHONE: (312) 299-1080

CONTACT: Jim Frommeyer

PHOTOVOLTAIC PRODUCTS:

Silicon cells and panels

DATA SHEETS: See Appendix

SOLAR PHOTOVOLTAIC SUPPLIERS

COMPANY: Tideland Signal

ADDRESS: Box 52430-TR
Houston, TX

PHONE: (713) 681-6101

CONTACT: Carl Kotila

PHOTOVOLTAIC PRODUCTS:

Solar P/V power stations for remote, off-shore navigational stations for 12 V and 6 V operation. Solar P/V generators in 2V - 24V range for variety of applications, e.g., communications, automated controls, navigation aids, cathodic protection. MG-600 solar P/V module for various applications.

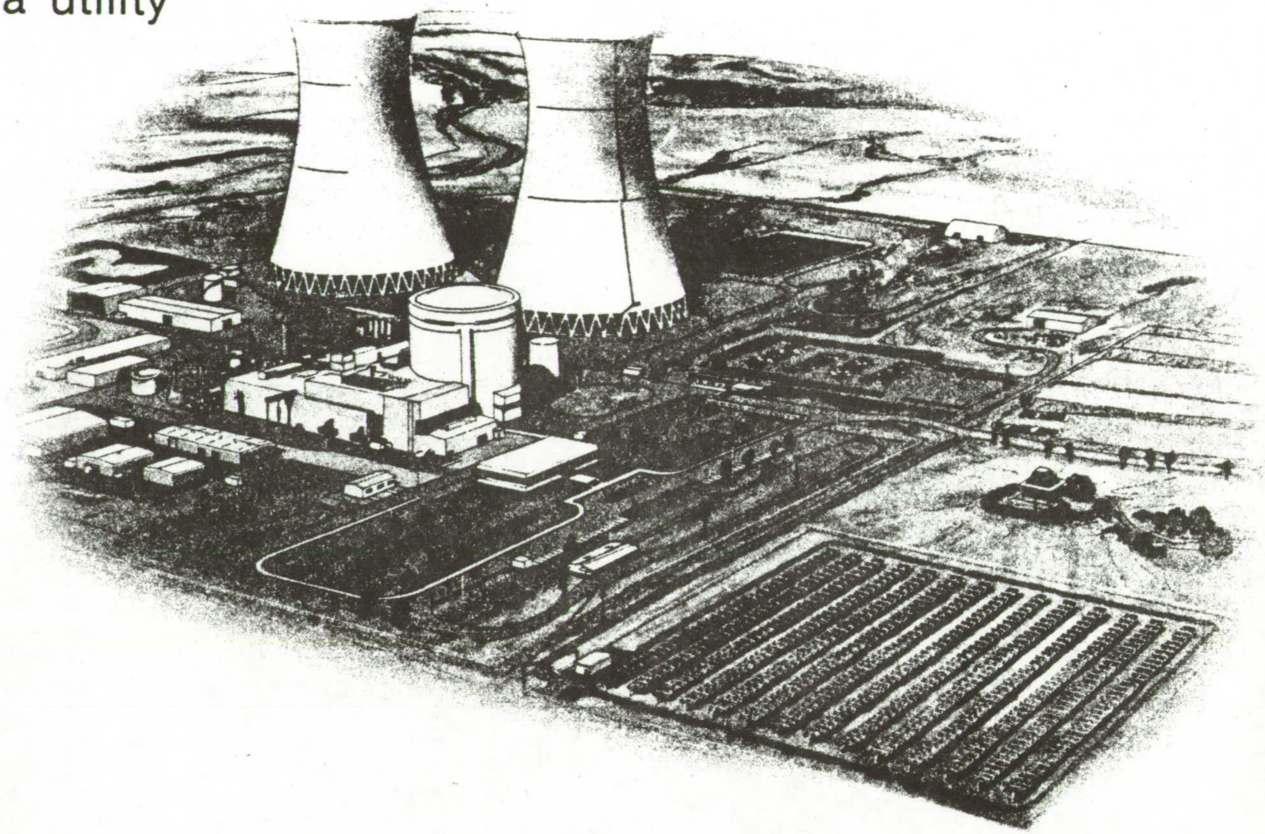
DATA SHEETS: See Appendix I

APPENDICES

ACUREX

Solar Photovoltaic Power System

Solar energy for a utility



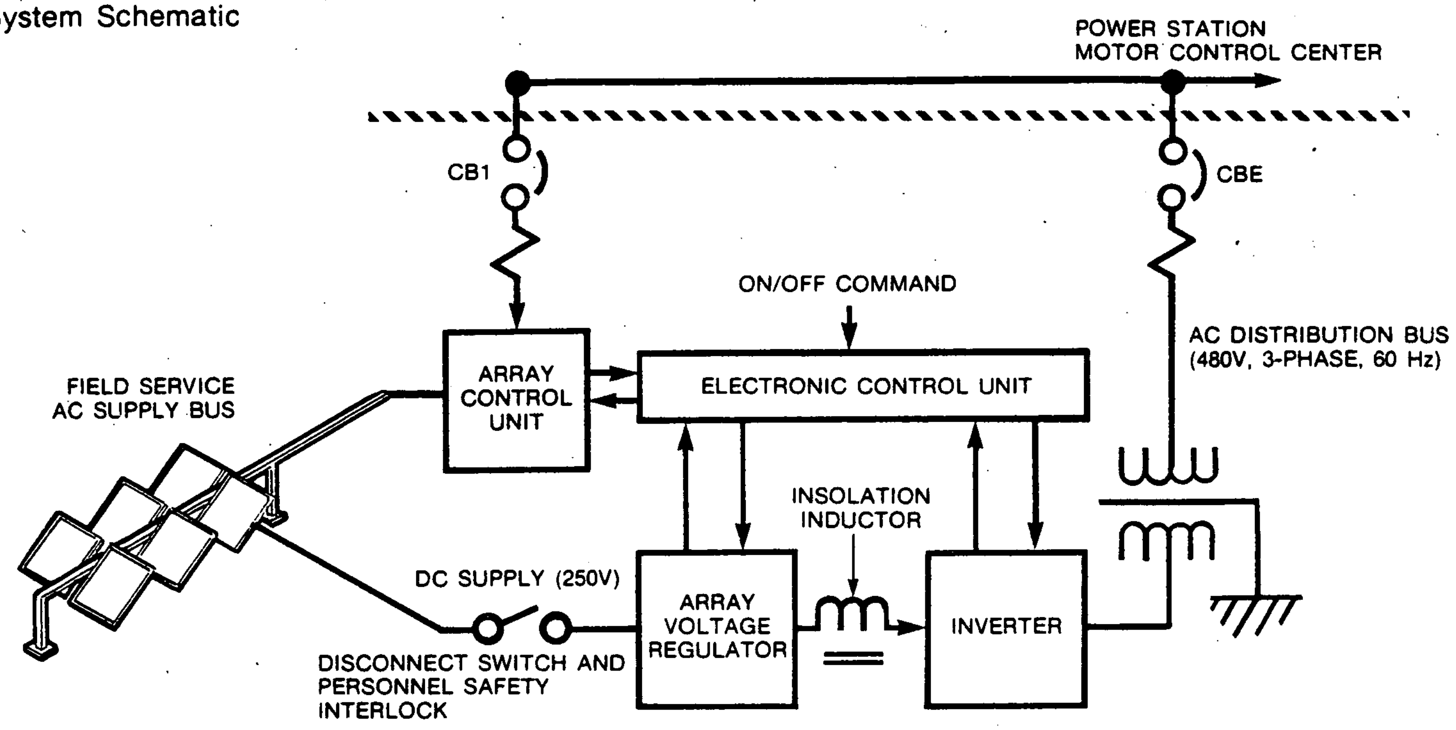
Consumption of electricity in the United States has been increasing about 7 percent each year — almost twice as fast as overall energy use. Conventional power plants are becoming increasingly expensive to build and operate as the price of fuels and environmental controls increases. Solar photovoltaic power systems can provide an alternative to help meet our growing demand for electricity. By producing electricity directly from sunlight, photovoltaic systems offer the potential for efficient, environmentally safe production of electric power.

To help make solar photovoltaic systems a commercial reality, Acurex Corporation has teamed with the Sacramento Municipal Utility District in central California to demonstrate a flat-plate photovoltaic power system. Designed by Acurex under contract to the Department of Energy, the system will deliver approximately 200,000 kWh annually.

The Acurex system uses photovoltaic modules mounted in single-axis tracking arrays. Clock-driven controls turn the arrays to follow the sun throughout the day, ensuring that the modules operate at peak efficiency. Compared to fixed arrays, tracking arrays produce from 12 to 22 percent more electricity per year. Electricity generated by the modules is converted from dc to 480V ac by a power conditioning unit.

To demonstrate economical construction and maintenance, the Acurex system takes advantage of low-cost materials, standard parts, common manufacturing technology, and simple assembly techniques. Systems such as this one will help pave the way for solar production of electrical power at locations throughout the country.

System Schematic



System Description

A field of 26 flat-plate tracking arrays are oriented north-south. Each array holds 144 flat-plate photovoltaic cell modules, attached to a torque tube at a fixed angle of 20° from horizontal. The photovoltaic cells, supplied by Motorola, are fully developed, state-of-the-art technology with proven reliability and low cost per watt.

A clock-drive automatically rotates the torque tube and the arrays at 15° per hour during the day. Automatic controls included in the power conditioning system, start up and shut down the entire system, and will hold in standby if there is insufficient solar energy to generate electricity. The entire system or individual arrays also can be operated manually, if desired. Power from the arrays is fed into a power conditioning system to supply 480V ac (3-phase, 60 Hz) to the utility bus.

Specifications

Estimated yearly energy production: 200,000 kWh
Peak output: 90.85 kWe at 1 kW/m^2 insolation
Overall system efficiency: ~10%

Acurex Photovoltaic Programs

Acurex Corporation designs and constructs a full range of solar photovoltaic collectors and collector systems for commercial and industrial applications. Acurex photovoltaic collectors range from flat-plate tracking arrays to mass-producible concentrators, offering efficient alternatives to conventional power sources.

For more information, call the Alternate Energy Division at (415) 964-3200, extension 3354.

ACUREX Corporation
Alternate Energy Division
485 Clyde Ave., Mt. View, CA 94042
(415) 964-3200 Telex: 34-6391

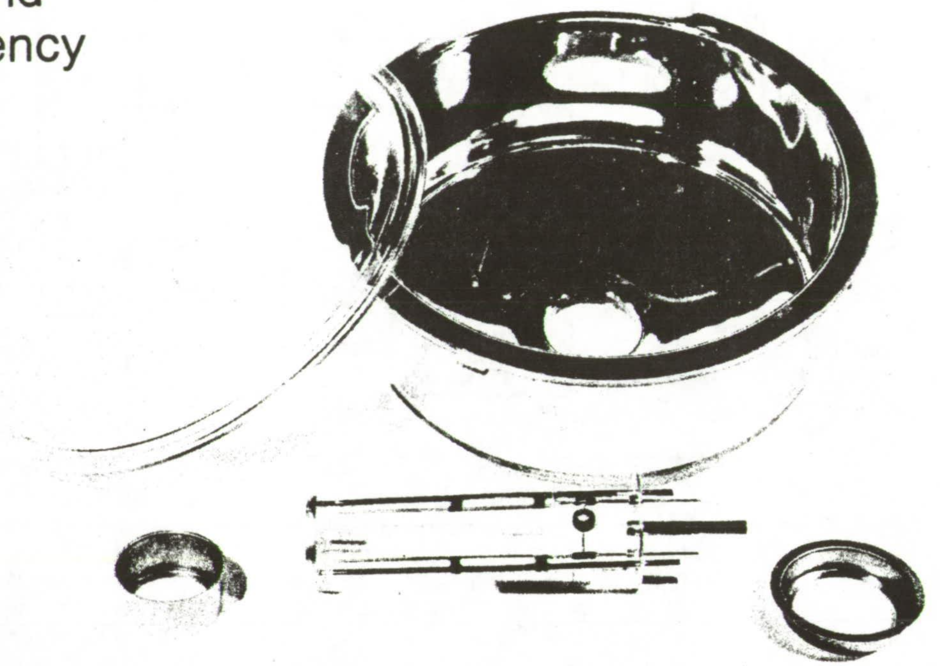
Acurex Corporation, Europe
Esplanade 6
2000 Hamburg 36
West Germany
Phone (4940) 354800, 345093
Telex: 841214448

Acurex Far East, Inc.
Kyodo Building, Suite 47
2-2, 4-Chome, Hatchobori
Chuo-ku, Tokyo 104, Japan
Phone: 03-552-2017
Telex: 78128719

AED-7 1.5K Printed in U.S.A. 5/79

Solar Photovoltaic Concentrator

Sealed-beam headlight technology achieves low cost and high efficiency



Photovoltaic cells that convert the sun's rays directly to electricity are one of today's most promising new energy technologies. Photovoltaic systems are clean, silent, and dependable — and the energy source they tap is virtually unexhaustible. But until now, widespread commercial development of photovoltaic technology has been seriously hindered by the high cost of photovoltaic cells.

Acurex Corporation is working to lower the cost of photovoltaic systems with concentrating collectors that increase the amount of sunlight falling on each photovoltaic cell. Under contract to the U.S. Department of Energy, Acurex has developed a new low-cost, high-efficiency photovoltaic concentrator that uses the proven technology of sealed-beam automobile headlights. This new concentrator is capable of focusing the sunlight falling on each photovoltaic cell at very high concentrator ratios — from 100 to 1000 suns. Concentrating the sun's radiation means that fewer photovoltaic cells are required, and results in significantly higher cell efficiency.

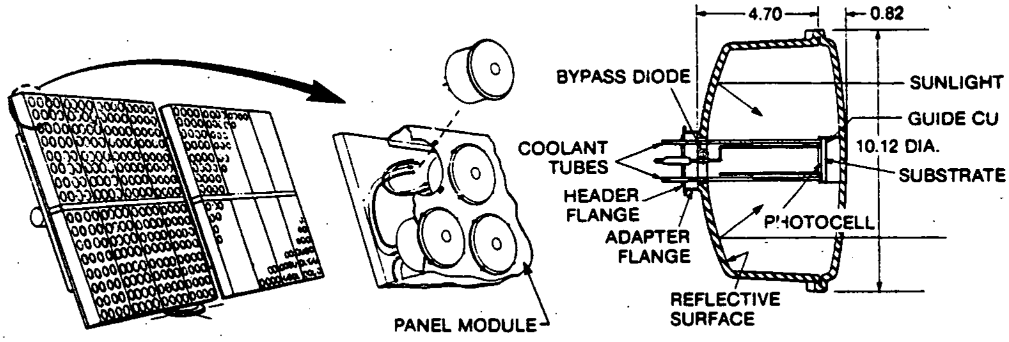
Like sealed-beam automobile headlights, Acurex photovoltaic concentrators are extremely durable. Because the concentrator's reflector and solar cell assembly are hermetically sealed in glass, they can withstand extreme temperatures, humidity, winds, dust, hail, and other atmospheric conditions. In addition, since manufacturing procedures for sealed-beam headlights are already well established, the concentrators can be mass-produced at low unit cost.

Acurex photovoltaic concentrators will be mounted in arrays that move to track the sun's motion during the day. Each one of the concentrators in these arrays can be individually replaced, making maintenance easy. An active cooling system is built into the arrays to maintain the concentrators at an efficient working temperature. The thermal energy recovered by this cooling system can also be put to use — making this photovoltaic system ideal for hospitals, schools, offices, and groups of homes, where both electricity and hot fluids are needed.

Acurex photovoltaic concentrators are an important step towards making solar photovoltaic technology a commercial reality in the near future.

Solar Photovoltaic Concentrator

Tracking Array Structure and Concentrator



Description

The Acurex concentrator is made up of solar cells and a reflector in a durable, molded glass unit that provides protection from the weather. Mounted in two-axis tracking arrays for maximum efficiency, the concentrators provide both electricity and recoverable thermal energy.

512 concentrators are mounted in arrays on a two-axis tracking structure. Fabricated of mild steel, the array structure is configured in a torque tube and rib arrangement and fitted on a pedestal mount. Two stepper motors turn the array structure to follow the sun throughout the day.

Concentrator Performance

	Silicon Photovoltaic Cell	Gallium-Arsenide Photovoltaic Cell
Transmission	0.925	0.925
Reflectance	0.96	0.96
Intercept	0.88	0.88
Cell efficiency	0.12	0.34
Overall Concentrator Efficiency	0.0937	0.266
Aperture area	50.62 in.^{2}	50.62 in.^{2}
Power Output	3.2 watts	9.06 watts

Future Development

Prototype concentrator units, assembled with hand-pressed glass modules are now being tested. Acurex is working closely with glass manufacturers to refine the basic design and to develop plans for mass production. The next step will be to produce the collectors using automated equipment. Other plans include refining the shape of the concentrator for more efficient operation and adapting the concentrator for use of gallium arsenide cells.

For more information, call the Alternate Energy Division at (415) 964-3200, ext. 3354.

ACUREX Corporation
Alternate Energy Division
485 Clyde Ave., Mt. View, CA 94042
(415) 964-3200 Telex: 34-6391

Acurex Corporation, Europe
Esplanade 6
2000 Hamburg 36
West Germany
Phone (4940) 354800, 345093
Telex: 841214448

Acurex Far East, Inc.
Kyodo Building, Suite 47
2-2, 4-Chome, Hatchobori
Chuo-ku, Tokyo 104, Japan
Phone: 03-552-2017
Telex: 78128719

AED-8 15K Printed in U.S.A 5/79

This page has been removed because of copyright information. For information on the 500 Series, ARCO Power Modules Specifications contact ARCO Solar, Inc. 20554 Plummer Street, Chatsworth, CA 91311.

This page has been removed because of copyright information. For information on the 1000 Series, ARCO Power Modules Specifications contact ARCO Solar, Inc. 20554 Plummer Street, Chatsworth, CA 91311.

This page has been removed because of copyright information. For information on the 2000 Series, ARCO Power Modules Specifications contact ARCO Solar, Inc. 20554 Plummer Street, Chatsworth, CA 91311.

ARCO Solar, Inc.

A Subsidiary of AtlanticRichfieldCompany
20554 Plummer Street
Chatsworth, CA 91311
(213) 998-0667 • Telex 181 211

Solar Power Requirements

Please complete this post-paid form, fold and mail to obtain system design, price and/or additional information.

1. Application: ______________________________

____

____

2. Geographic Location: ______________________________

Latitude & Longitude: ______________________________

3. Storage Battery Temperature: Min. ______________ **Max.** ______________

4. Equipment/Battery Voltage: Nominal ______________ **Min.** ______________ **Max.** ______________

5. Power Requirements:

Operating Mode	Amperes	x Minutes/Hr	x Hours/Day	x Days/Week / 7	= Amp. Hours/Day
		÷ 60			
		÷ 60			
		÷ 60			
		÷ 60			

Amp. Hrs./Day ______________

÷ 24

Average Continuous Load ______________

6. Number of Systems Required: ______________________________

Expected purchase date:

☐ Immediate ☐ 1-3 months ☐ 3-6 months

☐ 6-12 months ☐ Longer ☐ Information only

7. Do you wish to be on our mailing list? ☐ **Yes** ☐ **No**

8. Have you used solar power before? ☐ **Yes** ☐ **No**

If "yes", brand name ______________________________

9. What additional information may we supply? ______________________________

____

____

____

From:

Name ______________________________ Title ______________________________

Company ______________________________ Telephone: ( ) ______________________________

Address ______________________________ City ______________ State ______________ Zip ______________

Litho in U.S.A.

ARCO Solar 021 11-78 Rev. 1

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

BUSINESS REPLY MAIL

FIRST CLASS PERMIT NO. 272 CHATSWORTH, CA

POSTAGE WILL BE PAID BY ADDRESSEE

ARCO Solar, Inc.

20554 Plummer St.
Chatsworth, CA 91311

SOLAR SYSTEMS

MSP SERIES SOLAR MODULES

General Information

PHOTOVOLTAIC PRODUCTS

36 AND 48 CELL SOLAR MODULES

The 36 1/2 cell (8 peak watts, typical), 36 cell (18 peak watts, typical) and the 48 cell (24 peak watts, typical) solar modules offer a highly reliable and efficient power source. Each module has advanced technology 3" silicon solar cells which are connected in various series/parallel combinations to provide several output voltage and current options. Cells are redundantly interconnected to increase reliability and reduce resistance losses.

Modules are fabricated with a corrosion-resistant stainless-steel frame. Glass glazing provides for high transmittance of solar irradiation and reliable environmental protection. Cells are encapsulated in void-free silicone to increase protection from shock and vibration and sealed to exclude moisture and atmospheric contamination.

These modules are ideally suited for remote site applications such as isolated repeater stations, cathodic protection of underground pipelines and offshore equipment.

Other module sizes are available for various power requirements.

FEATURES

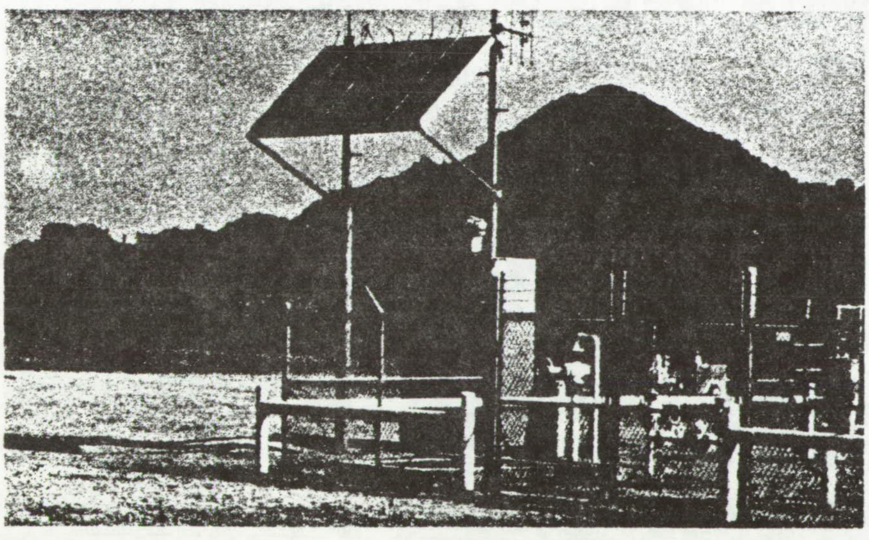
- 8, 18 and 24 Peak Watt Typical Output
- Silicon Cells
- High Efficiency Cells, 3 Inch Diameter
- Various Series/Parallel Cell Connection Options
- High Reliability, Redundant Interconnects
- Rugged, Maintenance-Free Construction, Stainless-Steel Case, Glass Glazing, Silicone Encapsulant

APPLICATIONS

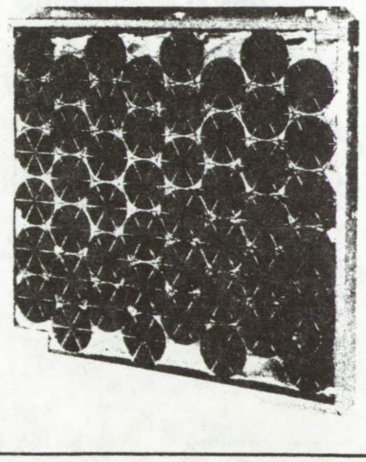
Microwave relay
Telephone repeater
Cathodic protection
Offshore equipment
Navigational aids
Portable equipment
Weather monitors
Airport equipment
Forestry equipment
Fire phones
Emergency phones
Boats
Cabins

APPLICATIONS SUPPORT

The Motorola staff of solar energy application engineers is available to assist in system definition, determination of module size requirements, battery selection, and regulator design.



48 CELL SOLAR MODULE



SELECTOR GUIDE

48 CELL MODULES

Part Number	*Configuration	Electrical Characteristics (Cell Temperature = 25°C, Solar Irradiation = 100 mW/cm²)					
		I_{SC}	I_M @ V_M		V_{OC}	P_M	
		Typ	Min		Typ	Min	Typ
MSP01A05	1P X 48S	1.1	0.98	21.10	25	20.7	21.7
A10		1.2	1.10	21.10	26	23.2	24.3
A30		1.3	1.20	21.10	27	25.3	26.5
B05	2P X 24S	2.2	1.96	10.55	12.5	20.7	21.7
B10		2.4	2.20	10.55	13.0	23.2	24.3
B30		2.6	2.40	10.55	13.5	25.3	26.5
D05	4P X 12S	4.4	3.92	5.28	6.25	20.7	21.7
D10		4.8	4.40	5.28	6.50	23.2	24.3
D30		5.2	4.80	5.28	6.75	25.3	26.5
E05	6P X 8S	6.6	5.88	3.52	4.10	20.7	21.7
E10		7.2	6.59	3.52	4.30	23.2	24.3
E30		7.8	7.19	3.52	4.50	25.3	26.5

36 CELL MODULES

Part Number	Configuration	Electrical Characteristics (Cell Temperature = 25°C, Solar Irradiation = 100 mW/cm²)					
		I_{SC}	I_M @ V_M		V_{OC}	P_M	
		Typ	Min		Typ	Min	Typ
MSP02A05	1P X 36S	1.10	0.98	15.84	18.75	15.5	16.3
A10		1.20	1.10	15.84	19.50	17.4	18.3
A30		1.30	1.20	15.84	20.00	19.0	20.0
MSP26A05	1/2P X 36S	0.50	0.44	15.84	18.75	7.0	7.3
A10		0.55	0.50	15.84	19.50	7.9	8.3
A30		0.60	0.55	15.84	20.00	8.7	9.1

*CONFIGURATION — Defines solar cell electrical interconnect configuration, i.e., the number of cells connected in parallel (P) and the number of cells in series (S). 1/2P indicates 1/2 of a 3" cell.

I_{SC} = Short Circuit Current, Adc
I_M = Current, Adc, measured at V_M
V_M = Voltage, Vdc, at approximate maximum power point
V_{OC} = Open Circuit Voltage, Vdc
P_M = Maximum Power, Watts

CASE OPERATING TEMPERATURE

$T_C = T_A + 25°C$ (w/o wind)
$T_C = T_A + 15°C$ (w/> 1 m/s wind)

OPERATIONAL CONDITIONS

Temperature (ambient): -40°C to +80°C
Wind: constant velocity — 160 Km/hr (100 MPH) maximum
gust velocity — 200 Km/hr (125 MPH) maximum

MECHANICAL SPECIFICATION

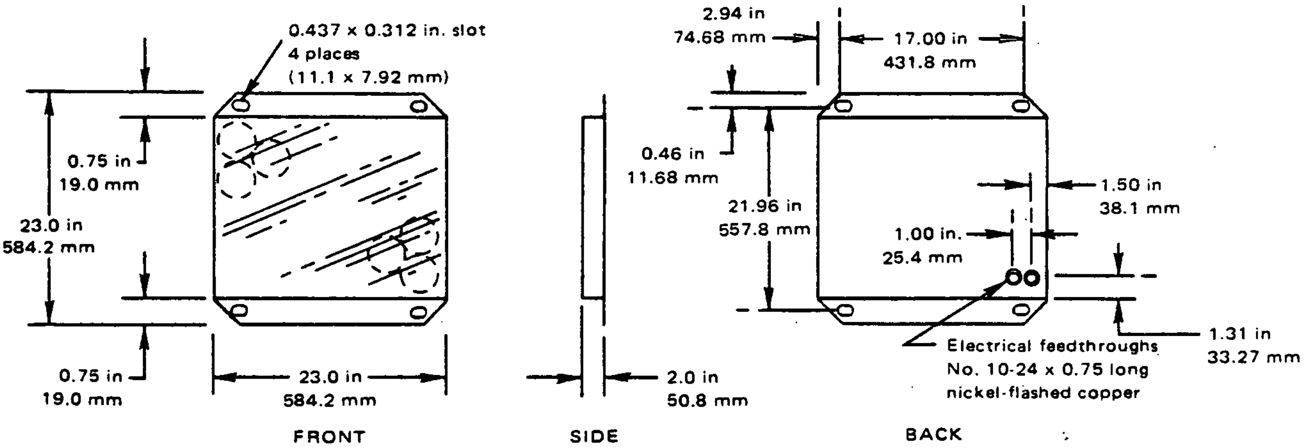
Shock: 0.4 m (15 inch) drop per MIL STD 810B, Method 516, Procedure V
Vibration: per MIL STD 810B, Method 514, Procedure X
Snow loading: 290 Kg/m² (60 lb/ft²) maximum

STORAGE CONDITIONS

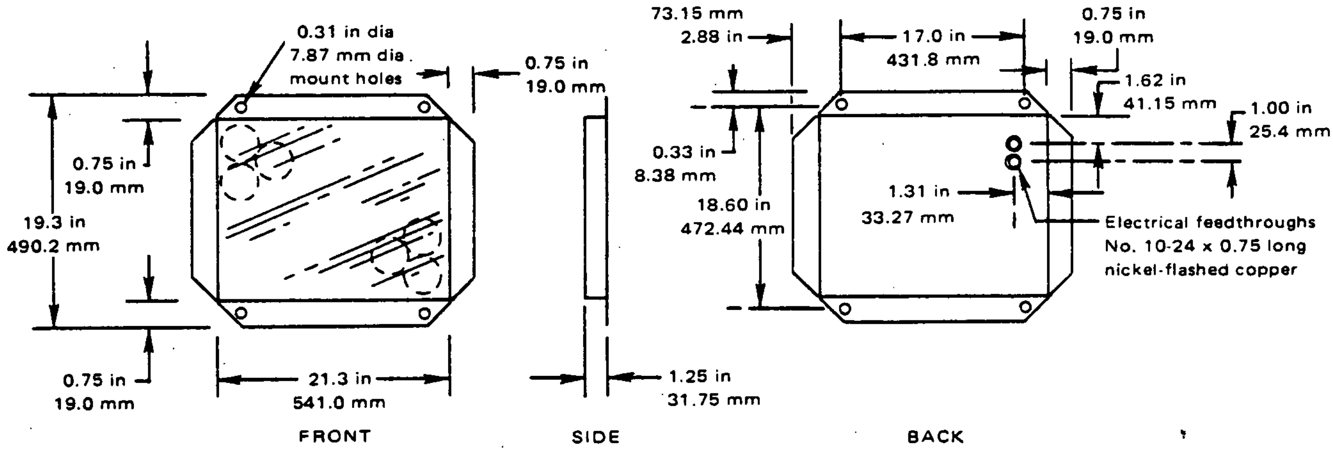
Temperature (ambient): -40°C to +80°C
Weight: 4.3 lb, 2.0 kg (36 1/2 cell module)
9.2 lb, 4.2 kg (36 cell module)
12.0 lb, 5.4 kg (48 cell module)
Electrical insulation to ground: 600 Vdc minimum

PHYSICAL DIMENSIONS

48 CELL MODULES



36 CELL MODULES



36 1/2 CELL MODULES

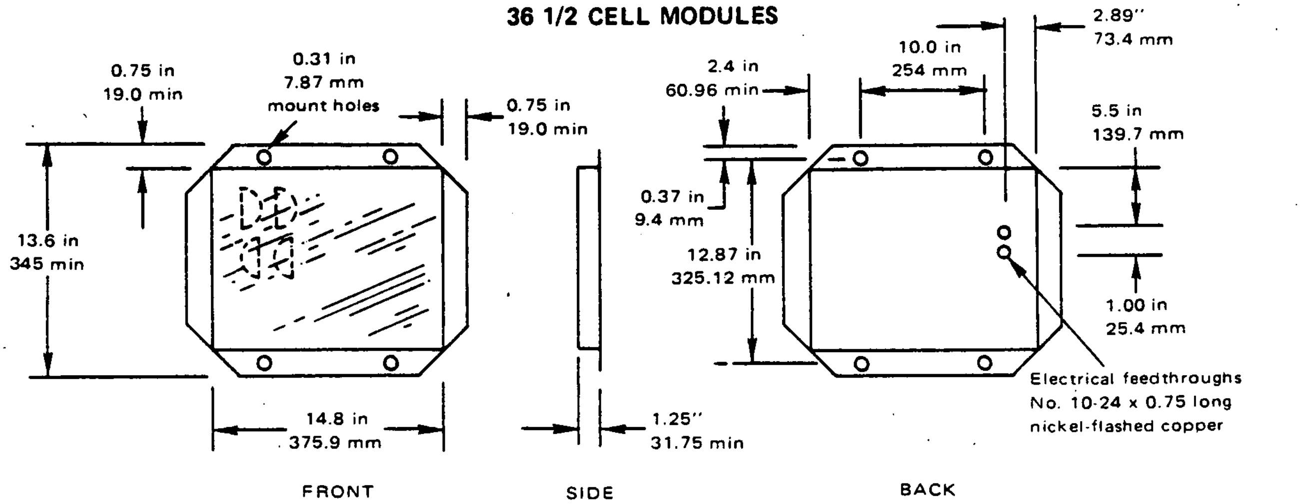


FIGURE 1 – TYPICAL SINGLE CELL CHARACTERISTICS
(Nominal 3" diameter cell, encapsulated, case temperature 25°C, cell temperature 31°C)

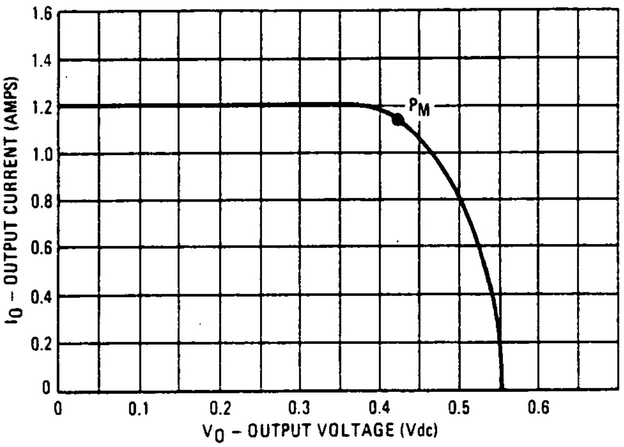


FIGURE 2 – TYPICAL PERFORMANCE CURVE

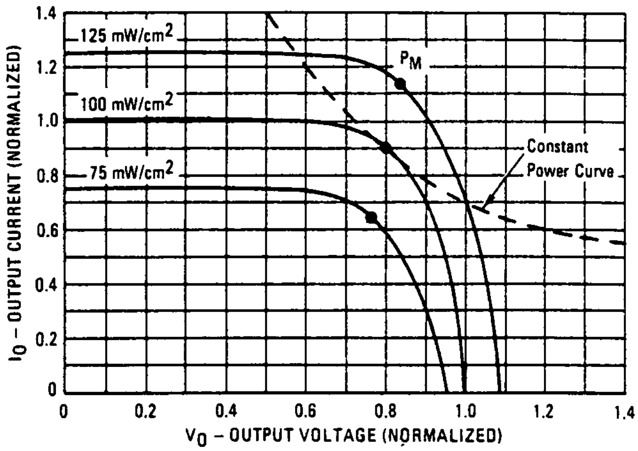


FIGURE 3 – NORMALIZED CURRENT/VOLTAGE CHARACTERISTIC AT SPECIFIED CASE TEMPERATURES

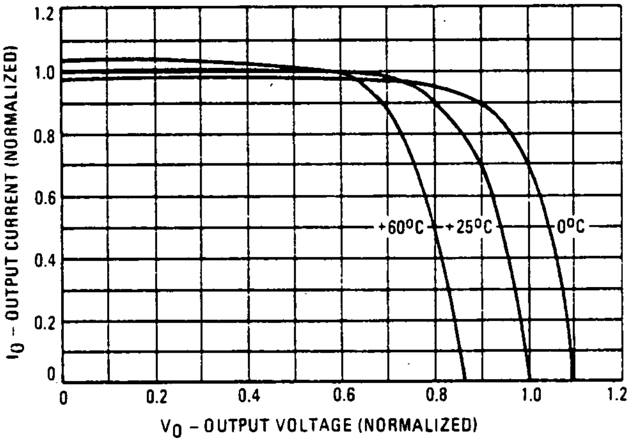
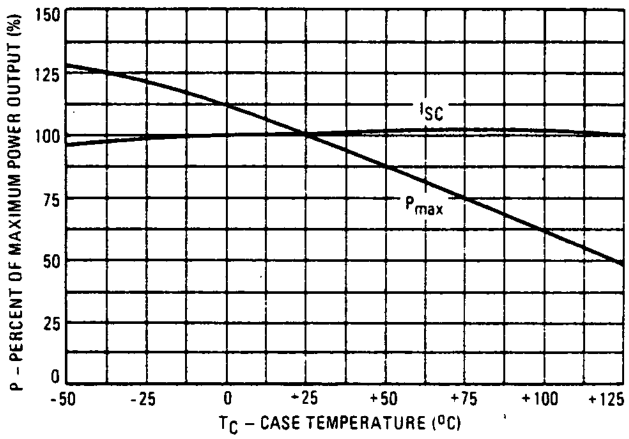
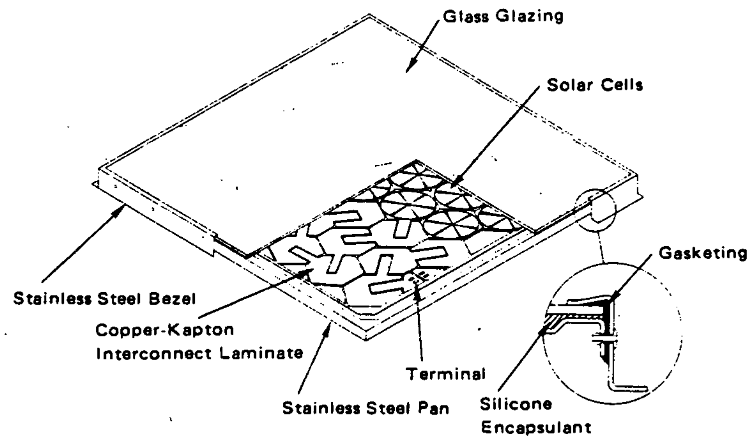


FIGURE 4 – TYPICAL POWER OUTPUT VARIATION WITH TEMPERATURE



NOTE: Case temperature is typically 20°C above ambient, for 100 mW/cm² irradiation, free convention cooling.

FIGURE 5 – MOTOROLA SOLAR PHOTOVOLTAIC MODULE SECTION SHOWING CONSTRUCTION DETAILS AND INTERNAL ARRANGEMENT OF CELL INTERCONNECTION



MOTOROLA *Semiconductor Products Inc.*

BOX 20912 • PHOENIX, ARIZONA 85036 • A SUBSIDIARY OF MOTOROLA INC.

MOTOROLA

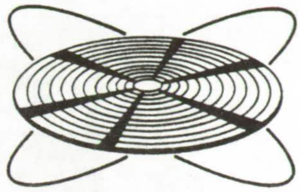
MSP 43A40

BOX 20912 • PHOENIX, ARIZONA 85036

The MSP43A40 utilizes advanced technology 100 mm X 100 mm (4" X 4") square cells to provide maximum power in minimum space. The 33 series cell module provides more 12 volt battery charging current per watt of module power than modules with a higher number of cells. Both analysis and tests have proven that the 33 cell configuration provides ample charging voltage in all climates. Balance-of-system costs are reduced by increased packing density. All materials and construction techniques have a proven history of reliability.

- High Packing Density (82% of total area) using 100 mm X 100 mm square cells
- High Reliability due to Redundant Interconnects
- Across-The-Cell Contacts Eliminate Potential Power Loss Due to Cracked Cells
- 33 Cells in Series
- 40 Watts Peak Power
- Maintenance Free Construction, Tempered Glass Superstrate, Stainless Steel Frame
- Low Cell Temperature, NOCT = 45C
- Metric Dimensions, 340 mm by 1200 mm
- Designed to Exceed JPL Block 4 Requirements
- Exceeds National Electrical Code

THIS DOCUMENT CONTAINS INFORMATION ON A NEW PRODUCT. MECHANICAL AND ELECTRICAL INFORMATION IS SUBJECT TO CHANGE WITHOUT NOTICE.



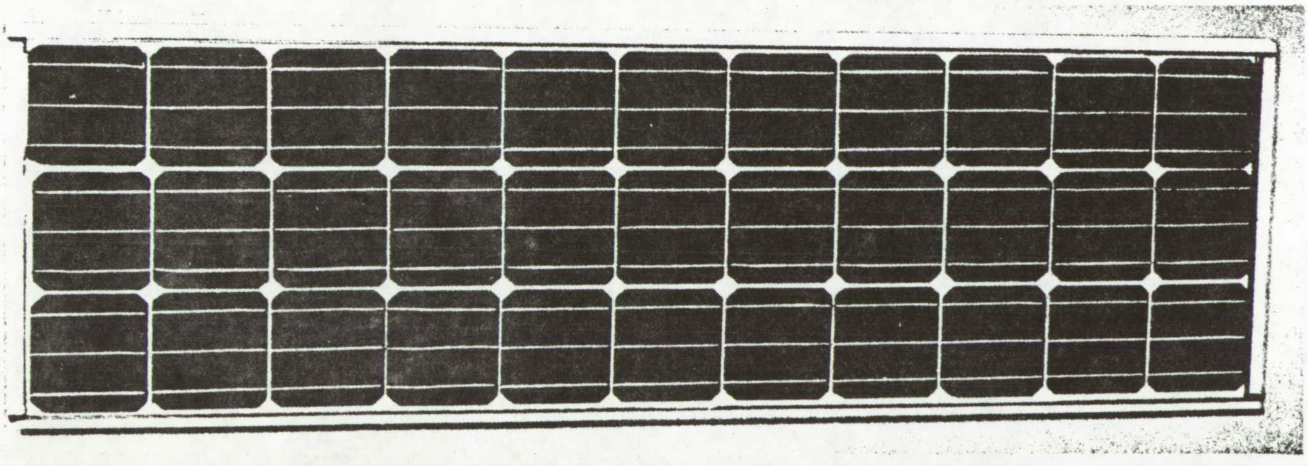
APPLICATIONS

Village Power
Remote Communications
Offshore Equipment
Cathodic Protection
Forestry Equipment
Boats
Instrumentation
Water Pumping
Microwave Relays
Navigational Aids
Portable Equipment
Emergency Phones
Cabins
Remote Refrigerators

SYSTEMS ENGINEERING

In addition to photovoltaic modules, we can supply other system components, including voltage regulators, steel support structures, batteries and related wiring.

Our staff of application engineers is available to assist you in system definition and system sizing.



4/26/79

CONDITIONS AIR MASS 1.5	I_{SC} TYP	I_M AT MIN	V_{NO}	V_{OC} TYP	P_M MIN	P_M TYP
T_C = 28C, 100 mW/cm^2	2.6	2.3	15.8	19.5	36.5	40.0
T_A = 20C, T_C = 50C, 100 mW/cm^2	2.6	2.3	14.3	17.9	33.3	36.6
T_A = 20C, T_C = 45C, 80 mW/cm^2	2.1	1.9	14.4	17.9	26.9	29.5
T_A = 40C, T_C = 65C, 80 mW/cm^2	2.1	1.9	13.0	16.4	24.6	27.1

I_{SC} = Short Circuit Current, Adc

I_M = Current, Adc, Measured at V_{NO}

V_{NO} = Nominal Operating Voltage, Vdc, is the Reference Voltage Level at which the Modules are Designed to Provide Maximum Power Output at Specified Operating Conditions.

V_{OC} = Open Circuit Voltage, Vdc

P_M = Maximum Power, Watts

T_A = Ambient Temperature, C

T_C = Cell Temperature, C

Temperature Coefficients:

TC V_{OC} = −0.0022 V/C/Cell (Series)

TC V_{NO} = −0.00213 V/C/Cell (Series)

TC I_{SC} = 0.00159 A/C/Cell (Parallel)

TC I_M = 0.00159 A/C/Cell (Parallel)

Voltage Changes: V_{OC} decrease 2% when irradiation decreases from 100 mW/cm^2 to 80 mW/cm^2

V_{NO} does not change appreciably with changes in irradiation level

Outside Dimensions (Nominal): 336 mm x 1200 mm (13.2 in. X 47.2 in. X 1.5 in.)
Weight (Nominal): 5.7 Kg (12.5 lb.)
Shock: 0.4 m (15 inch) drop per MIL-STD-810B, Method 516, Procedure V
Snow Loading: 290 Kg/m^2 (60 lb/ft^2) maximum
Vibration: per MIL STD 810B, Method 514, Procedure X

Cover Glass: 0.125 in. tempered Solatex® 91.6% transmittance
Encapsulant: Polyvinyl Butyral
Cells: 33 in Series, 100 mm X 100 mm Square Single-Crystal Silicon, Part No. MSPC2300S
Back: Aluminized Tedlar® (Polyvinyl Fluoride)
Edge Sealant: Butyl Rubber
Frame: Type 304 Stainless
Interconnect (Cell): Three Continuously Bonded Copper Ribbons Across Top and Bottom of Cells.
Connection (External): Junction Box with Binding Posts

1600 Vdc minimum

Temperature (Ambient): −40C to 60C

Nominal Operating Cell Temperature: 45C at T_A = 20C, 80 mW/cm^2, Wind at 1 m/s, Module Tilted

Wind: Constant Velocity, 160 Km/hr (100 mph) maximum
Gust Velocity, 200 Km/hr (125 mph) maximum

−40C to +60C

This page has been removed because of copyright information. For information on the MSPS 3 H4WG and MSPS2H2WP, Solar Array Support Structures, contact Motorola Inc., Box 20912, Phoenix, AZ 85036.

This page has been removed because of copyright information. For information on the MSPS3H4WG and MSPS2H2WP, Solar Array Support Structures, contact Motorola, Inc., Box 20912, Phoenix, Arizona 85036.

MOTOROLA SOLAR PRODUCTS

PRICE LIST

Effective 1/15/79

MSP Series Solar Modules

		MSP02A05	MSP02A10	MSP02A30	*MSP01X05	*MSP01X10	*MSP01X30
QUANTITY	**WATTS**	**16.3**	**18.3**	**20.0**	**21.7**	**24.3**	**26.5**
1-9	$ Each $/Watt	411 25.20	461 25.20	576 28.80	488 22.50	547 22.50	684 25.81
10-24	$ Each $/Watt	317 19.45	356 19.45	445 22.25	378 17.41	423 17.41	529 19.96
25-99	$ Each $/Watt	289 17.70	324 17.70	405 20.25	343 15.80	384 15.80	480 18.11
100-up	$ Each $/Watt	270 16.56	303 16.56	379 18.95	321 14.80	360 14.80	450 16.98

MSPR Series Voltage Regulators	
MSPR125LXX† 100 W Voltage Regulator Master †4, 6, 8, 12 or 24 Volts only Consult factory for other voltages.	Any Qty $90.00 each
MSPR125LS 100 W Voltage Regulator Slave	Any Qty $78.00 each
Wiring Harness	$10.00 per module
MSPS Series Support Structures Support Structure 1-9 (modules) (Standard Mount) 10-up (modules)	 $57.00 per module $46.00 per module

All prices quoted are FOB Phoenix, Arizona and are subject to change without notice.
*"X" represents A, B, D or E, which defines solar cell electrical interconnect configuration, e.g., MSP01D10 defines 4 cells in parallel by 12 cells in series. See data sheet for additional description.

MOTOROLA INC.

Solar Product Marketing, P.O. Box 2953,
Phoenix, Arizona 85062 (602) 244-5458.

MOTOROLA SOLAR PRODUCTS

PRICE LIST

Effective 8/1/79

MSP Series Solar Modules

QUANTITY	WATTS	MSP34A08	MSP01D10	* MSP43A40
		8.0	24.3	40.0
1-9	$ Each	281	547	766
	$/Watt	35.12	22.50	19.15
10-24	$ Each	218	423	620
	$/Watt	27.25	17.41	15.50
25-99	$ Each	197	384	590
	$/Watt	24.62	15.80	14.75
100-up	$ Each	185	360	536
	$/Watt	23.13	14.80	13.40

* MSP 43A40 Available After October, 1979

MSPR Series Voltage Regulators	
MSPR125LXX† 100 W Voltage Regulator Master †4, 6, 8, 12 or 24 Volts only Consult factory for other voltages.	Any Qty $90.00 each
MSPR125LS 100 W Voltage Regulator Slave	Any Qty $78.00 each
Wiring Harness	$10.00 per module
MSPS Series Support Structures Support Structure 1-9 (modules) (Standard Mount) 10-up (modules)	 $57.00 per module $46.00 per module

All prices quoted are FOB Phoenix, Arizona and are subject to change without notice.

MOTOROLA INC.

Solar Product Marketing, P.O. Box 2953,
Phoenix, Arizona 85062 (602) 244-5458.

MOTOROLA Solar Systems

Please complete this form, fold and tape it for your postage-paid reply.

REQUIREMENTS FOR PHOTOVOLTAIC POWER SUPPLY

1. APPLICATION: ____________________

____

____

____

2. GEOGRAPHIC LOCATION: ____________________

____

LATITUDE: __________ LONGITUDE: __________ ELEVATION: __________

3. TEMPERATURE: __________ °F MIN __________ °F MAX

4. SYSTEM VOLTAGE: __________ VDC NOM __________ VDC MIN __________ VDC MAX

5. CURRENT DRAIN: AVERAGE OPERATING CURRENT __________ AMPS

__________ AH/DAY

6. SPECIAL OR UNUSUAL CONDITIONS: ____________________

____

____

____

____

____

7. NUMBER OF SYSTEMS REQUIRED IN: 1978__________

1979__________

1980__________

Call or Write:

Solar Marketing Dept.
Solar Operations, A110
P.O. Box 2953
Phoenix, Arizona 85062
(602) 244-5459

From:

NAME: ____________________

TITLE: ____________________

COMPANY: ____________________

ADDRESS: ____________________

____

TELEPHONE: ____________________

FIRST CLASS
PERMIT NO.
2565
PHOENIX, AZ

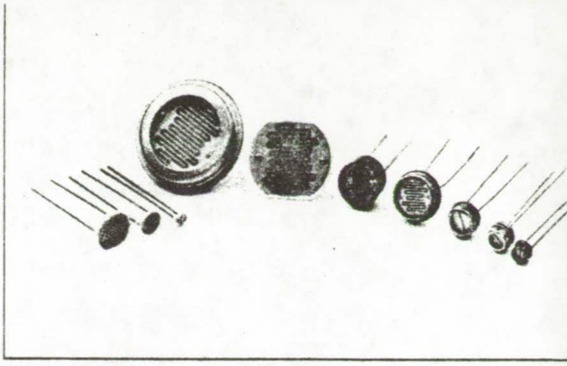
BUSINESS REPLY MAIL

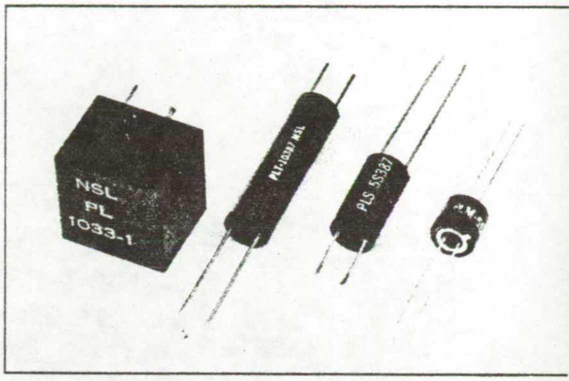
NO POSTAGE STAMP NECESSARY IF MAILED IN THE UNITED STATES

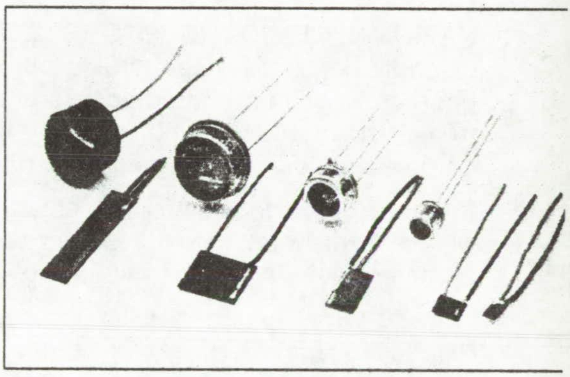
—Postage will be paid by:—

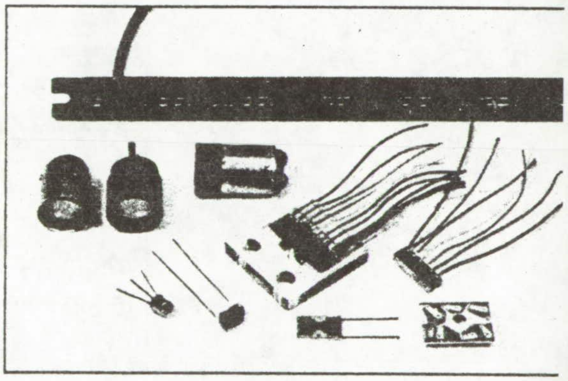
Motorola Solar Systems
P.O. Box 2953
Phoenix, Arizona 85062

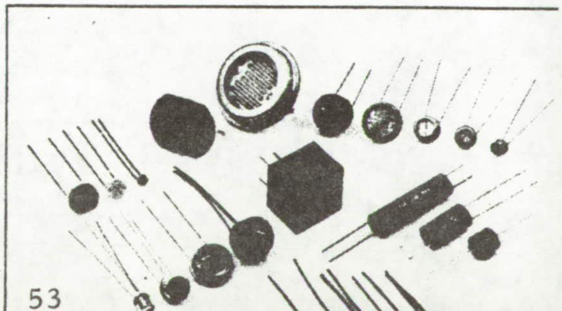
Attn: Solar Marketing Dept., Solar Operations, A110




NSL
PL
1033-1

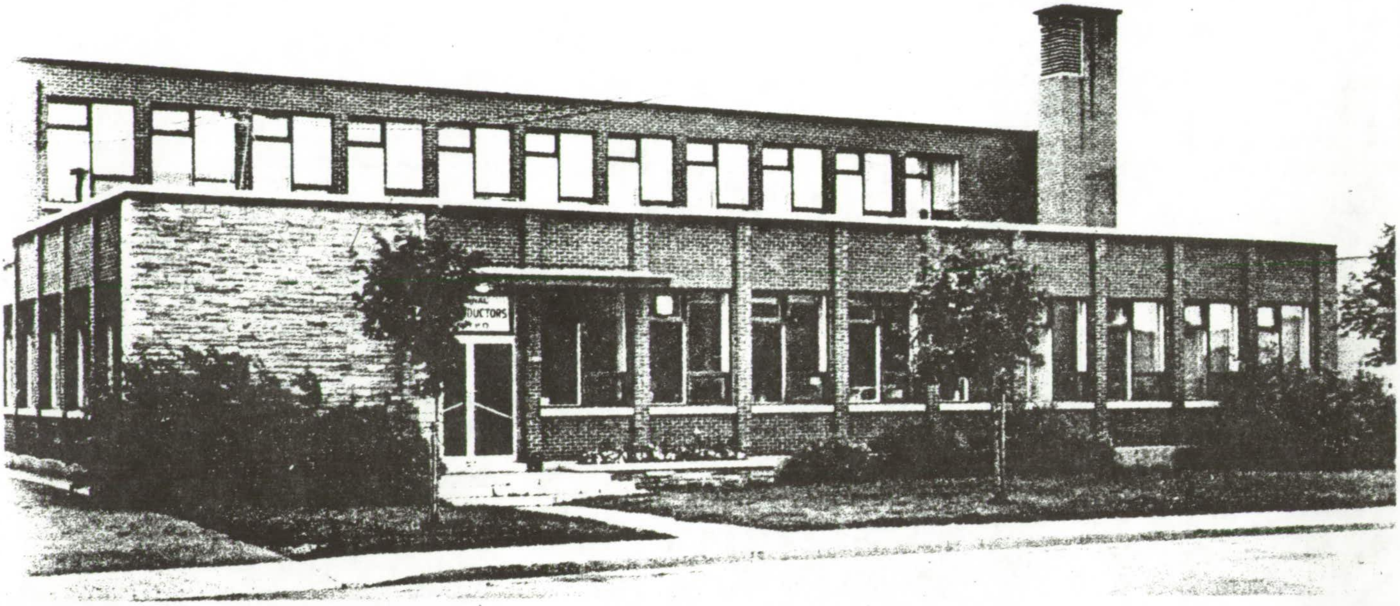






NATIONAL SEMICONDUCTORS LTD.

TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE, WA14 1DR. TELEX 51 669 663 TEL. (061) 928-3417



NATIONAL SEMICONDUCTORS LTD., founded in 1958, specialize in the design, manufacture and marketing of photoelectric devices. NSL's current product line includes Cadmium Sulphide and Cadmium Selenide photocells, silicon photodiodes and photovoltaic cells, high voltage optocouplers and customized optoelectronic arrays and assemblies. On-going research and development is conducted in the general field of optoelectronics with present emphasis on fibre optics communications and solar energy.

National Semiconductors has established facilities in Canada, the United States and the United Kingdom with a world-wide network of representatives and agents to assist the customer in the selection of their optoelectronic components and to provide after sales support.

With 20 years experience in photodetectors, reference Fig. 1, NSL is able to provide design assistance with respect to a wide variety of standard products; or design to customers' requirements, a specialized optoelectronic component where warranted. Specialization, in photodetectors, and stability, both with respect to detectors themselves and NSL as a source of supply, is the keynote to NSL's continuing success.

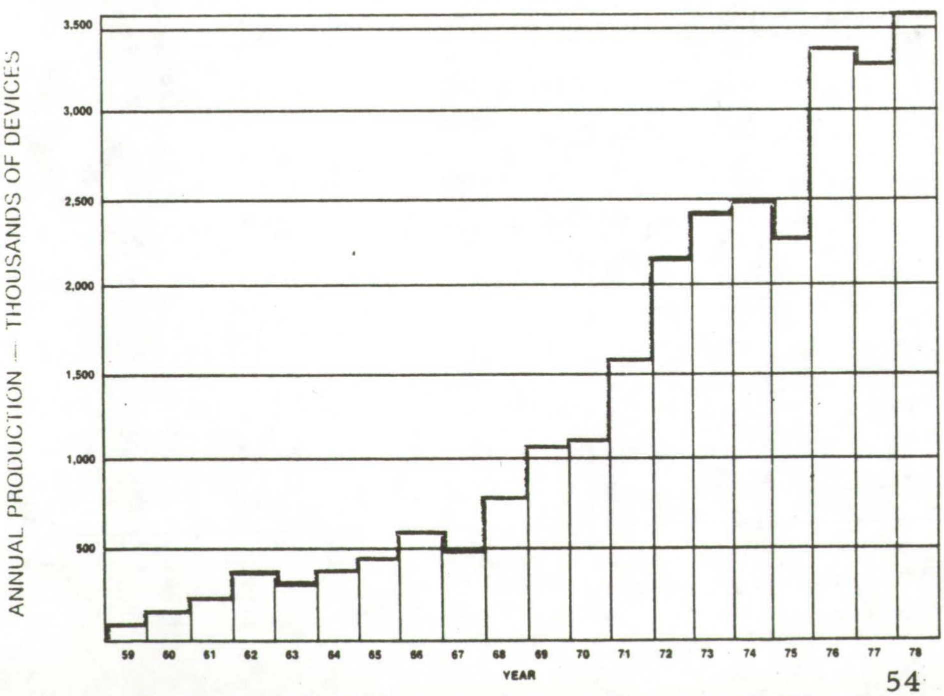


Fig. 1 — ANNUAL PRODUCTION OF PHOTOELECTRIC DEVICES

NSL OPTOELECTRONIC

- PHOTOCELLS
- PHOTODIODES
- PHOTOTRANSISTORS
- PHOTODARLINGTONS
- PHOTOVOLTAIC CELLS
- OPTICALLY COUPLED ISOLATORS
- OPTOELECTRONIC ARRAYS
- UV/BLUE SENSITIVE LDRs

CdS & CdSe PHOTOCELLS

Cell Type No.	Typ. 1 Ft Res. KΩ	Min. Dark Res. MΩ	Max. Peak Volt.	Max. Power MW.	Description	
NSL-312	75	100	70	50	CdSe Photoconductive	
NSL-3[illegible]	30	100	70	50	Cell in Hermetic Glass	Fig. 27
NSL-[illegible]	14	100	70	50	and Metal TO-18.	
NSL-315	550	1000	250	50	Hermetic CdS and	
NSL-316	260	1000	250	50	epoxy coated "open	
NSL-317	110	1000	250	50	pill" versions also	Fig. 28
NSL-318	50	500	120	50	available.	
NSL-443	200	300	2000	1000	CdS Photoconductive	Fig. 1
NSL-444	120	100	2000	1000	Cell in Hermetic Glass	
NSL-445	26.0	15	420	1000	and Metal 1.25" Dia.	
NSL-446	11.4	5	420	1000	Case. Epoxy coated	
NSL-447	5.5	1	420	1000	"open pill" versions also available.	Fig. 2
NSL-461	65	80		80	CdS	
NSL-462	28	20		80	Photoconductive	
NSL-463	12	2.7		80	Cell in Hermetic	
NSL-464	5.2	0.7		80	Glass and Metal ¼"	Fig. 3
NSL-465	550	160		250	Dia. Case. Hermetic	
NSL-466	230	20		250	CdSe versions	
NSL-467	100	4		250	also available.	
NSL-481	43.0	65	120	200	CdS Photoconductive	
NSL-482	18.6	15	120	200	Cell in Hermetic Glass	Fig. 4
NSL-483	8	1.8	120	200	and Metal TO-5.	
NSL-484	3.5	0.25	120	200	Hermetic CdSe and	
NSL-485	330	200	250	200	epoxy coated "Open	
NSL-486	155	130	250	200	Pill" versions also	Fig. 5
NSL-487	66	20	250	200	available.	
NSL-294	.75	10	70	500	CdS/Se photo-	Fig. 6
NSL-297	7.5	100	250	500	conductive cell	
NSL-3921	4.0	2	80	200	CdSe Photoconductive	Fig. 7
NSL-3931	1.7	2	80	200	Cell in Plastic Case.	
NSL-3941	0.75	1	80	200	Glass Lens and Epoxy	
NSL-3951	40.0	20	320	200	Coated "Open Pill" and	
NSL-3961	17.0	20	320	200	CdS versions also	Fig. 8
NSL-3971	7.5	10	320	200	available	
NSL-491	9.3	14	80	500		
NSL-492	4.0	3.2	80	500	CdS Photoconductive	
NSL-493	1.7	0.4	80	500	Cell in Hermetic Glass	
NSL-494	0.75	0.05	80	500	and Metal TO-8.	Fig. 6
NSL-495	40	32	320	500	Hermetic CdSe version	
NSL-496	17	4.0	320	500	also available.	
NSL-497	7.5	0.54	320	500		
NORP-11	20	2.5		320	CdS Photocell	
NORP-12	9	1		320	in lensed,	Fig. 11
NORP-13	4	.5		320	epoxy package.	

PHOTODETECTOR LAMP ASSEMBLIES

CdSe Photodetector

Module Type No.	Emitter Volts	Emitter Current MA	Detector Max. ON Res. Ω	Detector Min. OFF Res. MΩ	Max. Volts	Max. Power	Description	
PL-1033-1	10	15	100	10	80	250	Phenolic .75"	
PL-1036-1	10	15	400	100	320	250	x .75" x .625"	
PL-2H33-1	200	2	100	10	80	250	Pin Leads for	
PL-2H36-1	200	2	400	100	320	250	P.C. Board	Fig. 9
PL-3A33-1	100	2	150	10	80	250	Mounting.	
PL-3A36-1	100	2	500	100	320	250	(Matched,	
PL-5S33-1	2	25	200	10	80	250	Multi-Detector	
PL-5S36-1	2	25	2000	100	320	250	Configurations also available.)	
PLT-10384	10	15	250	10	80	100		
PLT-10387	10	15	3,000	100	320	100	Standard	
PLT-2H384	200	2	500	10	80	100	tube;	Fig. 10
PLT-2H387	200	2	10000	100	320	100	Axial	
PLT-3A384	100	2	750	10	80	100	leads.	
PLT-3A387	100	2	15000	100	320	100		
PLS-5S380	2	25	250	10	80	100	Small tube;	Fig. 12
PLS-5S387	2	25	4000	100	320	100	Axial leads.	
PLM-5S310	2	25	500	10	80	50	Miniature	Fig. 13
PLM-5S317	2	25	5000	100	320	50	tube; Axial leads.	

Silicon Photodetector

Module Type No.	Emitter Volts	Emitter Current MA	Detector Min. BV_{CEO}	Typ. Dark Curr. nA	Coupled Characteristics Curr. Trans. Ratio %	Coupled Characteristics Rise Fall Time µsec	Description	
PLM-6S610	1.5	50	30	1	30	5	Miniature	
PLM-6S510	1.5	50	50	2	0.1	1	Tube, Axial	Fig. 13
PLM-6S910	1.5	50	15	20	1000	70	Leads. Isolation: 2.5 kV	
PLS-6S610	1.5	50	30	1	30	5	Small Tube,	
PLS-6S510	1.5	50	50	2	0.1	1	axial leads.	Fig. 12
PLS-6S910	1.5	50	15	20	1000	70	Isolation: 5kV.	

PIN PHOTODIODES

NSL Type No.	Light Current* MA	Dark Current	Rise Time	Fall Time	Description	
NSL-530	.3	10 nA	3 nS	6 nS	TO-18 Package	Fig. 14
NSLX-140	3	500 nA	1 uSec	1 uSec	.4" x .4" Chip — BNC Package	

*At 500 Ftc (25 MW/cm²) 2870°K Source

SILICON PHOTODIODES

NSL Type No.	Minimum Short Ckt. Curr. MA	Min. Open Ckt.* Volt.	Dark Curr. µA @ 1 V @ 55°C	Reverse Voltage Recom. Maximum	Description	
NSL-701-1	0.30	0.35	10	5	.1" x .2" Chip.	Fig. 16
NSL-801-1	0.325	0.275	5	10	Wire Leads	
NSL-701-9	0.30	0.35	10	5	9 element Cell, 0.1" Spacing	
NSL-702	0.6	0.35	10	5	.2" x .2" Chip.	Fig. 17
NSL-802	0.65	0.275	5	10	Wire Leads	
NSL-703	1.4	0.35	40	5	.2" x .4" Chip.	Fig. 18
NSL-803	1.5	0.275	20	10	Wire Leads	
NSL-705	4.5	0.35	50	5	.76" x .354" Chip.	Fig. 19
NSL-805	4.77	0.275	25	10	Wire Leads	
NSL-706	2.9	0.35	40	5	.4" x .4" Chip.	Fig. 20
NSL-806	3.0	0.275	20	10	Wire Leads	
NSL-707	3.3	0.35	50	5	.2" x 1" Chip.	Fig. 21
NSL-807	3.5	0.275	25	10	Wire Leads	
NSL-708	1.3	0.35	30	5	.1" x 1" Chip.	Fig. 22
NSL-808	1.4	0.275	15	10	Wire Leads	
NSL-710	0.125	0.4	2	5	TO-18 Package	Fig. 23
NSL-810	0.150	0.275	1	10		
NSL-751	1.4	0.35	40	5	0.5" dia.	Fig. 24
NSL-851	1.5	0.275	20	10	Epoxy Package	
NSL-781	0.28	0.35	10	5	Hermetic TO-5	
NSL-881	0.3	0.275	5	10	Case	Fig. 25
NSL-782	0.42	0.35	10	5		
NSL-791	0.60	0.35	10	5	Hermetic TO-8	Fig. 26
NSL-792	1.1	0.35	30	5	Case	
NSL-8932	0.65	0.275	5	10	0.5" Dia. Ceramic	Fig. 15

*At 500 Ftc (25 MW/cm²) 2870°K Source

SILICON PHOTOTRANSISTORS & PHOTODARLINGTONS

NSL Type No.	I_{CEO} MA @ 5 V Min.	Typ.	MW/cm²	Dark I_{CEO} @ 15V 25°C — nA Typ.	Max.	Description	
NSL-610-1	.2	1	10	1	50	TO-18 Encased	
NSL-610-3	1	3	10	1	50	Power	Ref.
NSL-610-6	4	6	10	1	50	Dissipation @	Fig. 23
NSL-610-9	7	9	10	1	50	25°C 200 mW,	
NSL-611	8	15	10	10	100	BV_{CEO} 30 volts	
NSL-910	1	6	.1	20	250	TO-18, BV_{CEO} 15 V	

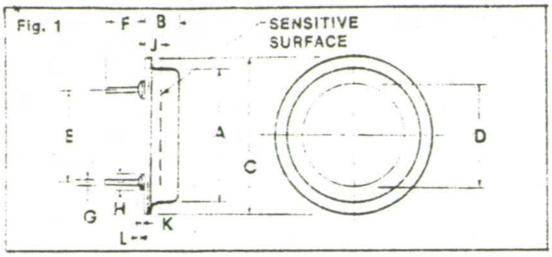
UV / BLUE SENSITIVE LDRs

Cell Type No.	Type 1 Ftc. Res. KΩ	Min. Dark Res. MΩ	Max. Peak Volt	Max. Power MW	Description	
NSL-2129/3	2	.5	80	200	.5" Plastic Case	Ref.
NSL-2129/6	20	1	320	200	Quartz Window	Fig. 7
NSL-593	30	1.5	70	500	TO-8	Fig. 6

NSL OPTOELECTRONIC
NATIONAL SEMICONDUCTORS LTD.

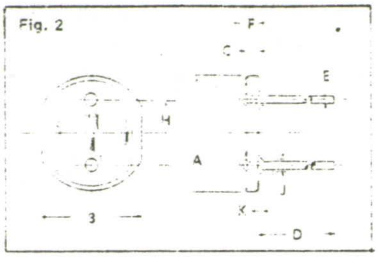
TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE WA14 1DR TELEX 51 669 663 TEL. (061) 928-3417

Fig. 1



Dims	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	1.097	1.103	27.86	28.03
B	.257	.273	6.52	6.92
C	1.247	1.260	31.66	32.00
D	.810	.820	20.57	20.82
E	.745	.755	18.91	19.17
F	.484	.516	12.29	13.10
G	.038	.042	.96	1.06
H	.180	.187	4.57	4.74
J	.077	.101	1.96	2.56
K	.042	.055	1.06	1.39
L	-	.015	-	.38

Fig. 2



Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	1.014	1.024	25.85	26.0
B	.855	.865	21.85	22.0
C		.087	2.05	2.2
D	17.02	19.32	14.0	14.6
E	.044	.046	1.1	1.2
F	.87	.07	2.55	2.7
H	.742	.758	18.85	19.25
J	.85	.100	2.4	2.55
K	.020	.030	.65	.5

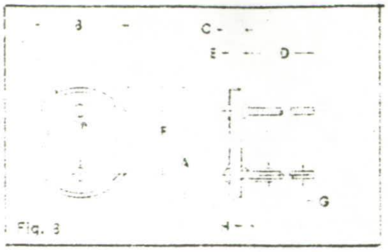
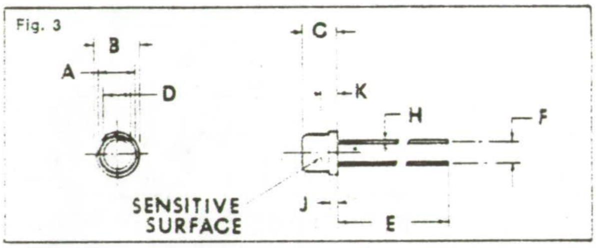


Fig. 8

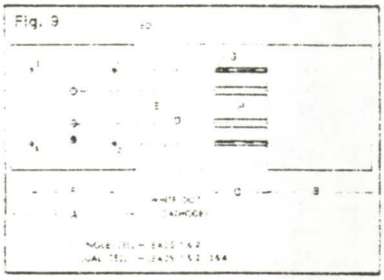
Dims	[illegible]		[illegible]	
[illegible]	[illegible]	[illegible]	[illegible]	Max.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	.50	[illegible]	[illegible]
D	[illegible]		[illegible] Nom.	
F	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	.58
G	[illegible]	[illegible]	.61	.68
H	[illegible]	[illegible]	.80	.95

Fig. 3



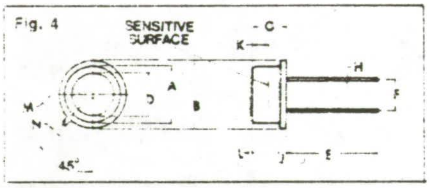
Dims.	Inches		Millimetres	
Ref.	Min	Max	Min.	Max.
A	.245	.265	6.210	6.720
B	.290	.302	7.380	7.630
C	.171	.183	4.320	4.640
D	.173	.182	4.401	4.620
E	1.5 Nom.		38.1 Nom.	
F	.171	.178	4.350	4.520
H	.016	.018	.409	.459
J	.056	.064	1.420	1.630
K	.083	.090	2.105	2.290

Fig. 9



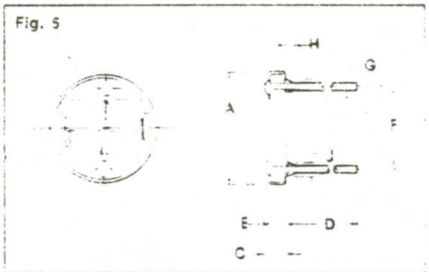
Dims	Inches		Millimeters	
Ref.	Min	Max.	Min.	Max.
A	.743 Sq.	.787 Sq.	18.85 Sq.	19.85 Sq.
B	.618	.622	15.50	15.85
C	.31 Nominal		8 Nominal	
D	.415	.432	10.80	11.00
E	.78	.172	4.32	4.38
F	.490	.507	12.45	12.88
G	.024	.026	.61	.64
H	.0385	.0415	.99	1.04

Fig. 4



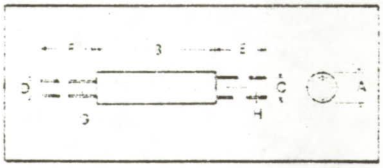
Dims.	Inches		Millimetres	
Ref.	Min.	Max	Min.	Max.
A	.320	.330	8.15	8.35
B	.355	.365	9.05	9.25
C	.173	.182	4.40	4.62
D	.235	.245	5.98	6.22
E	1.50	1.56	38.00	39.80
F	.195	.205	4.80	5.20
H	.016	.019	.409	.482
J	.036	.043	.92	1.10
K	.075	.098	1.90	2.50
L	− .010	+ .010	− .26	+ .26
M	.035	.045	.90	1.15
N	.026	.036	.68	.92

Fig. 5



Dims.	Inches		Millimetres	
Ref.	Min.	Max	Min.	Max
A	.265	.275	6.72	6.99
C	.039	.049	1.00	1.20
D	.375		24.33	
E	.028	.038	.712	.968
F	.195	.205	4.975	5.205
G	.024	.026	.61	.661
H	.020	.030	.51	.762
J	.035	.045	.90	1.15

Fig. 10



Dims.	Inches		Millimeters	
Ref.	Min	Max	Min.	Max.
A	.211	.221	5.30	5.57
B	1.170	1.203	29.80	30.55
C	.165	.205	4.08	5.21
D	.182	.193	4.62	4.89
E	1.0	-	25.4	-
F	1.0	-	25.4	-
G	.018	.026	.46	.66
H	.024	.026	.61	.66

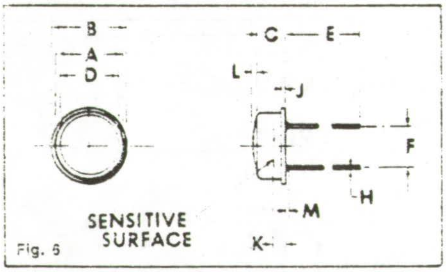


Fig. 6

Dims	Inches		Millimetres	
Ref	Min	Max.	Min.	Max.
A	.480	.492	12.192	12.446
B	.542	.567	10.82	14.10
C	.180	.198	4.59	5.03
D	.423	.437	10.90	11.10
E	1.5 Nom.		38.1 Nom.	
F	.292	.298	7.42	7.59
H	.016	.019	.409	.492
J	.021	.035	.538	.889
K	.080	.100	2.02	2.59
L	.022	.032	.559	.819
M	.020	.028	.510	.712

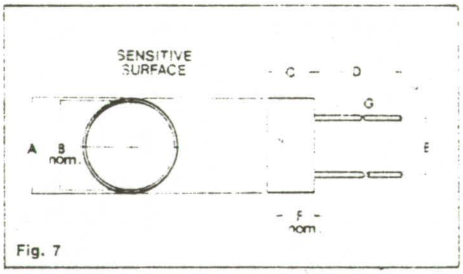
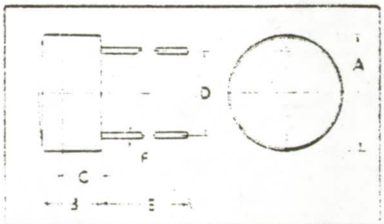


Fig. 7

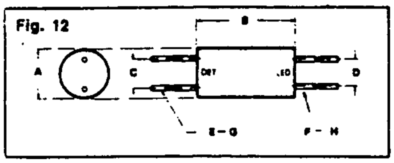
Dims.	Inches		Millimetres	
Ref	Min	Max.	Min.	Max.
A	.493	.507	12.40	12.80
B	.458	.472	11.50	12.00
C	.243	.267	6.18	6.62
D	1.594 Nom.		40.50 Nom.	
E	.288	.302	7.32	7.68
F	.158	.172	4.02	4.38
G	.023	.027	.59	.69

Fig. 11



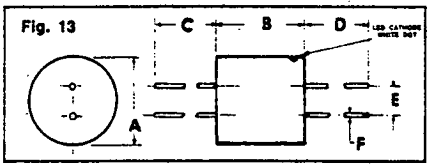
Dims	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.490	.510	12.446	12.954
B	.240	.260	6.096	7.004
C	.155	.175	3.937	4.445
D	.168	.188	4.271	4.779
E	1.3 [illegible]	1.3 [illegible]	30.16	36.04
F	.020	.027	.534	.685

Fig. 12



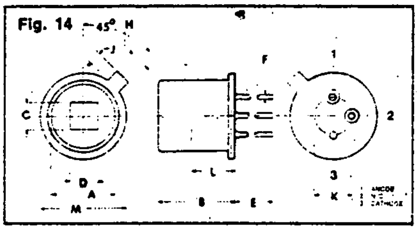
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.316	.323	8.02	8.21
B	.618	.632	15.85	16.05
C	.195	.205	4.96	5.20
D	.182	.192	4.62	48.8
E	.024	.028	.61	.64
F	.019	.021	.48	.53
G	1.5 Nominal		38.1 Nominal	
H	.75 Nominal		19.05 Nominal	

Fig. 13



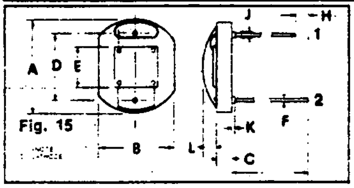
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.305	.315	7.85	8.00
B	.290	.315	7.38	8.00
C	1.5 Nominal		38.1 Nominal	
D	1.0 Nominal		25.4 Nominal	
E	.095	.105	2.41	2.68
F	.016	.019	.41	.48

Fig. 14



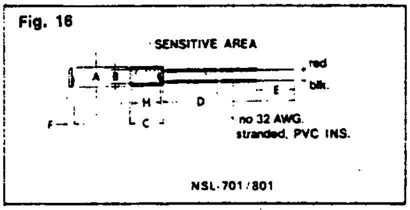
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.178	.188	4.52	4.78
B	.195	.205	4.96	5.21
C	.075	.080	1.91	2.03
D	.075	.080	1.91	2.03
E	.5 Nominal		12.8 Nominal	
F	.016	.019	.41	.48
H	.035	.045	.89	1.15
J	.033	.048	.84	1.22
K	.096	.104	2.43	2.65
L	.105	.115	2.68	2.92
M	.202	.213	5.12	5.41

Fig. 15



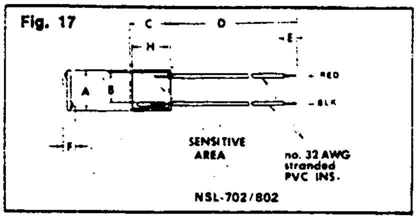
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.357	.367	9.05	9.32
B	.303	.313	7.70	7.94
C	.065	.075	1.66	1.92
D	.260	.270	6.61	6.86
E	.195	.205	4.90	5.22
F	.019	.021	.049	.053
H	.124	.188	3.17	4.78
J	.035	.045	.09	.12
K	.010	.020	.026	.051
L	-	.045	-	.115

Fig. 16



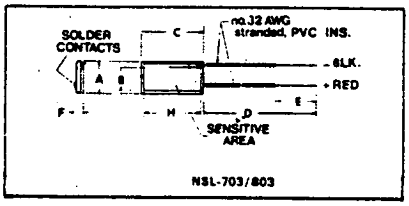
Dims.	Inches		Millimeters	
Ref	Min.	Max.	Min.	Max.
A	.095	.105	2.41	2.66
B	.080	.090	2.03	2.28
C	.195	.205	4.95	5.20
D	6.0 Nom.		152. Nom.	
E	.15	.30	3.8	7.62
F	.030	.060	.76	1.5
H	.150	.160	3.81	4.06

Fig. 17



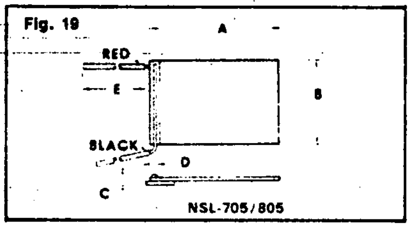
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.185	.195	4.70	4.94
B	.145	.155	3.68	3.94
C	.185	.195	4.70	4.94
D	6.0 Nom.		152. Nom.	
E	.15	.25	3.8	6.3
F	.030	.050	.76	1.27
H	.170	.180	4.31	4.57

Fig. 18



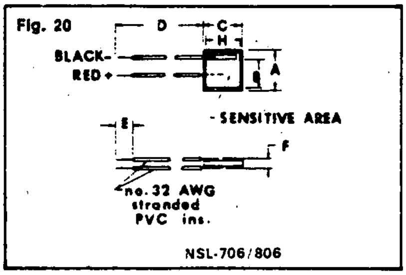
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.195	.205	4.35	5.20
B	.152	.162	3.86	4.11
C	.390	.410	9.91	10.45
D	6.0 Nom.		152. Nom.	
E	.15	.25	3.8	6.2
F	.030	.050	0.76	1.27
H	.375	.390	9.50	9.90

Fig. 19



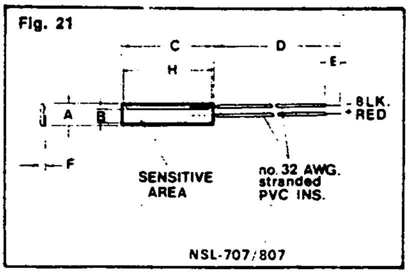
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.750	.770	19.02	19.72
B	.349	.359	9.85	9.18
C	.050	.060	1.27	1.41
D	.040	.050	1.01	1.21
E	6.0 Min. (Leads)		152. Min. (Leads)	

Fig. 20



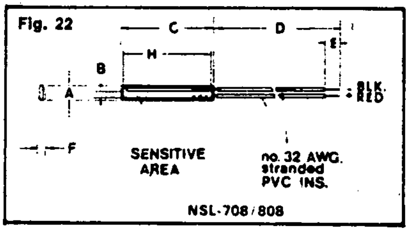
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.390	.410	10.0	10.4
B	.334	.364	8.4	9.2
C	.390	.410	10.0	10.4
D	6.0 Nom.		152. Nom.	
E	.19 Nom.		4.9 Nom.	
F	.040	.050	1.02	1.28
H	.375	.385	9.4	9.8

Fig. 21



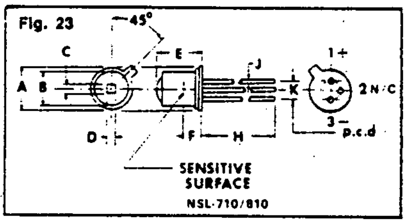
Dims.	Inches		Millimeters	
Ref	Min.	Max.	Min.	Max.
A	.190	.210	4.8	5.35
B	.150	.160	3.81	4.06
C	0.99	1.01	25.14	25.65
D	6.0 Nom.		152 Nom.	
E	5/32	7/32	4	5.5
F	.030	.050	0.76	1.27
H	.975	.995	24.76	25.27

Fig. 22



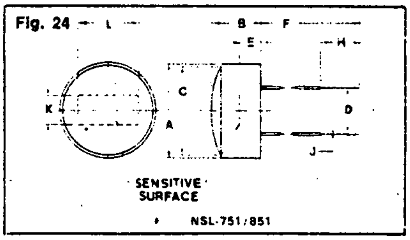
Dims.	Inches		Millimeters	
Ref	Min.	Max.	Min.	Max.
A	.090	.110	2.3	2.8
B	.050	.060	1.27	1.52
C	0.99	1.01	25.1	25.65
D	6.0 Nom.		152 Nom.	
E	5/32	7/32	4.	5.5
F	.030	.050	0.76	1.27
H	.975	.995	24.76	25.27

Fig. 23

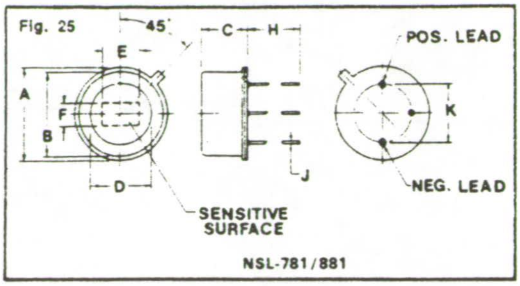


Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.205	.215	5.21	5.46
B	.178	.188	4.52	4.77
C	.070	.080	1.78	2.03
D	.070	.080	1.78	2.03
E	.220	.235	5.59	5.97
F	.110	.120	2.79	3.04
H	1" Nominal		25.4 Nominal	
J	.017	.019	.43	.48
K	.096	.104	2.44	2.64

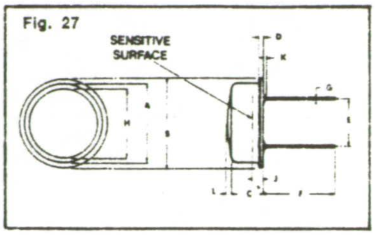
Fig. 24



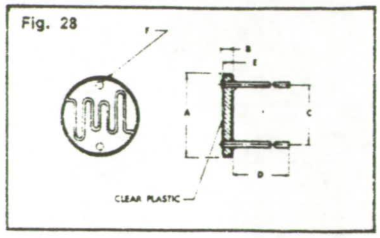
Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.497	.512	12.8	13.0
B	.270	.290	6.85	7.38
C	.460	.470	11.75	12.00
D	.285	.305	7.22	7.75
E	.130	.150	3.32	3.8
F	6.0 Nom.		152.0 Nom.	
H	.19 Nom.		5. Nom.	
J	No. 32 AWG 7 Strand PVC			
K	.180	.200	4.58	5.08
L	.380	.400	9.69	10.25



Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.355	.365	9.20	9.28
B	.320	.330	8.13	8.38
C	.180	.190	4.58	4.82
D	.235	.245	5.98	6.22
E	.145	.155	3.69	3.92
F	.085	.095	2.15	2.41
H	1.50	1.60	38.	40.8
J	.016	.019	.41	.48
K	.235	.245	5.98	6.22

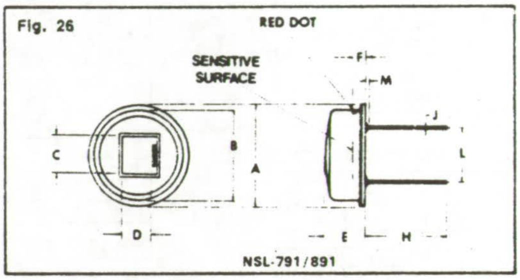


Dims.	Inches		Millimeters	
Ref.	Min.	Max	Min.	Max.
A	182	193	4.62	4.90
B	205	215	5.21	5.46
C	140	150	3.56	3.81
D	015	025	.381	.636
E	.096	104	2.42	2.65
F	1.5 Nominal		38.0 Nominal	
G	016	019	410	.482
H	.150	160	3.81	4.08
J	068	080	1.72	2.02
K	.010	020	.254	.556
L	005	015	128	380



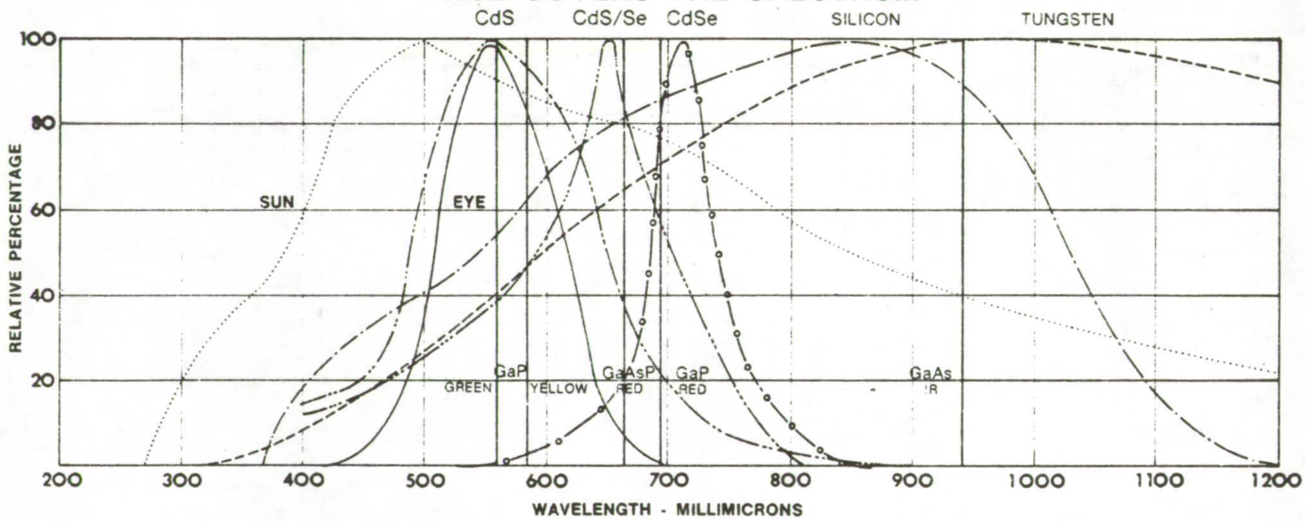
Dims.	Inches		Millimeters	
Ref.	Min	Max.	Min.	Max.
A	.152	.162	3.86	4.11
B	039	049	.99	1.26
C	096	.104	2.46	2.64
D	1.53 Nominal		38.9 Nominal	
E		.038		.968
F	024	.026	.61	.66

LEADS: SOLDER COATED COPPERWELD



Dims.	Incnes		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.545	.555	13.84	14.10
B	.481	.491	12.21	12.46
C	.185	.195	4.70	4.95
D	.145	.155	3.68	3.94
E	.200	.226	5.08	5.73
F	.031	.101	2.31	2.56
H	1.50	1.60	38.10	40.64
J	.016	.019	.40	.48
L	.290	.300	7.36	7.62
M		.025		.63

NSL COVERS THE SPECTRUM



REPRESENTATIVES AND DISTRIBUTORS WORLDWIDE

BULLETIN
15019 Rev. 1

NSL OPTOELECTRONIC
NATIONAL SEMICONDUCTORS LTD.

TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE, WA14 1DR. TELEX 51 669 663 TEL. (061) 928-3417

do it the LIGHT way

OPEN SILICON PHOTOVOLTAIC CELLS

NSL-701/708
NSL-801/808

GENERAL DESCRIPTION

Silicon cells are generally used for light sensing and power generation because of their stability and high efficiency. No additional power supplies are usually required due to the cells' photovoltaic properties. In power conversion applications, the cells' low internal impedance, relatively high shunt impedance, stability and humidity resistant characteristics are utilized to convert light directly into DC power or for storage in chargeable batteries, etc. When cells are connected in series, the output voltage is additive, while in parallel configurations output currents are additive.

Open silicon cells also provide a reliable, inexpensive detector for instrument and light beam sensing applications. NSL cells are generally of N on P construction but reverse polarity P on N devices can also be provided. Although standard NSL cells are offered with leads and a clear protective coating, uncoated cells without leads are available upon request, see Notes (1) and (2).

FEATURES

- **Quick response**
- **High reliability, long life**
- **Protective, humidity resistant coating**
- **Operating Temperature Range: — 65°C to 125°C**
- **Ideal for moderate reverse (bias) voltage operation**
- **Short circuit current linear over wide ranges of illumination**
- **Choice of low capacitance, high speed 800 material or the higher open circuit voltage, 700 series**

NSL PART NO.	SHORT CIRCUIT CURRENT (mA) @ H = 500 FTC* (25 mw/cm²)		OPEN CIRCUIT VOLTAGE (V) @ H = 500 FTC* (25 mw/cm²)		DARK CURRENT (uA) @ V = 1 V		CAPACITANCE (ZERO BIAS) TYP. (pF)	REVERSE BIAS (V) MAX.	ACTIVE AREA (cm²)	OUTPUT CURRENT SCALE FACTOR (NOTE 3)	DESCRIPTION
	MIN.	TYP.	MIN.	TYP.	MAX. @T 25°C	TYP. @T 55°C					
NSL-701	.3	.39	.35	.4	3.	6.	3,000	5	.0950	10.51	.1" x.2" Chip, Wire Leads; Fig. 11
NSL-702	.6	.77	.35	.4	5.	10.	6,000	5	.1870	5.32	.2" x.2" Chip, Wire Leads; Fig. 12
NSL-703	1.4	1.8	.35	.4	15.	30.	13,500	5	.439	2.28	.2" x.4" Chip, Wire Leads; Fig. 13
NSL-705	4.5	5.75	.35	.4	25.	50.	50,000	5	1.59	.713	.76"x.354" Chip, Wire Leads; Fig. 14
NSL-706	2.9	3.7	.35	.4	20.	40.	27,500	5	.892	1.11	.4" x.4" Chip, Wire Leads; Fig. 15
NSL-707	3.3	4.3	.35	.4	25.	50.	35,000	5	1.041	.95	.2" x 1" Chip, Wire Leads; Fig. 16
NSL-708	1.3	1.7	.35	.4	15.	30.	16,500	5	.402	2.41	.1" x 1" Chip, Wire Leads; Fig. 17
NSL-801	.325	.4	.275	.3	1.5	3.0	375	10	.095	10.9	.1" x.2" Chip, Wire Leads; Fig. 11
NSL-802	.65	.8	.275	.3	2.5	5.	750	10	.187	5.45	.2" x.2" Chip, Wire Leads; Fig. 12
NSL-803	1.50	1.9	.275	.3	7.5	15.	1,700	10	.439	2.29	.2" x.4" Chip, Wire Leads; Fig. 13
NSL-805	4.77	6.1	.275	.3	12.5	25.	6,200	10	1.59	.714	.76"x.354" Chip, Wire Leads; Fig. 14
NSL-806	3.	3.9	.275	.3	10.	20.	3,450	10	.892	1.12	.4" x.4" Chip, Wire Leads; Fig. 15
NSL-807	3.5	4.5	.275	.3	12.5	25.	4,350	10	1.04	.97	.2" x 1" Chip, Wire Leads; Fig. 16
NSL-808	1.4	1.75	.275	.3	7.5	15.	2,100	10	.402	2.49	.1" x 1" Chip, Wire Leads; Fig. 17

* The light source is Tungsten Lamp at a color temperature of 2870°K

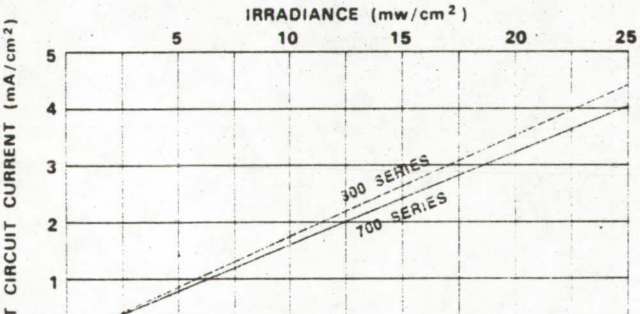


Fig. (1): SHORT CIRCUIT CURRENT CHARACTERISTICS
The short circuit current is extremely linear over wide ranges of illumination.

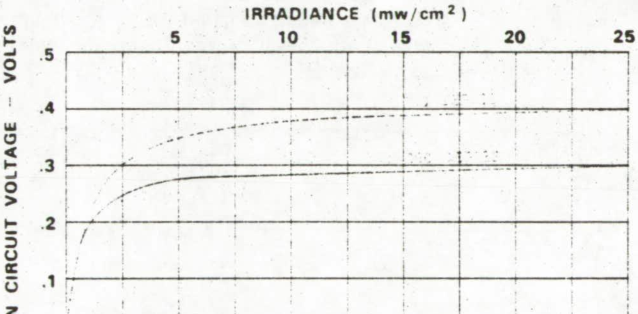


Fig. (2): OPEN CIRCUIT VOLTAGE CHARACTERISTICS
Open circuit voltage is generally independent of active area and varies logarithmically with linear variations of illumination.

NSL OPTOELECTRONICS
NATIONAL SEMICONDUCTORS LTD.
TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE, WA14 1DR. TELEX 51 669 663 TEL. (061) 928-3417

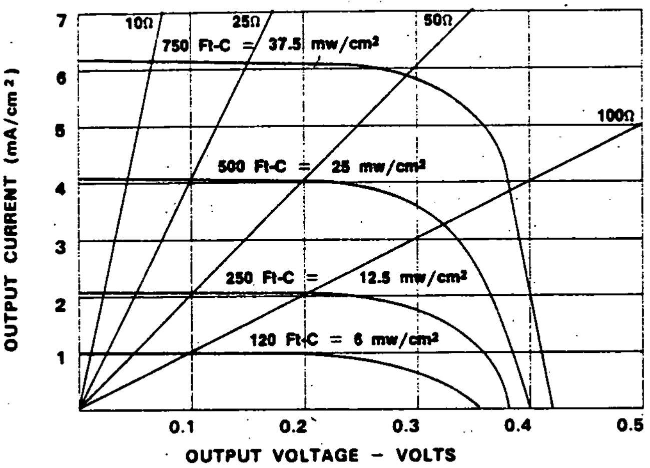


Fig. (3): 700 SERIES

TYPICAL VOLTAGE/CURRENT CHARACTERISTICS

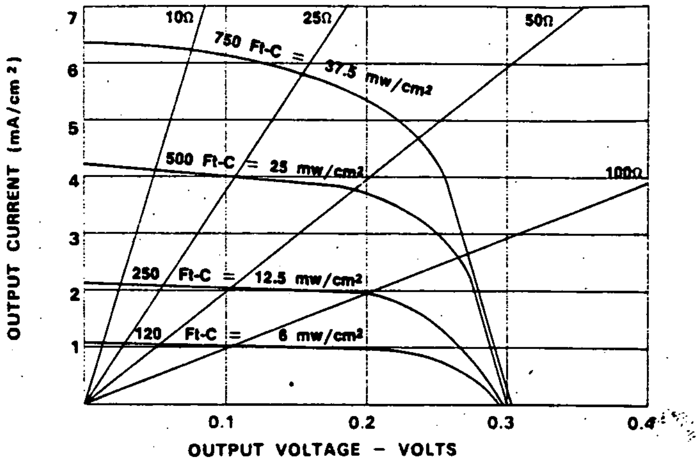


FIG. (4): 800 SERIES

TYPICAL VOLTAGE/CURRENT CHARACTERISTICS

The output current developed into a load is a function of illumination level, the load resistance and photosensitive active area.

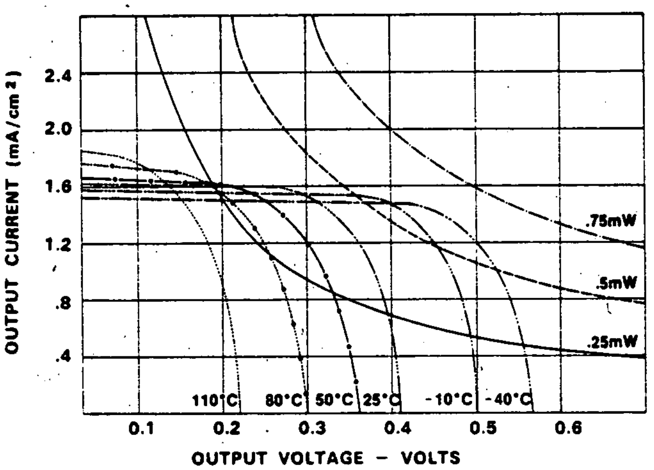


Fig. (5): EFFECTS OF TEMPERATURE OF 700 SERIES

I - V Characteristic: 200 FTC (10mW/cm²)

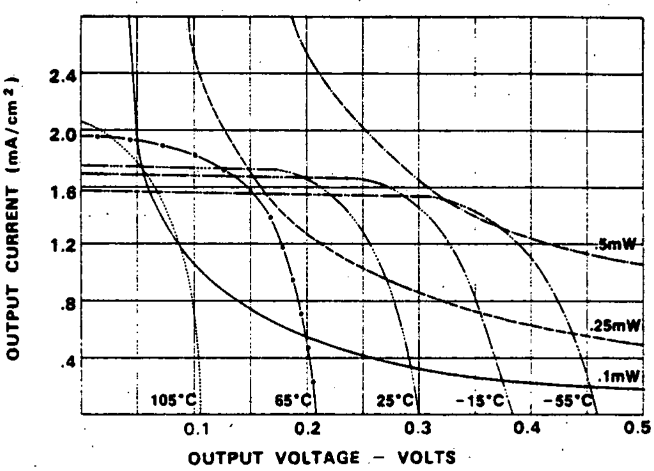


Fig. (6): EFFECTS OF TEMPERATURE OF 800 SERIES

I - V Characteristic: 200 FTC (10mW/cm²)

Optimum power transfer is obtained with a load impedance which results in a voltage and current combination that yields maximum power output. Output current for maximum power and short circuit current normally remain constant over the operating temperature range of the cell.

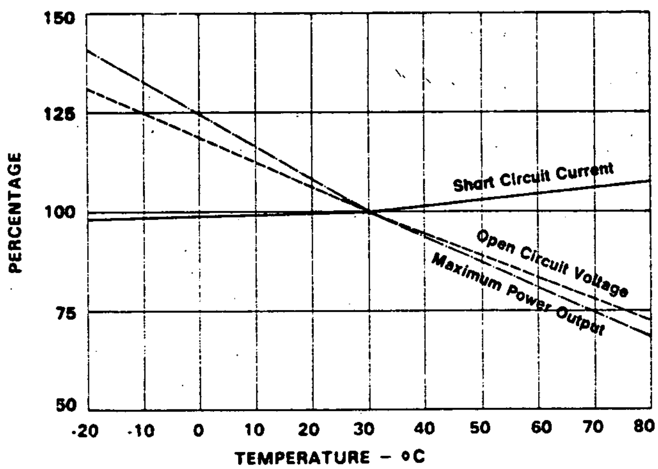


Fig. (7): TYPICAL OUTPUT VARIATIONS OF 700 SERIES

@ 200 FTC ((10mW/cm²)

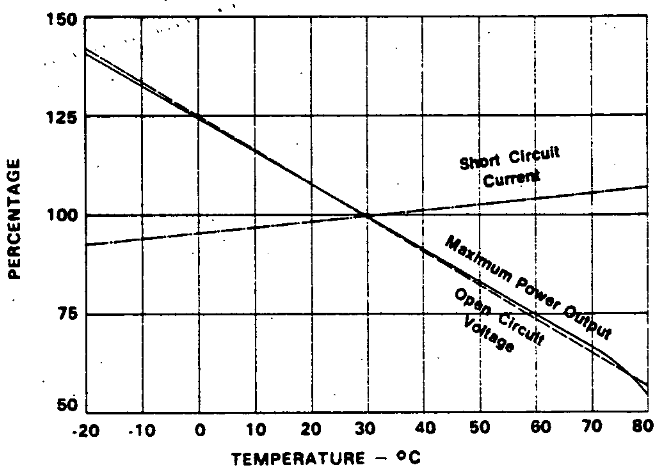


Fig. (8): TYPICAL OUTPUT VARIATIONS OF 800 SERIES

@ 200 FTC ((10mW/cm²)

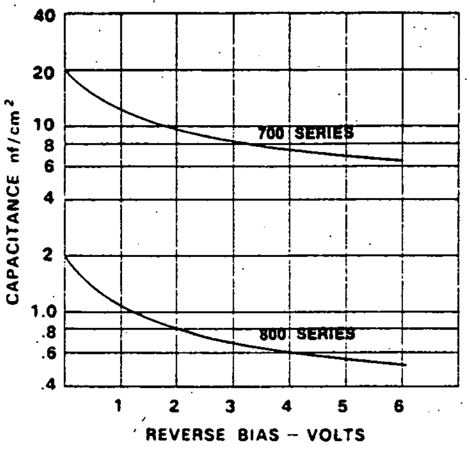


Fig. (9): CAPACITANCE AS FUNCTION OF REVERSE BIAS
Junction capacitance, which is constant per unit area of the cell at a given reverse voltage, has a major effect on the cell response time. Response time depends on load resistance, illumination level as well as junction capacitance. Best control over response time can be achieved by selecting smaller active areas for faster response.

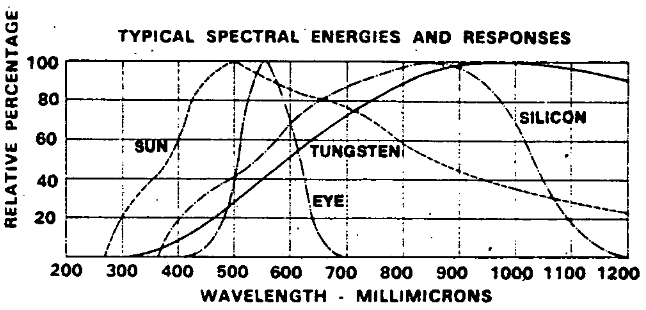


Fig. (10): TYPICAL SPECTRAL ENERGIES & RESPONSES

——— . . ——— HUMAN EYE

——————— TUNGSTEN

- - - - - - - - - - - - SUNLIGHT

———— . ———— SILICON

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.095	.105	2.41	2.66
B	.080	.090	2.03	2.28
C	.195	.205	4.95	5.20
D	6.0 Nom.		152. Nom.	
E	.15	.30	3.8	7.62
F	.030	.050	0.76	1.27
H	.150	.160	3.81	4.06

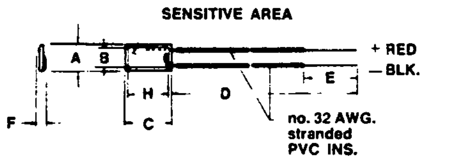


Fig. 11 NSL-701/801

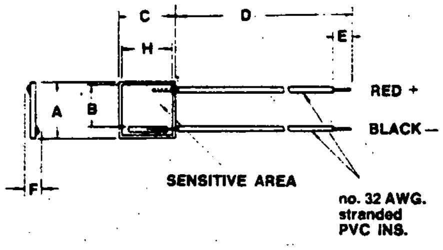


Fig. 12 NSL-702/802

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.185	.195	4.70	4.94
B	.145	.155	3.68	3.94
C	.185	.195	4.70	4.94
D	6.0 Nom.		152. Nom.	
E	.15	.25	3.8	6.3
F	.030	.050	.76	1.27
H	.170	.180	4.31	4.57

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.195	.205	4.95	5.20
B	.152	.162	3.86	4.11
C	.390	.410	9.91	10.45
D	6.0 Nom.		152. Nom.	
E	.15	.25	3.8	6.2
F	.030	.050	0.76	1.27
H	.375	.390	9.50	9.90

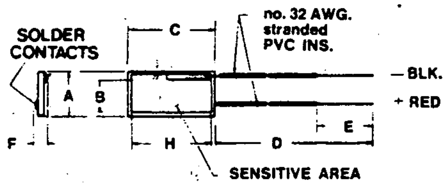


Fig. 13 NSL-703/803

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.750	.770	19.02	19.72
B	.349	.359	9.85	9.18
C	.050	.060	1.21	1.41
D	.030	.050	0.76	1.27
E	6.0 Min. (Leads)		152. Min. (Leads)	

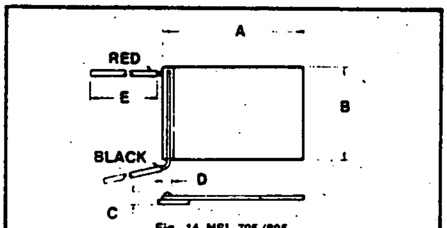


Fig. 14 NSL-705/805

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.390	.410	10.0	10.4
B	.334	.364	8.4	9.2
C	.390	.410	10.0	10.4
D	6.0 Nom.		152. Nom.	
E	.19 Nom.		4.9 Nom.	
F	.030	.050	0.76	1.27
H	.375	.385	9.4	9.8

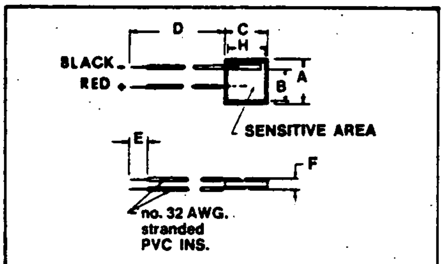


Fig. 15 NSL-706/806

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.190	.210	4.8	5.35
B	.150	.160	3.81	4.06
C	0.99	1.01	25.14	25.65
D	6.0 Nom.		152 Nom.	
E	5/32	7/32	4.	5.5
F	.030	.050	0.76	1.27
H	.975	.995	24.76	25.27

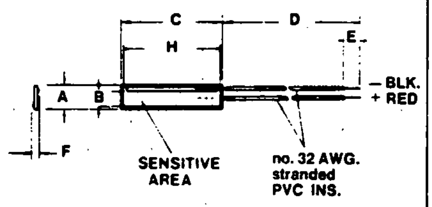


Fig. 16 NSL-707/807

Dims.	Inches		Millimeters	
Ref.	Min.	Max.	Min.	Max.
A	.090	.110	2.3	2.8
B	.050	.060	1.27	1.52
C	0.99	1.01	25.1	25.65
D	6.0 Nom.		152 Nom.	
E	5/32	7/32	4.	5.5
F	.030	.050	0.76	1.27
H	.975	.995	24.76	25.27

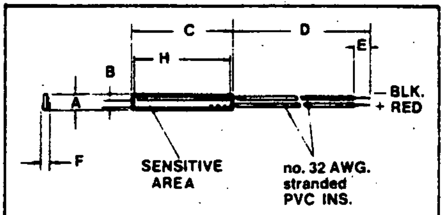


Fig. 17 NSL-708/808

NOTES:

NOTE 1: Avoid handling leadless cells with bare fingers since they have no protective coating as do cells with leads.

NOTE 2: The cells' front and back electrodes are solder-coated. Electrodes may be soldered using 60/40 tin-lead solder with an active flux capable of making a solder joint quickly to minimize heat, as excessive soldering temperatures can cause contact damage. Whenever possible, it is recommended that all soldering be done by NSL since it is possible to degrade the cells' characteristics with improper handling.

NOTE 3: Output Current Scale Factor. This parameter can be used to calculate the short circuit current of the various devices under illumination levels other than 500 Ft-c and 25°C. For example, the short circuit current for the NSL-701 at 250 Ft-c illumination and room temperature can be calculated by obtaining the short circuit current per unit area of 2.05 MA/cm^2 for the 700 series at 250 Ft-c (Fig. 1) and dividing by the 701 scale factor of 10.5, giving typical output of 0.195 MA.

This scale factor could also be used for calculating typical capacitances at various reverse voltages by using the data from Fig. 9 in a similar manner. Please note that capacitance calculated in this manner would only be first order approximation as contact areas must also be considered. For more representative data, contact NSL.

NOTE 4: All characteristics are for 25°C free air unless otherwise noted.

NSL OPTOELECTRONIC
NATIONAL SEMICONDUCTORS LTD.
TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE, WA14 1DR. TELEX 51 669 663 TEL. (061) 928-3417

SM 111/211 SILICON SOLAR MODULES

NATIONAL SEMICONDUCTORS Silicon Solar Modules utilize individual photovoltaic cells which are interconnected and packaged to provide protection from the environment. Glass or ultraviolet radiation stabilized plastic covers are offered.

TYPICAL CHARACTERISTICS
(@ 25°C and 100 mW/cm² Sunlight)

	SM 111	SM 211
Peak output power	16.5 W	8 W
Short circuit current	1.2 A	0.5 A
Open circuit voltage	20 V	20 V

Dimensions: 24½" x 18½" x 2"

Ref. Dwg. 5540

25 Apr 79

NSL PHOTOVOLTAIC CELLS AS POWER GENERATORS

Although NSL photovoltaic cells have been developed as sensitive detectors of light for control purposes, they may of course be used to generate modest amounts of power. The source of this power might be the sun or even a tungsten lamp. A photovoltaic cell generates a voltage when illuminated and when it is connected to a load a current flows.

The open circuit voltage, the voltage that would be read by a voltmeter, does not depend upon the size of the cell but only on the intensity of light falling on it. This voltage is not proportional to the light but follows a logarithmic law. It is a few tenths of a volt in moderate room light but does not exceed .6 volt even in bright sunlight.

The short circuit current that flows when a low impedance load is connected across the cell depends linearly upon the area of the cell and upon the intensity of the light. Usually, however, the load is neither zero nor infinite, a condition for the delivery of power to the load. The curves showing the current supplied to various loads and the corresponding voltages are known as the characteristic curves. Typical characteristic curves for two NSL photovoltaic cells are shown in fig. 1. and they illustrate the points that have been discussed. The area of the NSL-703 is twice the area of the NSL-702 and it will be noted that the short circuit current of the NSL-703 is twice as great.

Power. In fig. 1.b, one load line is shown. This particular load line is chosen to obtain the maximum power for this particular level of illumination. (The area of the shaded rectangle is maximized). In this example an NSL-703 under 500 ft-candles illumination produces 1.4 mA at a voltage of .3 volts or a power of .42 mw. In fig. 2. the characteristic curve is shown for an NSL-703 in full sunlight. Here power of 4 mw may be generated at 10 mA and .4 volts.

Efficiency. The total radiant power in full noon sunlight at the earth's surface is about 100 mw/cm^2. Since the active area of an NSL-703 is .4 cm^2 it intercepts 40 mw of sun power. A cell generating 4 mw will then be 10% efficient in converting sun power to electrical power. This value of efficiency is typical of the NSL photovoltaic cells.

Series and parallel connections. As seen above the silicon photovoltaic cell generates its greatest power at some particular voltage, generally about .4 volts in sunshine. If it is necessary to generate a higher voltage to operate some device or to charge a storage battery, then cells may be connected in series until the required voltage is attained. The current generated will be the current of one cell. To provide more current will require larger area cells or the paralleling of series strings. In charging a battery with photovoltaic cells, a precaution must be taken to avoid shorting out the battery by the cells during periods of darkness. The isolating diode shown in fig. 3. will prevent current from flowing from the battery through the photovoltaic cells which would be forward biased.

over ...

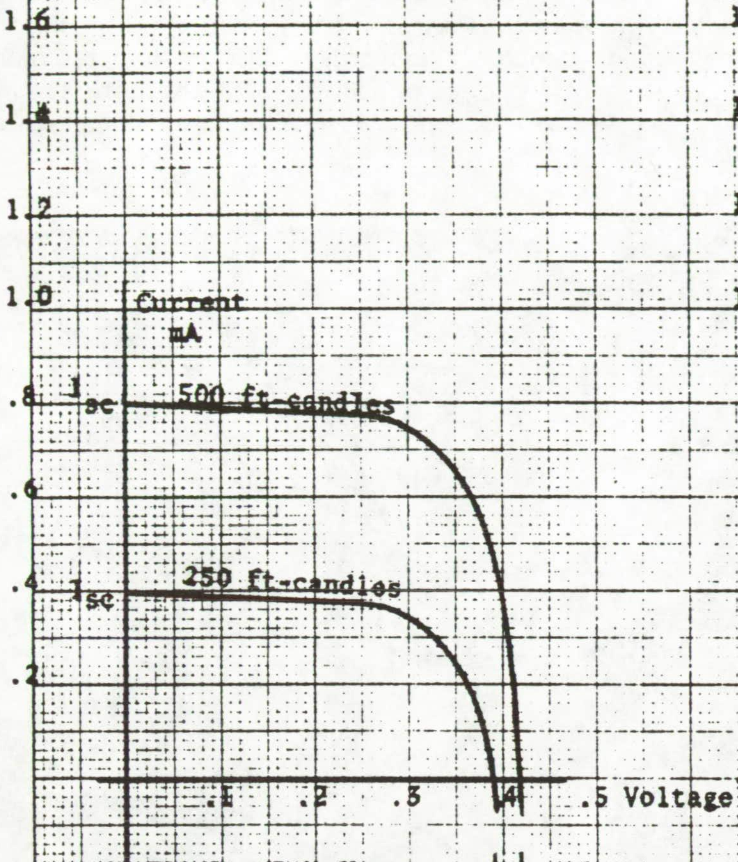


Fig. 1.a I-V Characteristics of NSL-702 at 2 light levels (Chip size .2 x .2 inches)

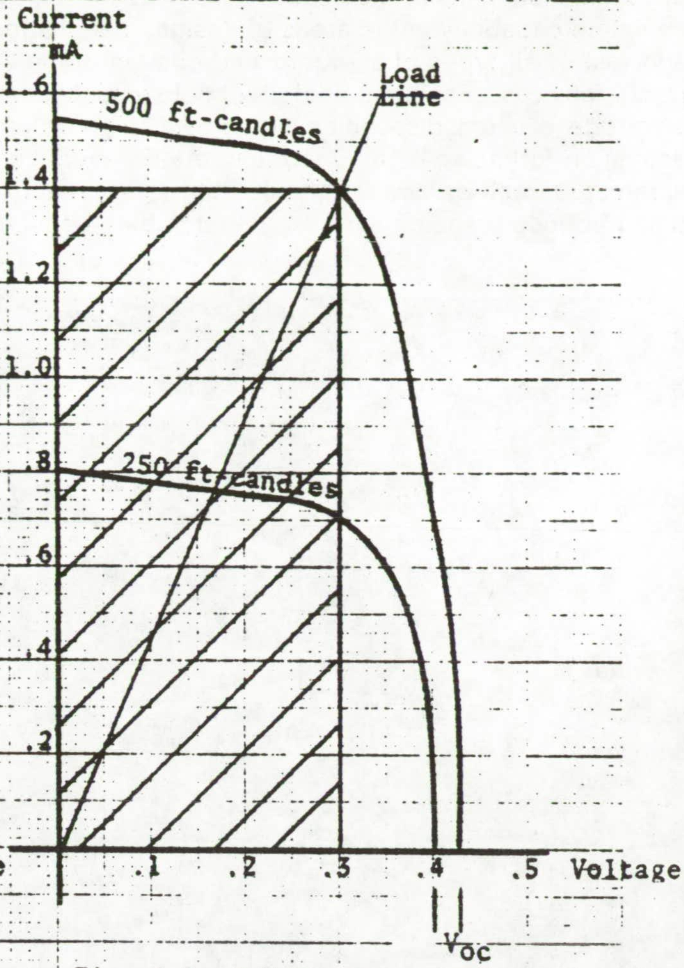


Fig. 1.b I-V Characteristics of NSL-703 at 2 light levels (Chip size .2 x .4 inches)

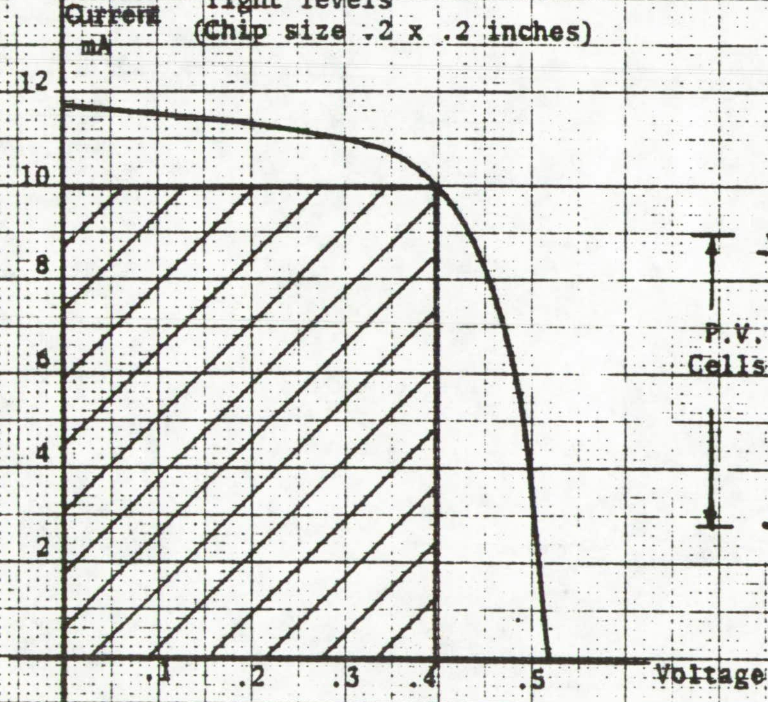


Fig. 2 NSL-703 under full sunlight

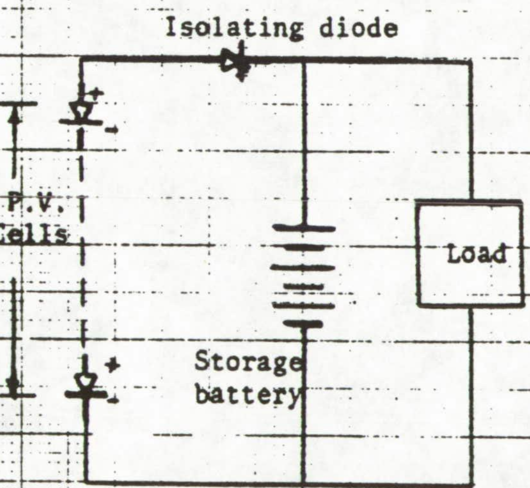
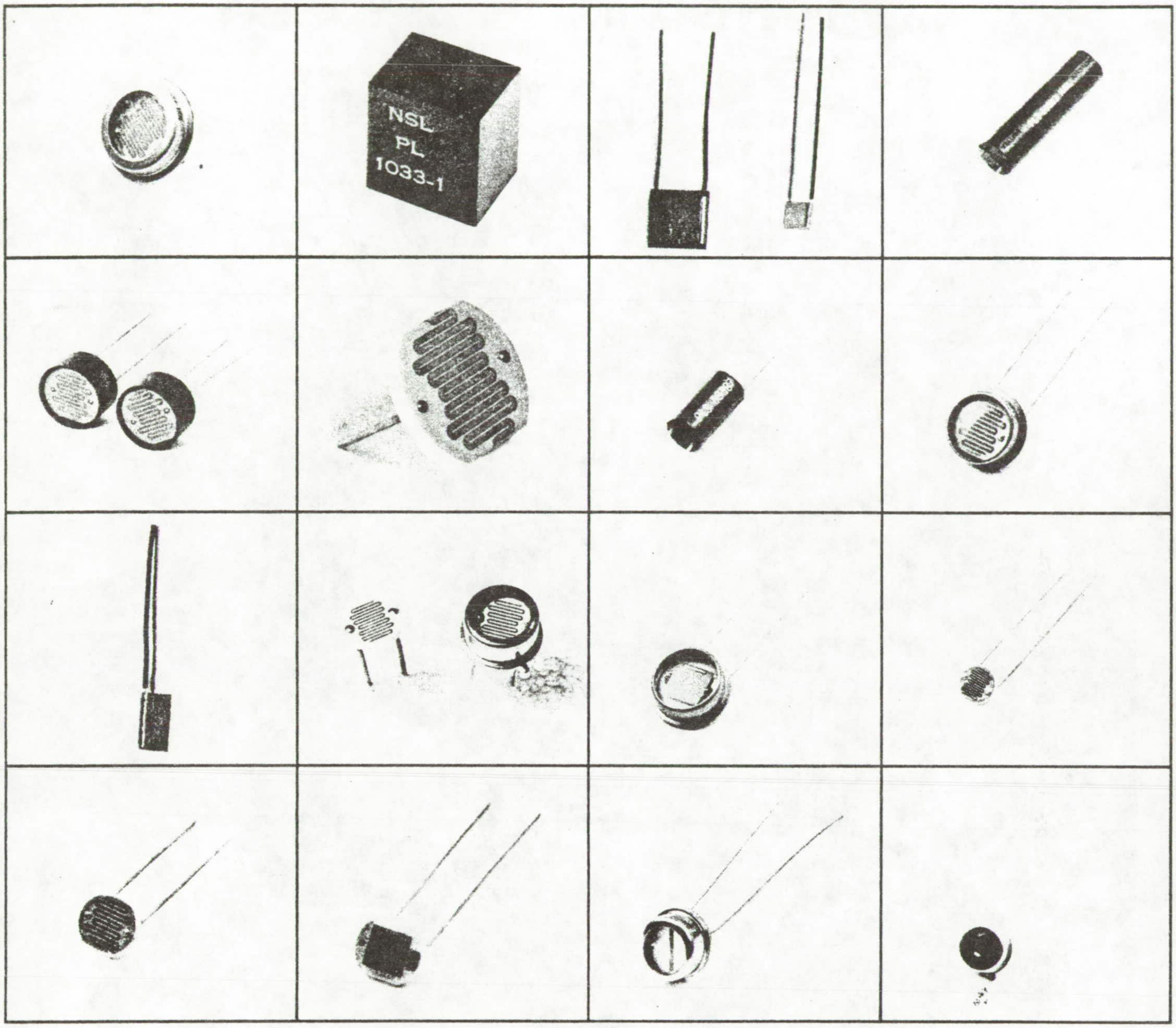


Fig. 3 Series connection of photovoltaic cells to attain higher voltage

As a result of National Semiconductors' 20 years of specialization in the photoelectric field, NSL has built up complete capability in the areas of design, manufacture and test of all types of standard and custom optoelectronic devices. Facilities include photosensitive and electrode vacuum disposition equipment, high volume activation furnaces, high speed lead attach equipment, automated multi-parameter photocell testers, photographic reduction equipment, ventilated clean benches, diffusion furnaces, die and lead bonders, automated silicon slicing equipment, ultra sonic and controlled environment welding equipment, leak detectors, wave soldering and sand blasting stations, ultra sonic cleaners, high speed printers, scribing equipment, calibrated optical bench, UV light source, LED photometer, atomic absorption spectrophotometer, light meters, microscopes, oscilloscopes, VTVMs, digital multimeters, etc.

- PHOTOCELLS
- PHOTODIODES
- PHOTOTRANSISTORS
- PHOTODARLINGTONS
- PHOTOVOLTAIC CELLS
- OPTICALLY COUPLED ISOLATORS
- OPTOELECTRONIC ARRAYS
- UV / BLUE SENSITIVE LDRs

Whether it be:
PHOTOCELLS for photoelectric smoke detectors, digital watches, water purifiers, photo-copiers, streetlight and photoelectric controls, or gas and oil flame detection: **PHOTODIODES** or **PHOTOVOLTAIC CELLS** for computer peripherals, optical character recognition, telephone facsimile, photographic, security or communication systems;
CUSTOMIZED OPTOCOUPLERS for electric heat controls, television receivers, electronic musical instruments or medical electronics;
NSL has the optoelectronic component.



REPRESENTATIVES AND DISTRIBUTORS WORLDWIDE

BULLETIN No. 15028

PRINTED IN CANADA

NSL OPTOELECTRONIC
NATIONAL SEMICONDUCTORS LTD.

TWX 610-421-3362
2150 WARD STREET, MONTREAL, QUE. H4M 1T7 TEL. (514) 744-5507
331 CORNELIA ST., PLATTSBURGH, N.Y. 12901 TEL. (518) 561-3160
ALTRINCHAM, CHESHIRE, WA14 1DR. TELEX 51 669 663 TEL. (061) 928-3417

do it the LIGHT way

SOLAR POWERED ELECTRICITY & HEAT

FROM ONE COMPACT SYSTEM

OUR UNIQUE CONCENTRATORS COLLECT MORE ENERGY

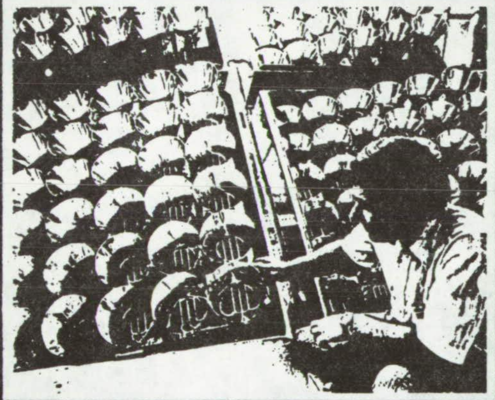
SOLECTRO THERMO INC.
1934 Lakeview Avenue
Dracut, Massachusetts
01826
(617)-957-0028

S.T.I.

S.T.I. Solar System*

SOLAR ENERGY —
A SOLUTION FOR TODAY

- It is compatible with the laws of ecology — CLEAN, NON-POLLUTING, and SAFE.
- It is INEXHAUSTIBLE — with immense potential. Enough sunlight falls on the roof of an average suburban home to supply 3 times as much energy as that home consumes. Sunrays are FREE — no one can charge you for them.
- It is CONTAINED WITHIN NATIONAL BOUNDARIES, eliminating reliance on foreign supplies.
- It is of no risk to nuclear weapons proliferation.
- It is CONDUCIVE TO DECENTRALIZATION.
- The President's Council on Environmental Quality, (CEQ) reports in "Solar Energy: Progress and Promise" . . . "It is now possible to speak realistically of the United States becoming a solar society. A goal of providing significantly more than ONE HALF our energy from solar sources BY THE YEAR 2020 should be achievable if our commitment to that goal and to conservation is strong . . . (Solar) is in fact our best hope."



WE, AT S.T.I. HAVE DEVELOPED A TRULY EXCITING LOW-COST SOLAR CONCENTRATION FOR DIRECT ELECTRICAL POWER AND THERMAL POWER. NO, YOU DON'T HAVE TO WAIT. IT'S IN USE NOW. WE CAN GIVE YOU THE VERY BEST MEANS CURRENTLY AVAILABLE TO CLAIM THE SUN.

S.T.I.
SOLECTRO-THERMO, INC.

WE'VE DESIGNED A COMPLETE SYSTEM — FOR SOLAR HEAT AND ELECTRICITY

Our collectors generate both electrical and thermal energy — a total energy system to supply a large percentage of all of your home or business energy needs. Our thermal recovery system combined with the solar reflectors, and tracking module collec... up to 75% of the available energy from the sun.

WE CONCENTRATED THE SUN'S RAYS TO GIVE MORE ENERGY

Our patented concentrators funnel up to 5 times more energy to the photovoltaic cells than standard flat plate collectors. If sol... energy levels are high, your electric meter may even run backwards (you'll be selling electricity to the power companies) or you can elect to store it in the system's batteries.

WE MAXIMIZED THE ABSORPTION OF SUNRAYS IN THE MORNING AND THE AFTERNOON

Our computerized tracking module senses the sun and move the collectors to face it.

THERMAL STORAGE

Thermal storage makes heat available on many sunless days — if needed it can be backed up automatically by a small burner.

NO FREEZING — NO POLLUTION

There's no water to freeze, no fluids to contaminate, and absolutely no pollution.

LONG LIFE EXPECTANCY — AS LONG AS 20 YEARS

Only materials of the very highest quality are used. Maintenance costs are near zero. We give a one year warranty against defec... and faulty workmanship.

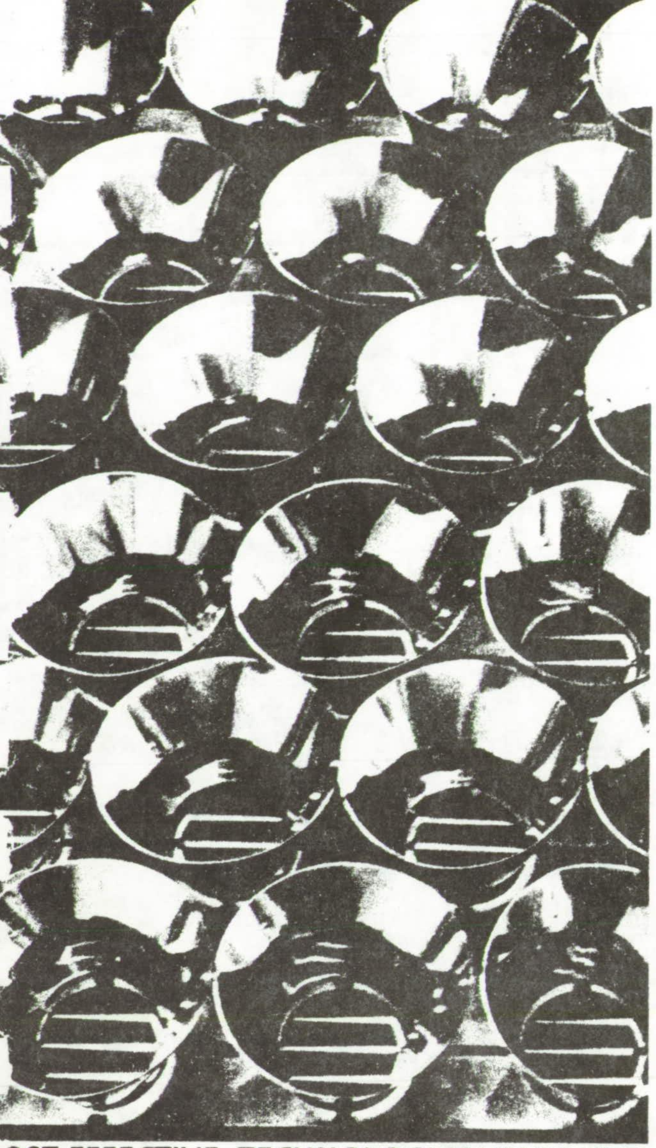
PAYS FOR ITSELF IN APPROXIMATELY 7 TO 10 YEARS

Not only will you save on heat and electricity — the new sol... energy tax credits help to make solar power a practical solution for you, today.

ADDITIONAL "PAYBACK"

The use of new solar energy saving technology is good busine... — it receives public attention and approval. Most importantl... you will have the satisfaction of knowing that you've joined the nation's efforts to conserve energy.

*U.S. PATENT 4,080,221



OST EFFECTIVE, TECHNOLOGICALLY SOUND

Unique Concentrators* collect more energy to provide you with economical Solar Heat & Electricity

S.T.I. solar systems consist, typically, of several 4 by 4 foot weather-tight modules arranged in one or more rows aligned in an east-west direction. Each module contains 33 or 36 solar cells and conical concentrators.

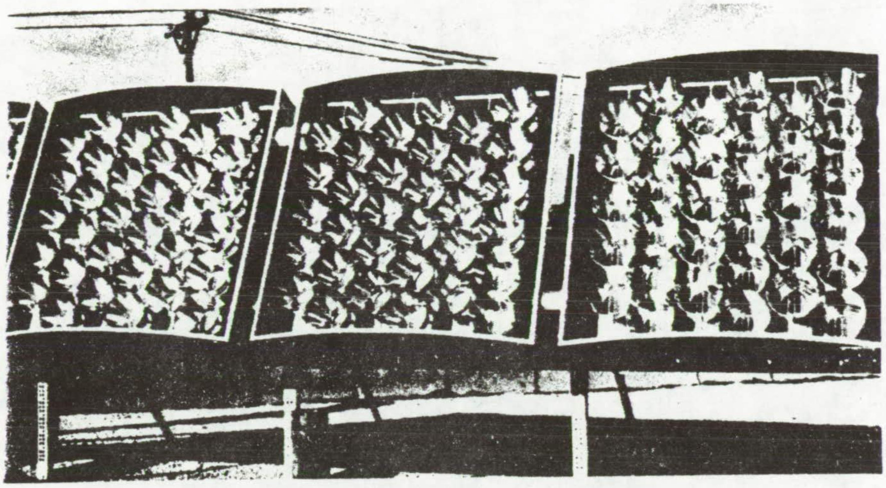
The heat normally wasted in a purely photovoltaic system is recovered in the S.T.I. modules by circulating air which is conducted to thermal storage for future heating requirements.

The electrical energy produced by the solar cells is transmitted to storage batteries, ready for use in powering your electrical needs — lights, business machines, computer, television, appliances — or even a stereo in your camper!

The S.T.I. concentrators focus approximately 5 times the amount of solar energy than flat plate photovoltaic cells would receive. This results in higher electrical output per cell, a reduction in the number of cells required, and a reduction in the cost per kwh. This **solar reinforcement** is aided by the **sunlock** capability of the concentrators which reduce the amount of energy re-radiating to the atmosphere.

The S.T.I. cell/concentrators are mounted on heat sinks that are pivoted and linked to an actuator that tilts them at the command of a computerized **sun sensor.** The sun is tracked throughout the day with three angular positions, increasing energy reception.

Fifteen S.T.I. Solar System modules were attached to garage roof rafters when this new home was built in Tewksbury, Mass. This eliminated the need for the more expensive aluminum shells and a "smooth" appearance was achieved.

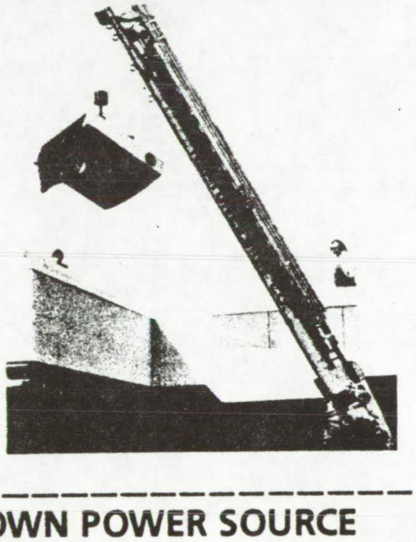


COMPUTERS ARE RUN BY THE SUN AT WESTCHESTER FEDERAL SAVINGS*
by a rooftóp
S.T.I. Solar System installation.

The system provides electricity for the bank's computer equipment in the office which computes balances and all major transactions. It provides some 200,000 BTUs of heat on a solar day.

Installation was completed in a single weekend with only two S.T.I. technicians and a crane operator. The eight, four foot square modules were quickly set into place on a prefabricated light weight but strong steel framework and aligned to the tracking system.

*Bedford Hills, New York



FEEL SECURE WITH YOUR OWN POWER SOURCE

SOLECTRO-THERMO, INC.
1934 Lakeview Avenue
Dracut, MA 01826 (617) 957-0028

We will be happy to visit your site to evaluate your particular needs and give you preliminary cost estimates.

Without cost or obligation, please arrange an appointment to discuss how the S.T.I. Solar System can benefit us.

☐ PLEASE CALL FOR AN APPOINTMENT — TEL. NO. ____________

☐ PLEASE HAVE YOUR SOLAR SPECIALIST CALL ON US

DATE ____________ TIME ____________

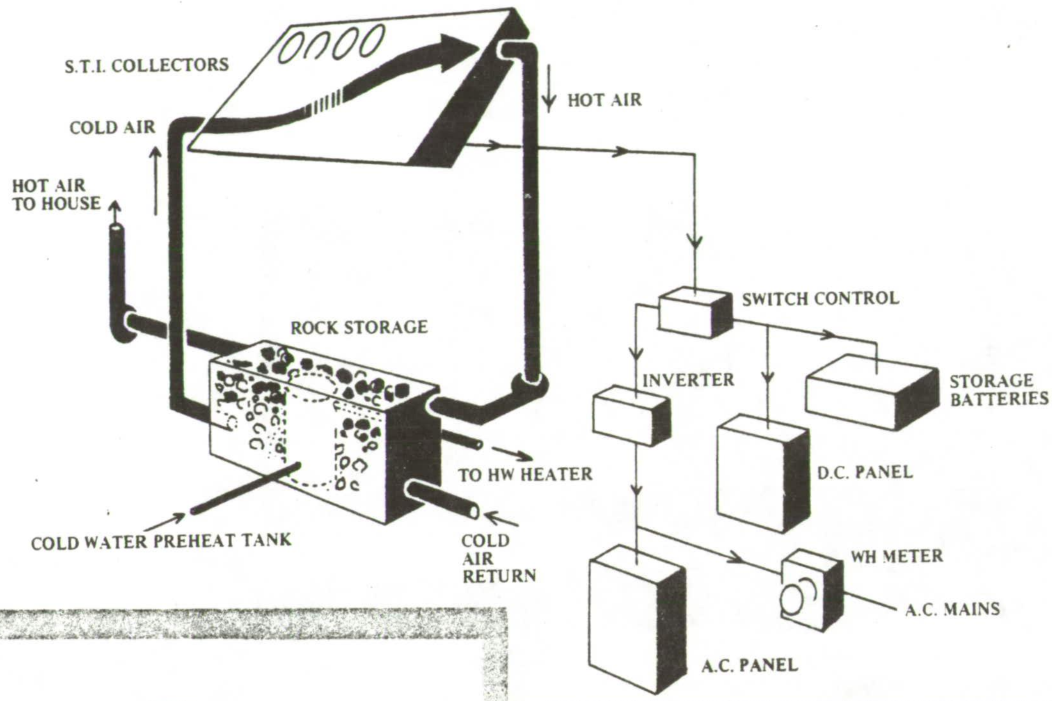
Name ____________ Company ____________

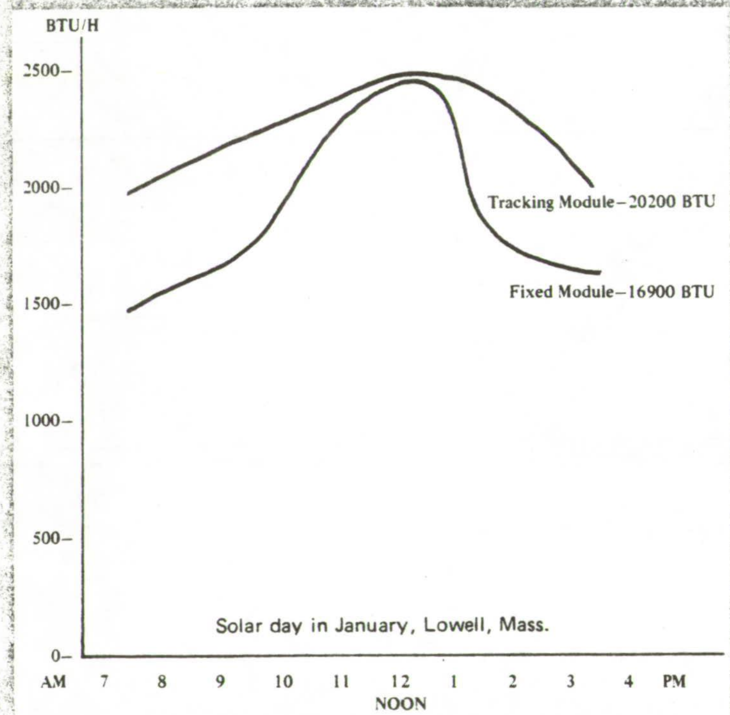
Street ____________

City ____________ State ____________ Zip ____________

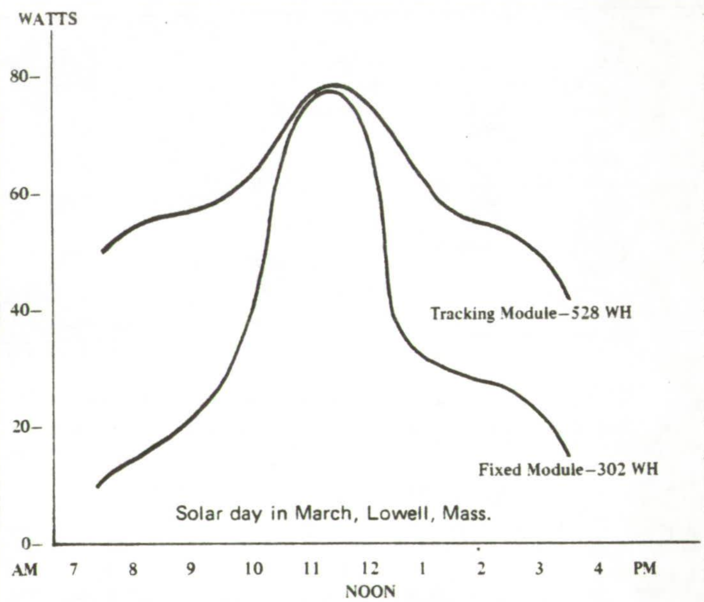
S.T.I. Solar System

- **THERMAL POWER**
- **DIRECT ELECTRIC POWER**
- **LOW COST SOLAR CONVERSION**





HEAT OUTPUT OF TRACKING AND FIXED MODULES COMPARED



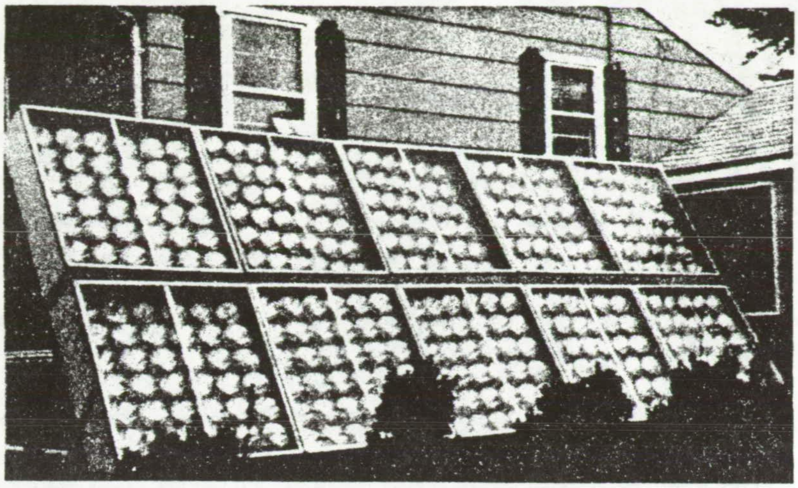
ELECTRICAL OUTPUT OF TRACKING AND FIXED MODULES COMPARED

Feel secure with your own power source. We've increased solar energy collection with our new patented concentrators. The S.T.I. system is efficient, cost effective, and technologically sound.

SOLECTRO THERMO INC.

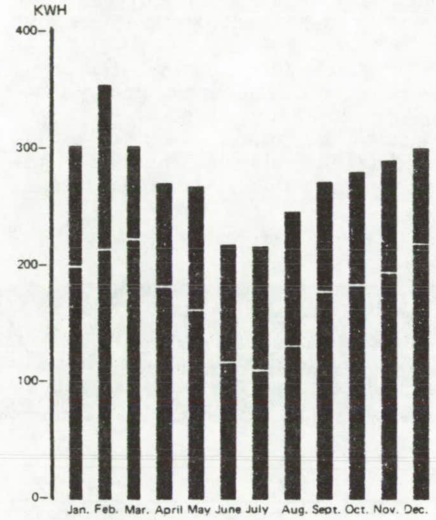
1934 Lakeview Ave., Dracut, MA 01826
(617) 957-0028

Our unique 3-position tracking system provides approximately 35% more electrical energy than our stationary system, illustrated and graphed, below:

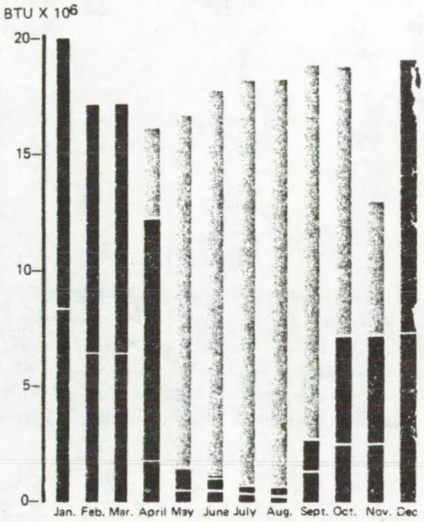


GROUND INSTALLATION

In this average six room home located in Lowell, Mass, the S.T.I. Solar System ground installation consists of 10 collectors. It provides 50 to 60 percent of daily heating and hot water and almost 36 percent of electrical needs. It has been under continuous testing for two years. (Non-tracking system)



ELECTRICAL CONTRIBUTION of an S.T.I. Solar System ground installation of 10 collectors at a home in Lowell, Mass., 1977.
SOLAR ELECTRICITY–1171 KWH–35.6%
UTILITY ELECTRICITY–2125 KWH–64%



HEAT CONTRIBUTION of an S.T.I. Solar System ground inst ation of 10 collectors at a home in Lowell, Mass., 1977.
SOLAR HEATING–66.6 MBTU–62%
UTILITY HEATING–40.7 MBTU–38%
EXCESS SOLAR HEATING–available for pool, etc.
(Utility heating shown in warm months for gas appliances.)

We would like to hear from you —

STAMP

SOLECTRO-THERMO, INC.
1934 Lakeview Avenue
Dracut, MA 01826

SILICON SENSORS, INC.
Solar Systems, Inc., Div.
Highway 18 East
Dodgeville, Wisconsin 53533
Telephone: (608) 935-2707

SILICON SOLAR CELLS

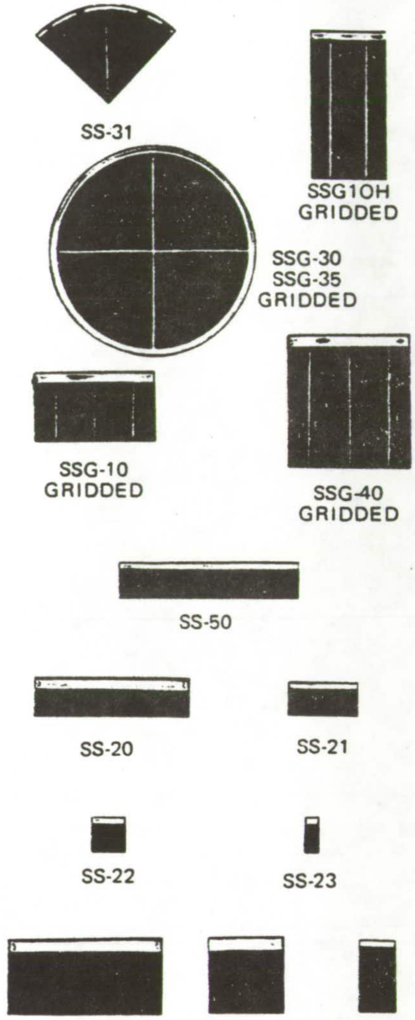
High Efficiency Photovoltaic

Converters and Detectors

TECHNICAL BULLETIN SS 1000

NOTES:

1. **MINIMUM RATINGS**: Outputs listed are the ***minimum*** that will be supplied. Average output of convertors is generally higher than values shown.
2. **THICKNESS**: Standard Converters have thickness dimensions of approximately .025".
3. **LEAD WIRES**: Converters are supplied with attached 6" color coded wires, #30 AWG polyvinyl insulated unless otherwise specified.
4. **COATING**: All converters supplied with epoxy coating unless otherwise specified.
5. **HIGHER CURRENT** can be obtained by connecting converters in parallel.
6. **HIGHER VOLTAGE** can be obtained by connecting converters in series. Units are designed to be "stacked" together.
7. **SPECIALLY SELECTED OR MATCHED CELLS** are available at additional cost.
8. **MECHANICAL TOLERANCE:** The mechanical dimensions of all converters are closely held. Mechanical specifications for any of the standard converters are available upon request.
9. **ILLUMINATION LEVEL**: Standard Converters are measured at an illumination level equivalent to 100 MW/CM^2 of energy. This is equal to the amount of energy that strikes the earth on a sunny cloudless summer day at noon time, (1 sun).
10. **CONVERSION EFFICIENCY** may be determined by the ratio of power output (in milliwatts per photo-active area) to power input (in milliwatts per cm^2). High efficiency converters are available for use with space projects and other special applications.
11. **N-P TYPES**: Optional.
12. **GRIDDED CONVERTERS**: Optional.



TUNGSTEN LIGHT SOURCE ILLUMINATION EQUIVALENT TO 100 MW/CM^2 COLOR TEMPERATURE OF 2800°K						
STANDARD TYPE NUMBERS	OVERALL DIMENSIONS cm x cm	PHOTO-ACTIVE AREA cm^2	AVERAGE WEIGHT grams	CURRENT OUTPUT ma	VOLTAGE OUTPUT volts	POWER* OUTPUT mw
SS-10	1 x 2	1.8	.25	28	.4	11.2
SS-11	1 x 1	.9	.12	14	.4	5.6
SS-12	1 x .5	.45	.06	7	.4	2.8
SS-20	.5 x 2	.8	.15	12	.4	4.8
SS-21	.5 x 1	.4	.07	6	.4	2.4
SS-22	.5 x .5	.2	.03	3	.4	1.2
SS-23	.5 x .25	.1	.015	1.5	.4	.6
SS-30	1-1/8"diameter	4.8	.82	75	.4	30
SS-31	1/4 of SS-30	1.2	.20	18	.4	7.2
SS-35	2" diameter	17.3	3.0	300	.4	120(min)
SS-40	2 x 2	3.8	.50	60	.4	24
SS-50	.5 x 2.5	1.0	.17	15	.4	6.0

APPLICATIONS:

Use and design of Solar Energy Converters is quite simple. For most applications, the designer must know the following information:

1. Output voltage requirements
2. Output current requirements
3. Illumination level and type of light source
4. Area available for converters

Consideration can also be given to speed of response, environmental conditions, mounting, packaging and other factors depending upon the application. Use of the data in this brochure will allow choice of a proper converter for your application.*

Solar Energy Converters are used basically in the following application categories:

1. **Photo-Electric**: Light is used to activate control mechanisms.
2. **Read-Out**: Converters arranged in mosaic patterns 'read-out' information from punched cards and tapes.
3. **Power**: Conversion of light energy directly into d.c. power, normally stored in rechargeable batteries.

The long life, instant response, high reliability characteristics of Solar Energy Converters make them desirable components in systems. Since they are photo-voltaic semi-conductors, no external power supplies are required, and the amplification of converter output is readily achieved with use of a simple transistor circuitry.

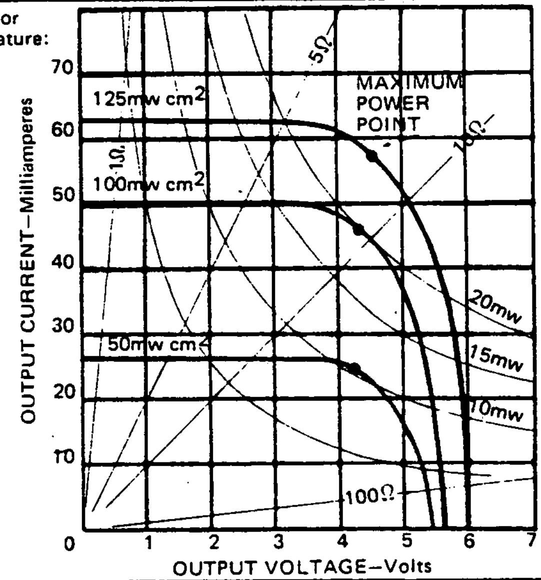
SILICON SENSORS, INC. Engineering Department and Field Sales Engineers are available to work with you on your specific requirements.

DESIGN DATA

- **SPEED OF RESPONSE**: The response time is 20 microseconds or less dependent upon the load resistance.
- **REVERSE VOLTAGE**: The converter can be designed to operate with reverse voltage. Bias voltage should not exceed -10.0 volts d.c. Special converters can be supplied to operate at higher reverse voltages.
- **LIFE**: Life expectancy of converter is essentially unlimited when operated within recommended specifications and properly protected against mechanical forces and corrosive environments.
- **HUMIDITY**: When used at 100% humidity and extremely high temperatures, the converter should be protected by an encapsulation. Special cases are available for such applications.
- **AGING**: No aging or fatigue will result when the converter is used within the recommended operating range.
- **TEMPERATURE:** The recommended operating temperature range is -65°C to +175°C.
- **PRESSURE**: No degradation in performance will result when the converter is subjected to large pressure variations.
- **SHOCK AND VIBRATION**: By proper mounting the converter will withstand all rigorous shock and vibration forces. Mechanical forces applied directly to the surface of the converter can possibly cause fracture since the strength of the unit is similar to that of quartz glass. Encapsulations are available to prevent such mechanical destruction.

Convertor Temperature: 25°C

FIG. 1



CURRENT–VOLTAGE CHARACTERISTICS FOR TYPICAL SOLAR ENERGY CONVERTERS

OUTPUT VOLTAGE: Open-circuit voltage varies logarithmically with illumination. Output voltage developed across a load is independent of converter area and is a function of illumination level and load resistance.

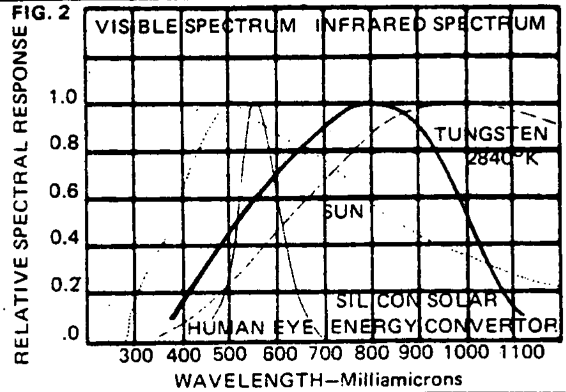
OUTPUT CURRENT: The short-circuit current varies linearly with illumination. The output current developed into a load is a function of converter photosensitive area, load resistance and illumination level.

LOAD CONDITIONS: Maximum power transfer can be achieved by choosing a load impedance the results in the voltage and current combination that yields maximum output power.

For large current changes with change in illumination level, low impedance loads should be chosen. Figure 1 indicates the linearity of current with illumination at low values of load impedance.

Small change in voltage with change in illumination is achieved by use of high impedances. Such voltage changes have an essentially logarithmic relation to illumination level change, as shown in Fig. 1.

FIG. 2

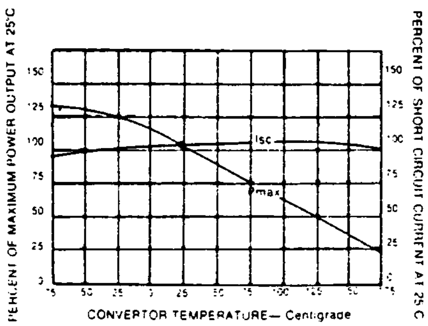


RELATIVE SPECTRAL RESPONSE OF SILICON SOLAR ENERGY CONVERTERS AND ILLUMINATION SOURCES

SPECTRAL RESPONSE: The curve in Figure 2. shows the response of the Solar Energy Converter in the visible and infra-red range. The characteristic allows for converter use in photographic and infra-red detector applications.

ILLUMINATION SOURCES: A light source must have a spectral energy distribution which is similar to the converter response. Fig. 2 shows that both sunlight and tungsten light (at a color temperature of 2840°K) are suitable for use with Silicon Converters. Fluorescent light results in low output from these Converters.

FIG. 3



TYPICAL VARIATION OF MAXIMUM POWER OUTPUT AND SHORT CIRCUIT CURRENT WITH TEMPERATURE

TEMPERATURE CHARACTERISTICS: The short-circuit current and the output current for maximum power are essentially constant over the operating temperature range of the Converter. The open-circuit voltage and output voltage for maximum power decrease linearly with increasing temperature. Fig. 3 shows the variation of short-circuit current and maximum available power over the operating temperature range.

SILICON SENSORS, INC.
Solar Systems, Inc., Div.
Highway 18 East
Dodgeville, Wisconsin 53533
Telephone: (608) 935-2707

PHOTOVOLTAIC PANEL ARRAYS

2.0 - 36.0 Volts

0.04 - 1.0 Amps

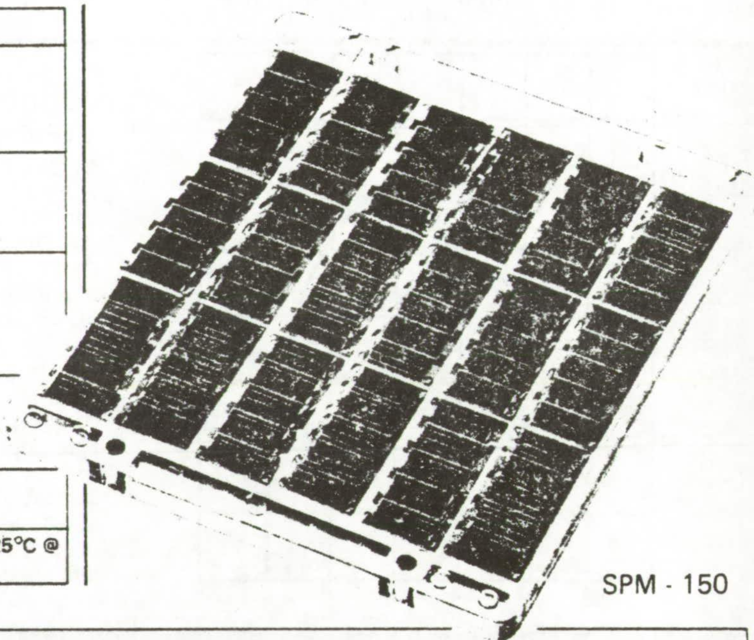
TECHNICAL BULLETIN SPM 1400

SOLAR POWER MODULES

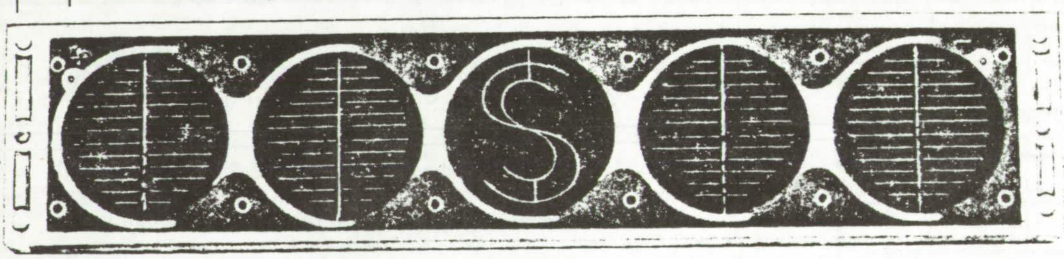
Silicon solar cells convert sunlight directly into electricity. The silicon solar cell technology was pioneered for space power applications and now has become widely adapted to earth use in such applications as power sources for monitor and control devices in reservoir level gauges and telephone repeaters, navigational beacons, climatological data recording and transmitting stations, fire control stations and transmission relay stations.

ELECTRICAL SPECIFICATIONS	
SPM-75-2	2V. *320MA
SPM-75-4	4V. 160MA
SPM-75-8	8V. 80MA
SPM-75-16	16V. 40MA
SPM-100-2	2V. 480MA
SPM-100-4	4V. 240MA
SPM-100-12	12V. 80MA
SPM-100-24	24V. 40MA
SPM-150-2	2V. 720MA
SPM-150-6	6V. 240MA
SPM-150-12	12V. 120MA
SPM-150-18	18V. 80MA
SPM-150-36	36V. 40MA
SPM-200-6	6 0V 180MA
SPM-200-18	18 0V 60MA
ECONOMY - 1 Watt (Min.) PANELS	
SPM-150-3.6	3.6V 300MA
SPM-200-2	2.0V 400MA

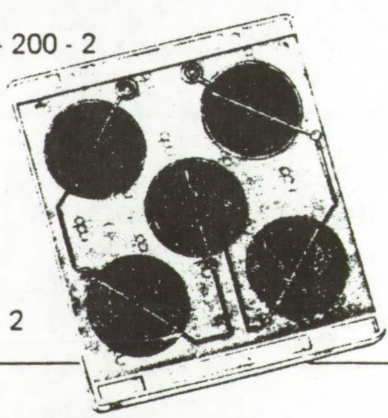
*All current values listed above are nominal @ 2800°K and 25°C @ 100mw/cm tungsten, and minimum under sunlight.



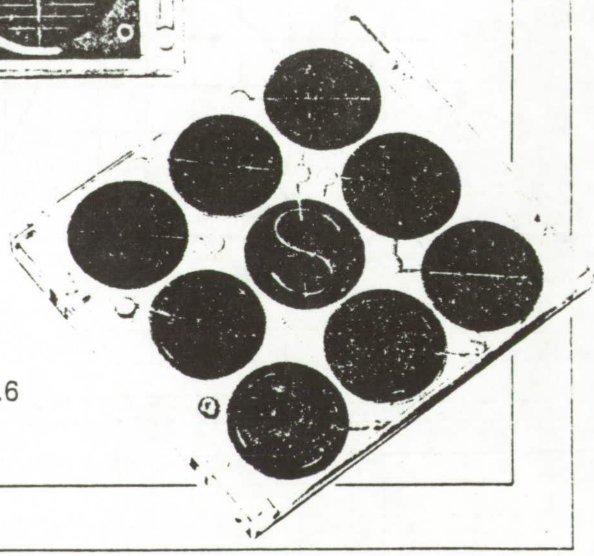
SPM - 150



SPM - 200 - 2



SPM - 150 - 2



SPM - 150 - 3.6

SILICON SENSORS, INC. Engineering Department and Field Sales Engineers are available to work with you on your specific requirements.

PHYSICAL CHARACTERISTICS

The silicon solar cells in each panel are totally encapsulated in transparent silicon rubber within a Lexan case. The Solar Systems modules have been designed to operate and endure severe thermal and physical shock and resist moisture and abrasion. Mounting holes are located on each end of the module. Termination is optional, choice of either wires or studs.

EFFECTS OF TEMPERATURE

The panel power (P max) varies with temperature. See the graph titled "Convertor Temperature - °Centigrade" on the front page. The output power (P max) and voltage drops when the panel temperature rises while the short circuit current (I_{sc}) remains relatively constant. Similarly the power output (P max) and voltage increases with temperature while the I_{sc} remains almost the same.

CURRENT/VOLTAGE

The "Power Module Current/Voltage" graph (see front page) denotes the extremes of output current vs. voltage and minimum power point for the SPM–150 series of panels. The current/voltage curve can similarly be plotted for any of the modules in the SPM-75 and SPM-100 series. See the table of "Electrical Specifications" for the detail electrical data on all the modules.

EFFECTS OF TIME

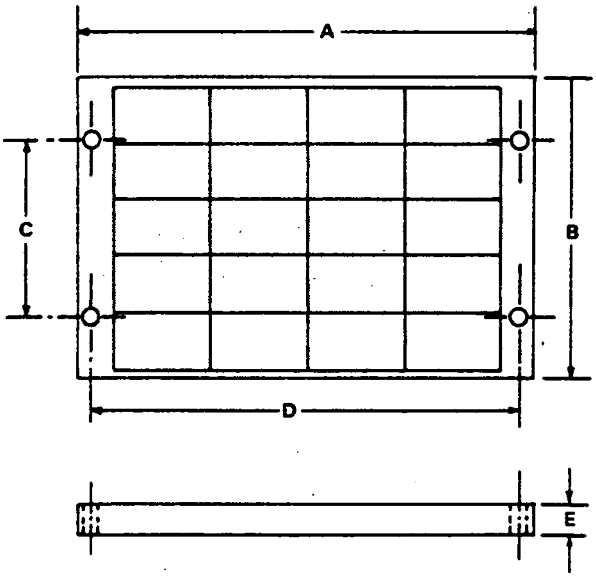
The output of a solar module varies according to the time of day and the incidence angle of the sun. The variation in module output is also affected by temperature and air mass.

The angle of incidence determines the amount of parallel light striking the module surface. When the incidence angle is zero (module is oriented so that the sun is normal to the module), maximum energy conversion is achieved. When the angle of incidence varies, the output varies by an amount approximately equal to the cosine of the incidence angle.

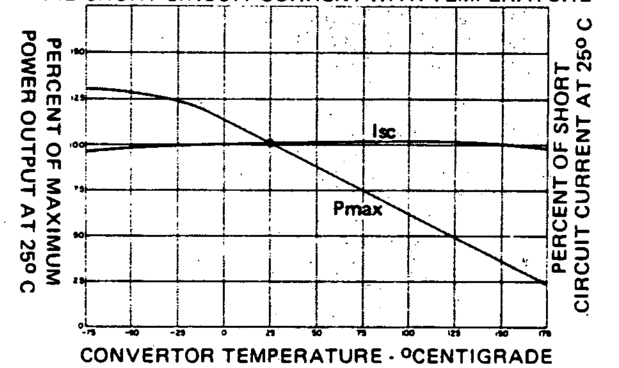
Air mass between the sun and a given point on earth changes with earth rotation. Air mass and its attenuation of solar energy reaching the earth's surface affects the energy output of the module. The greatest solar intensity occurs at noon when the air mass is lowest.

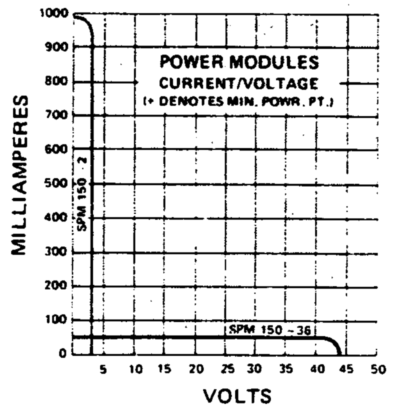
PHYSICAL DIMENSIONS

	A	B	C	D	E
SPM-75	5.750	4.820	2.820	5.150	0.440
SPM-100	7.710	4.820	2.820	7.250	0.440
SPM-150	8.000	7.000	4.000	7.400	0.440
SPM-200	14.50	3.600	2.750	13.000	0.440



TYPICAL VARIATION OF MAXIMUM POWER OUTPUT AND SHORT CIRCUIT CURRENT WITH TEMPERATURE





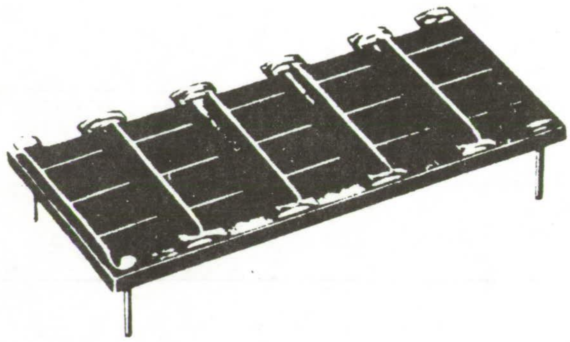
SOLAR SYSTEMS, INC.

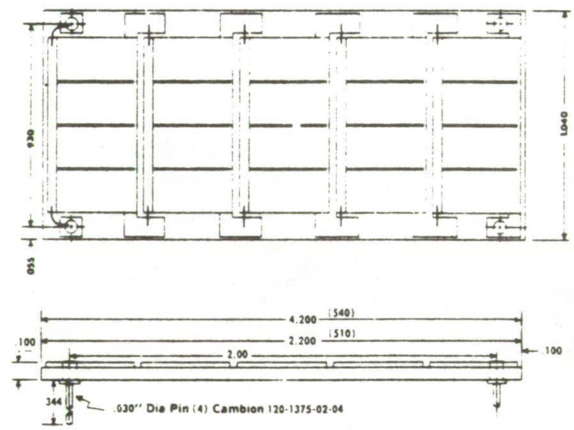
DIV. OF **SILICON SENSORS, INC.**

Highway 18 East
Dodgeville, Wisconsin 53533
608 - 935-2707

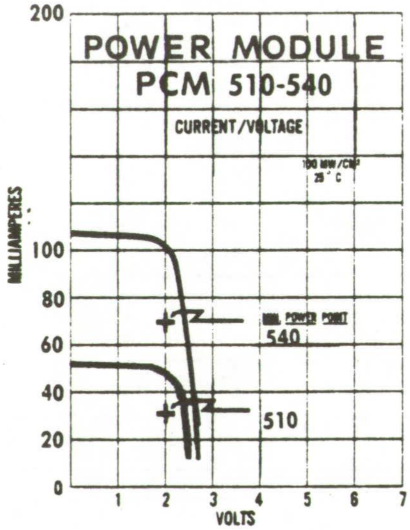
POWER - MOD

PCM 510
PCM 540



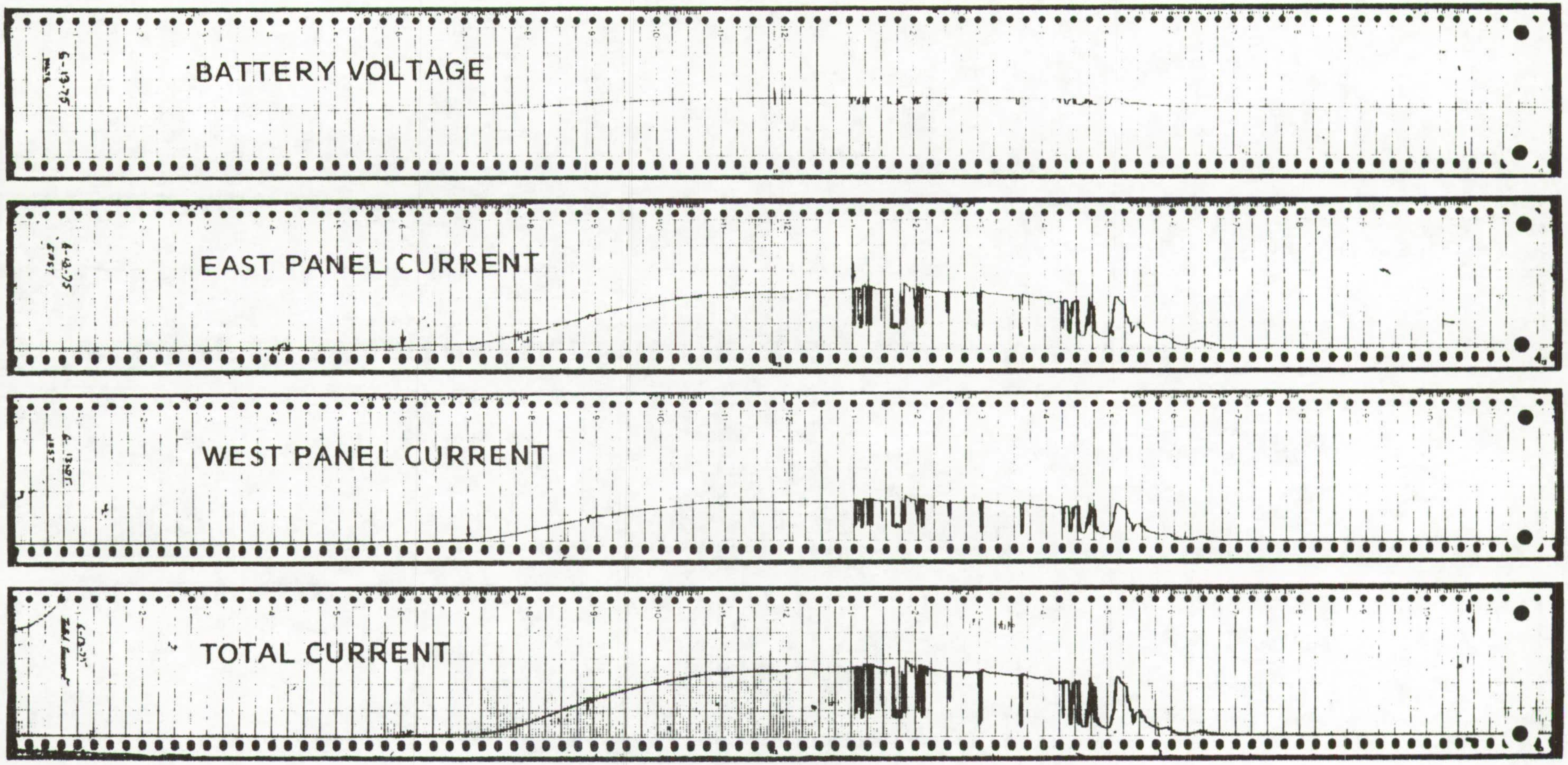


PHOTOVOLTAIC POWER CURVE



SOLOR SYSTEMS "POWER-MOD" provides instant electrical energy from sunlight and incandescent light sources. Light falling on the surface of the unit is converted directly into electricl energy. These units are compact in form, designed for easy installation and use, and are readily wired in series or parallel arrangements. The unique design of this unit allows maximum power per unit area. The 4 terminals are plainly marked for polarity and the entire unit is coated with a clear epoxy to protect the unit from dirt, moisture and surface damage. Appearance, quality and rugged construction provide the "POWER-MOD" PCM510 and PCM 540 with a lifetime guarantee of satisfaction.

SOLAR SYSTEMS, INC.
DIV. OF SILICON SENSORS, INC.
Highway 18 East
Dodgeville, Wisconsin 53533
608 - 935-2707



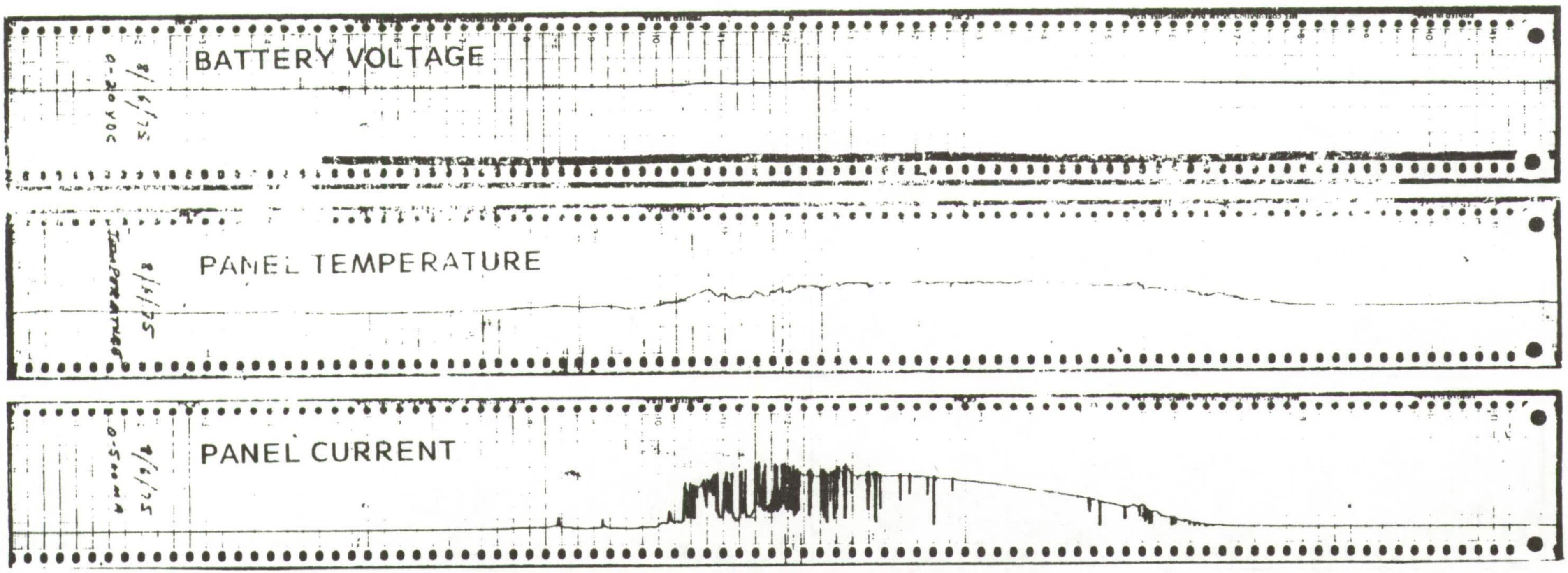
SPS 6-12

Strip chart recordings of battery voltage and total current output.

SOLAR SYSTEMS, INC.

DIV. OF **SILICON SENSORS, INC.**

Highway 18 East
Dodgeville, Wisconsin 53533
608 - 935-2707



SPS 12-¼

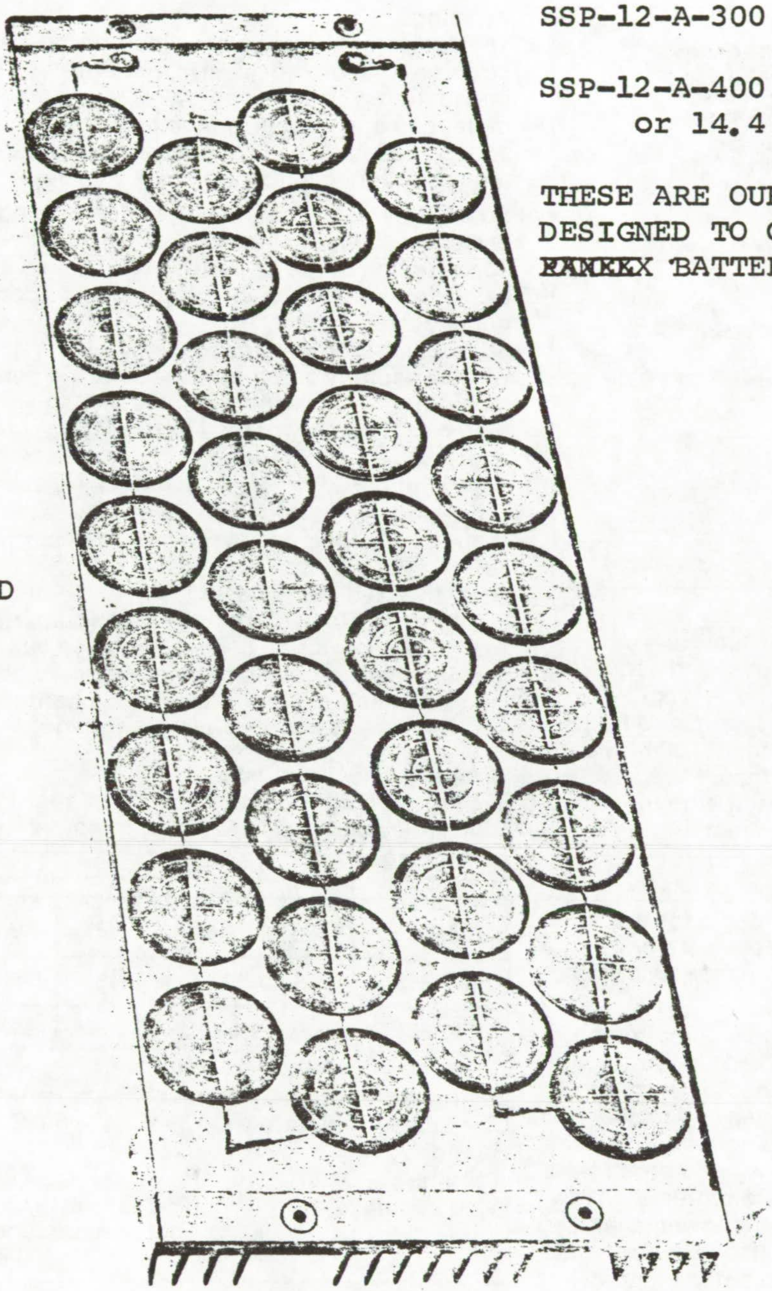
Recordings of Battery voltage, panel temperature, and panel current.

SSP12-A-400

MOUNTING HOLES

ALUMINUM SUBSTRAIT

GLASS COVERED



SSP-12-A-300 = 12V @ 300 ma

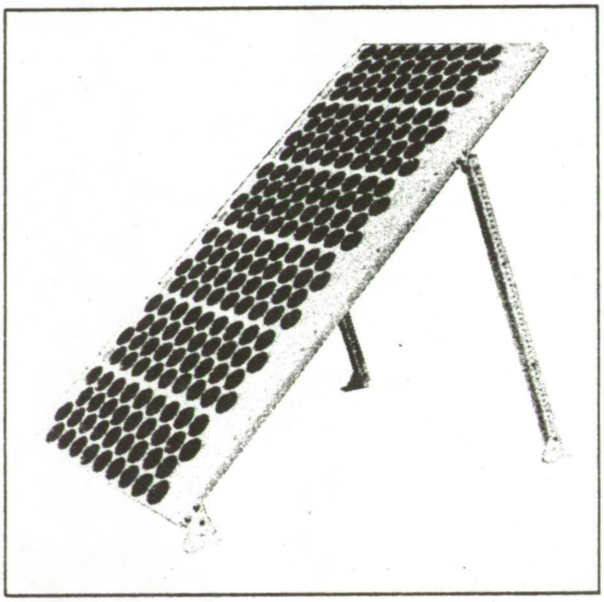
SSP-12-A-400 = 12 V. @ 400 ma
or 14.4 V @ .4 amps

THESE ARE OUR LATEST PANELS DESIGNED TO CHARGE A 12V LEAD ACID RANKEX BATTERY.

Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

"M" Series Solar Electric Generators



"M" Series Solar Modules

The new M-Series Solar Modules feature a unique construction that affords a practical and economical solution for a wide range of power requirements. Utilizing Solar Power Corporation's larger diameter silicon solar cells (90mm or 100mm) and unique reinforced mounting surface, the M-Series Solar Modules feature two layers of silicone encapsulant, a blocking diode, and ten feet of output cable.

Thirty-six interconnected cells are arranged in recessed wells on a rugged, molded base made of glass reinforced polyester. A 40 cell version is also available. 12V, 6V, and 4V outputs may be ordered in either version.

The 90mm solar cells use a "dagger" electrode and the 100mm solar cells use a "forked" electrode grid pattern with redundant interconnects. Both are designed to maximize the M-Series solar cell current collection efficiency and collection area of the solar cell, while minimizing voltage drop in the electrode. M-Series solar cells are protected by two layers of silicone encapsulant. The lower layer is a highly transparent, UV-stable silicone rubber that seals and protects the cells. The outer encapsulant is a highly transparent, UV-stable silicone varnish selected for low friction to shed dirt, dust, and precipitation. All interconnections in the solar module are either soldered or screwed down to the mounting base. The connections are also encapsulated for corrosion resistance.

A low voltage drop blocking diode is built into the M-Series solar units to prevent storage battery discharge through the solar module at night or during low illumination periods. Ten feet of neoprene-jacketed, two conductor output cable is also provided. This Type SJO cable is resistant to oil, grease, water, acids, and ozone.

Arraying

The design of M-Series base incorporates a molded rib structure that provides sufficient stiffness to allow field installation without extensive external bracing. Arrays requiring more than one module are bolted together and stiffeners are added to each side. A layout for six (6) M-Series modules arrayed in this fashion is shown on reverse side of spec sheet.

Solar Power Corporation will supply complete solar arrays with stiffeners, telescoping support legs and footpads. The construction of the M-Series module also allows the user to easily fabricate his own structure using commonly available materials.

Solar Electric Generator Systems

SPC can supply complete solar electric generator systems including self-arraying modules, voltage regulators, and batteries. You may order a total system, or individual arrays and modules.

High quality rechargeable batteries are used to allow operation at night and in periods of inclement weather. All modules and systems are designed to provide peak current at the charging point of the battery.

Computerized System Design

Solar Power Corporation provides a computerized system design and quotation service based on customer load specifications. Information necessary to provide a quotation includes electrical load (AH/day), location (altitude, latitude, longitude), and nominal system voltage.

Electrical Specifications

Exceeds JPL Environmental Performance Requirement No. 5-342-1. Output rated at 28°C cell temperature and 100mW/sq. cm.

Model No.	Charging Point*		Peak Power Point		Peak Power
	Volts	Amps	Volts	Amps	Watts
M12-369	13.6	1.62 ±10%	16.5	1.52 ± 10%	25.0 ±10%
M12-361	13.6	2.0 ±10%	16.5	1.90 ± 10%	31.0 ±10%

*Lead acid battery at or near full charge.

Environmental and Mechanical Specifications

Operating Temperature: -55°C to +60°C
Humidity: 0 to 100%
Altitude: to 25,000 ft. (7620 m)
Wind Loading: Module with supporting structure built to withstand winds in excess of 175 m.p.h. (280 k.p.h.)

Model No.	Dimensions						Weight*			
	L		W		D		Net		Ship	
	In.	cm.	In.	cm.	In.	cm.	lb.	kg.	lb.	kg.
M12-369	46	117	15.3	38.9	2	5.1	18	8.2	30	13.6
M12-361	46	117	15.3	38.9	2	5.1	18	8.2	30	13.6

*Excluding support legs, stiffeners, and footpads.

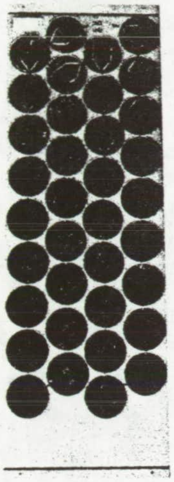
Solar Insolation Effect

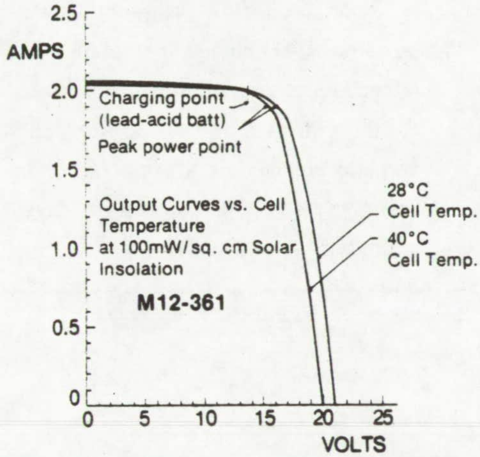
Voltage: Operating voltage attained at approximately 10mW/sq. cm. (dark overcast sky).

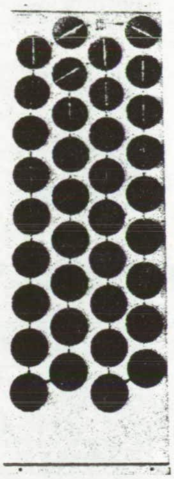
Current: Proportional to solar insolation, e.g. at 50mW/sq. cm. output current would be 50% of rated current.

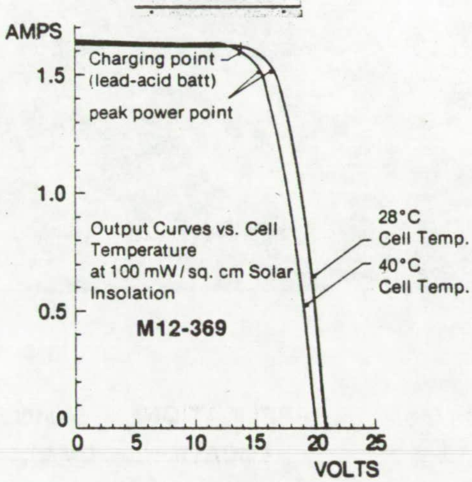
OUTPUT CHARACTERISTICS

Current vs. Voltage curves are shown for each M Series solar generator indicating peak power point and charging point for a lead-acid battery system. Curves are drawn for various cell and ambient temperatures at 100 mW/sq. cm. solar insolation.









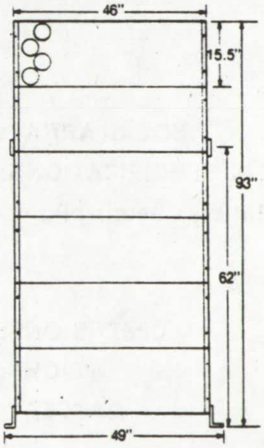
ORDERING CODE EXPLANATION

M 12- 01 369

- 369 → Module Utilized
- 01 → Number of Modules in Array
- 12 → System Voltage
- M → Product Type

NOTE: 6V and 4V "M" Series modules are also available.
Please consult factory for specifications.

MULTIPLE UNIT M-SERIES ARRAY
[Model M12-06361/9]



Solar Power Corporation Affiliate of EXXON Enterprises, Inc.

20 CABOT ROAD, WOBURN, MASSACHUSETTS 01801, TELEPHONE (617) 935-4600 TWX 710-348-0602

Branch Offices: Solar Power Limited 110-111 Strand London WC2R OAA England Tel.#01-836-8918 Telex 24973

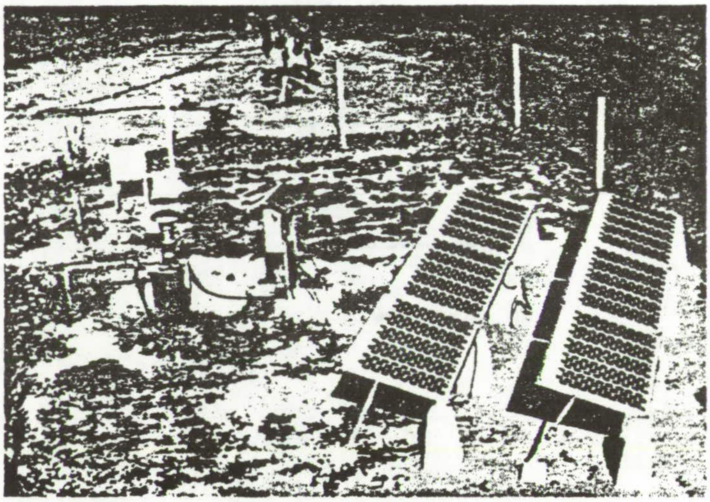
Solar Power Corporation One Kingwood Place Suite 200 Kingwood, Texas 77339 Tel.#713-358-3126

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

20 Cabot Road, Woburn, MA 01801 Tel. (617)935-4600 TWX 710 348-0602

WATER PUMPING
APPLICATION BULLETIN — No. 61



"M" SERIES SOLAR POWER SYSTEM

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fuel requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

APPLICATION: Water Pumping
LOCATION: Mali, Africa
VOLTAGE: 36 Vdc nominal
LOAD: 5660 gallons/day, 24-foot well depth, 6-8 hours/day

SOLAR ARRAY: M36-30361
ELECTRICAL SPECIFICATIONS: 49.5 Vdc, 19.0 A, 940 W
(At Battery Charging Point)

DIMENSIONS: 232" x 92" x 2"
WEIGHT: 750 lbs., including mounting hardware
BATTERY: Not required, water storage used

INSTALLED: Spring 1978

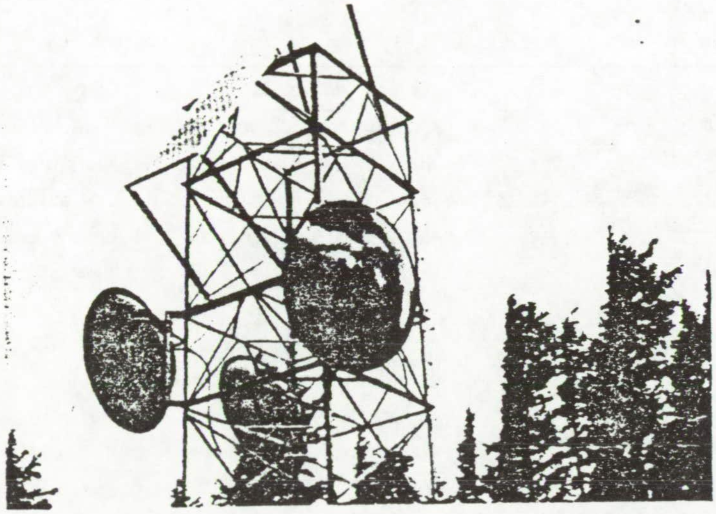
September 1978

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

COMMUNICATIONS
APPLICATION BULLETIN — No. 62

20 Cabot Road, Woburn, MA 01801 Tel. (617)935-4600 TWX 710 348-0602



"M" SERIES SOLAR POWER SYSTEM

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fuel requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

APPLICATION: Microwave Communications Repeater
LOCATION: Tacoma, Washington
VOLTAGE: 24 Vdc nominal
LOAD: 51 Ah/day

SOLAR ARRAY: Model M24-14361
ELECTRICAL SPECIFICATIONS: 27.6 Vdc, 14 A, 386 W
(At Battery Charging Point)

DIMENSIONS: 217" x 47" x 2"
WEIGHT: 325 lbs., including mounting hardware
BATTERY: 2807 Ah, 24 Vdc, lead-acid type with lead-calcium plates

INSTALLED: Winter 1977

September 1978

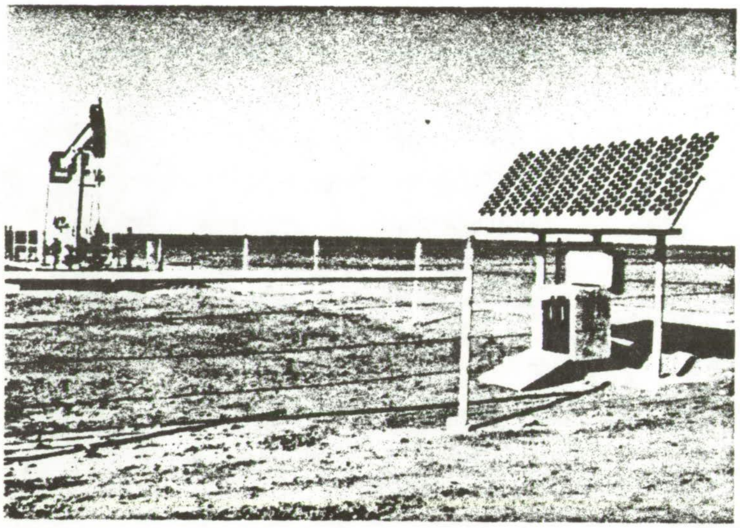
Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

APPLICATION BULLETIN

No. 58

CATHODIC (CORROSION) PROTECTION



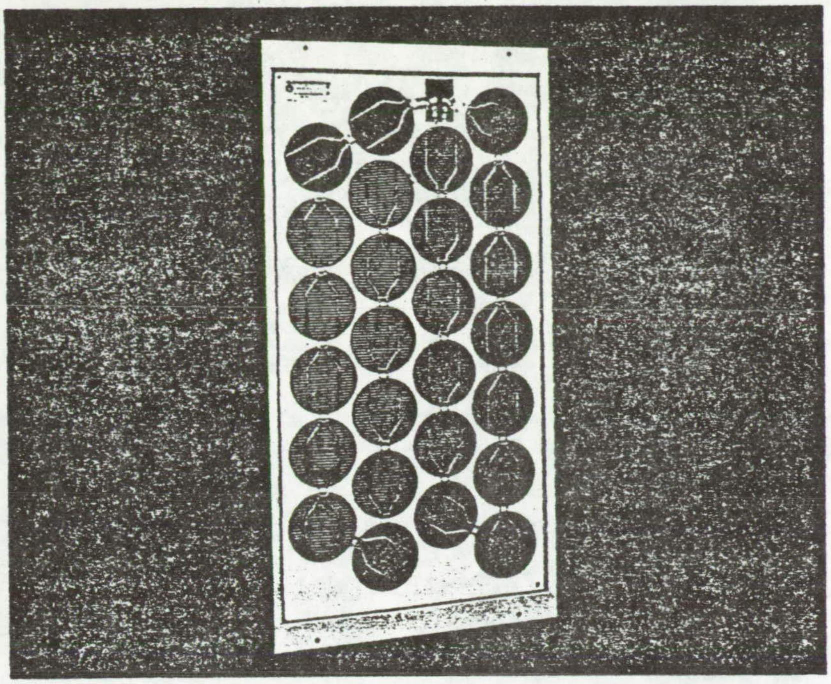
MODEL "SERIES M"

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance-free operation, no fueling requirement, and no pollution-producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are impervious to environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

APPLICATION:	Cathodic Protection System - Oil Well
LOCATION:	Liberal, Kansas
VOLTAGE:	6.0 VDC Nominal
LOAD:	7.0 Amps Continuous
	TOTAL LOAD: 168 AH/DAY
SOLAR ARRAY:	Model M6-08361; Charging Point
	7.2 VDC
	32.0 Amps
	230. Watts
DIMENSIONS:	124" x 46.5" x 2" (array only)
WEIGHT:	Approximately 165 lbs (array only)
BATTERY:	1925 AH, 6 VDC (3 cells)
	Lead-calcium cells
TILT ANGLE:	50° from horizontal

SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES: Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 • Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126

April 1979



Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

G-Series
PRODUCT DATA

G4-261 Solar Electric Generators

The Model G4-261 solar module consists of twenty-six (26), 100mm diameter silicon solar cells connected in series in a module package that features a glass top module surface. The top module surface material is a low iron, high transmission, tempered glass that provides a durable cover. The glass surface gives the module the capability to withstand salt spray, sand storms, hail stones, and attack by birds and vermin with minimal degradation of electrical performance.

Low iron glass was selected for its characteristically high light transmittance. Tempering increases the impact strength of the glass. The top surface of the glass module is glossy, thus preventing the buildup of debris on the module.

The solar cells are bonded to the glass sheet with silicone rubber. The silicone seals the solar cells and the electrical interconnections from the environment. Silicone has been chosen for various reasons including high light transmission, long term environmental stability, excellent electrical insulation properties, and the ability to resist degradation due to UV radiation.

The silicone/solar cell combination is covered at the rear surface by a white plastic film.

The 100mm diameter solar cells are produced from high purity, single crystal silicon wafers. The wafer initially doped with an "n", or negative, charge donor impurity has a "p", or positive, charge donor impurity diffused into the top layer of the wafer to form the p-n junction. Electrodes are attached to the top and bottom surfaces of the solar cells to collect the electrical energy. The bottom surface is completely covered by an electrode. The electrode pattern used on the top surface of the 100mm solar cell consists of a number of small conductor "fingers" criss-crossing the wafer and connecting to a tapering bifurcated main bus. This pattern has been designed to provide maximum surface area for light collection while providing a low resistance, efficient electrical conductor, and completely reduntant cell-to-cell electrical interconnections.

Individual modules are supplied with an output cable and blocking diode, or bypass diode, as required. The diodes and the connectors to the output cable are sealed in a glass reinforced phenolic junction box located in the rear of the module. (An optional galvanized steel screen is available to cover the rear of the module to protect the encapsulants from damage due to animals or birds.)

The module is supplied with an anodized aluminum support frame. The glass, solar cell, and silicone assembly is held in the glass frame by a one piece silicone gasket. The gasket isolates the glass assembly from shocks transmitted through the frame.

SPECIFICATIONS

Electrical

	Battery Charging Point	Peak Power Point
Current:	4.30 Amps ±10%	4.10 Amps ±10%
Voltage:	4.60 Volts	6.0 Volts
Power:	19.8 Watts ±10%	24.6 Watts ± 10%

Output rated at 28°C cell temperature and 100mW/sq. cm incident sunlight. Charging point based on 4-volt lead-acid battery near full charge. Peak power values do not include cable and blocking diode losses.

Structural

WEIGHT: excluding supporting legs
16 lbs (7.3 Kg)

OVERALL DIMENSIONS: excluding supporting legs.
34" x 17" x 2.25"
(86.4 cm x 43.2 cm x 6 cm)

Environmental

OPERATING TEMPERATURE:
-55° to +60°C

HUMIDITY: 0 to 100%

ALTITUDE: to 25,000 feet (7,620m)

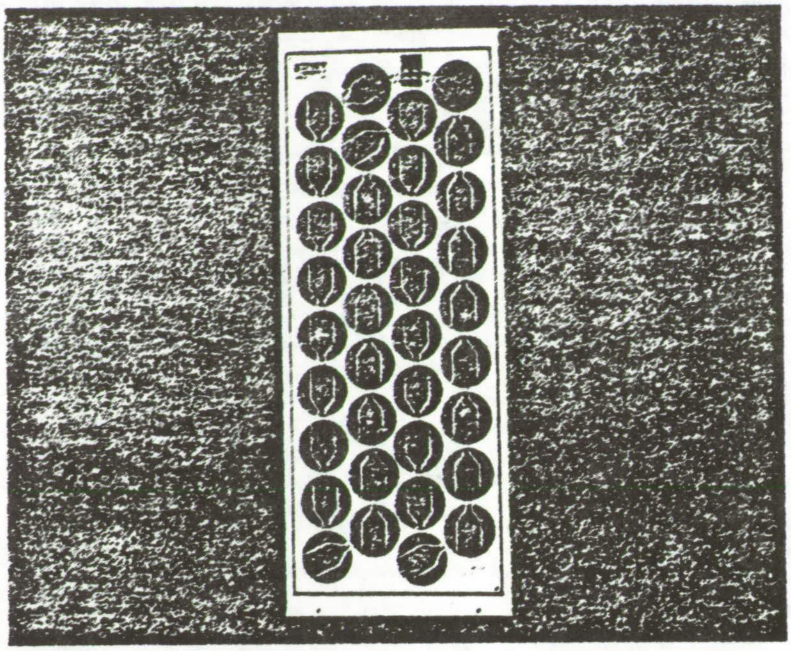
WIND LOADING:
Module with supporting legs built to withstand sustained winds in excess of 175 mph (280 Km/hour) (90 lbs/sq. ft.)

Solar Insolation Effect

VOLTAGE:
Operating voltage attained approximately 10m/Wsq cm (dark overcast sky)

CURRENT:
Proportional to solar insolation; e.g. at 50mW/sq cm, output current would be 50% of rated current.

SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES: Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 • Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126



Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

G-Series

PRODUCT DATA

G12-361 Solar Electric Generators

The Model G12-361 solar module consists of thirty-six (36), 100mm diameter silicon solar cells connected in series in a module package that features a glass top module surface. The top module surface material is a low iron, high transmission, tempered glass that provides a durable cover. The glass surface gives the module the capability to withstand salt spray, sand storms, hail stones, and attack by birds and vermin with minimal degradation of electrical performance.

Low iron glass was selected for its characteristically high light transmittance. Tempering increases the impact strength of the glass. The top surface of the glass module is glossy, thus preventing the buildup of debris on the module.

The solar cells are bonded to the glass sheet with silicone rubber. The silicone seals the solar cells and the electrical interconnections from the environment. Silicone has been chosen for various reasons including high light transmission, long term environmental stability, excellent electrical insulation properties, and the ability to resist degradation due to UV radiation.

The silicone/solar cell combination is covered at the rear surface by a white plastic film.

The 100mm diameter solar cells are produced from high purity, single crystal silicon wafers. The wafer initially doped with an "n", or negative, charge donor impurity has a "p", or positive, charge donor impurity diffused into the top layer of the wafer to form the p-n junction. Electrodes are attached to the top and bottom surfaces of the solar cells to collect the electrical energy. The bottom surface is completely covered by an electrode. The electrode pattern used on the top surface of the 100mm solar cell consists of a number of small conductor "fingers" criss-crossing the wafer and connecting to a tapering bifurcated main bus. This pattern has been designed to provide maximum surface area for light collection while providing a low resistance, efficient electrical conductor, and completely reduntant cell-to-cell electrical interconnections.

Individual modules are supplied with an output cable and blocking diode, or bypass diode, as required. The diodes and the connectors to the output cable are sealed in a glass reinforced phenolic junction box located in the rear of the module. (An optional galvanized steel screen is available to cover the rear of the module to protect the encapsulants from damage due to animals or birds.)

The module is supplied with an anodized aluminum support frame. The glass, solar cell, and silicone assembly is held in the glass frame by a one piece silicone gasket. The gasket isolates the glass assembly from shocks transmitted through the frame.

SPECIFICATIONS

Electrical

	Battery Charging Point	Peak Power Point
Current:	2.15 Amps ±10%	2.05 Amps ±10%
Voltage:	13.8 Volts	16.5 Volts
Power:	29.7 Watts ±10%	33.5 Watts ±10%

Output rated at 28°C cell temperature and 100mW/sq. cm incident sunlight. Charging point based on 12-volt lead-acid battery near full charge. Peak power values do not include cable and blocking diode losses.

Structural

WEIGHT: excluding supporting legs
20 lbs (9.1 Kg)

OVERALL DIMENSIONS: excluding supporting legs.
44" x 17" x 2.25"
(112 cm x 43.2 cm x 6 cm)

Environmental

OPERATING TEMPERATURE:
-55° to +60°C

HUMIDITY: 0 to 100%

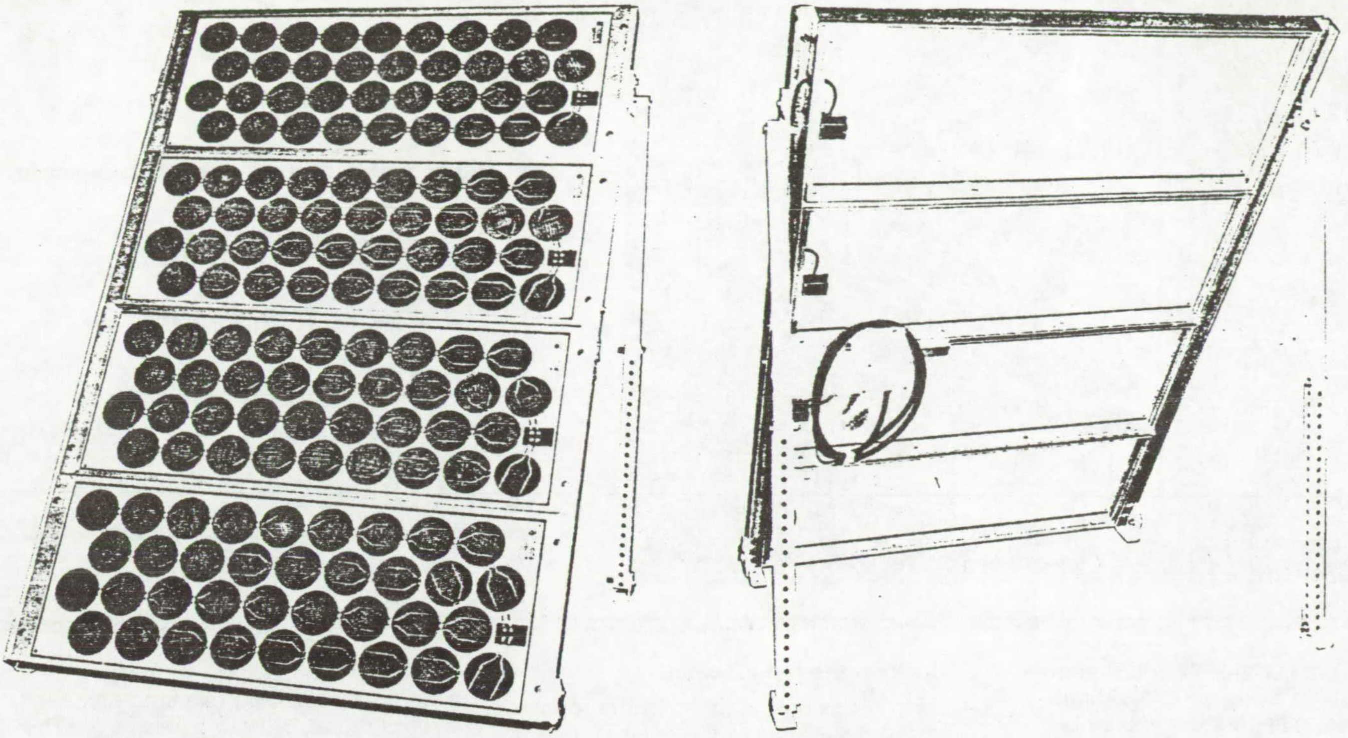
ALTITUDE: to 25,000 feet (7,620m)

WIND LOADING:
Module with supporting legs built to withstand sustained winds in excess of 175 mph (280 Km/hour) (90 lbs/sq. ft.)

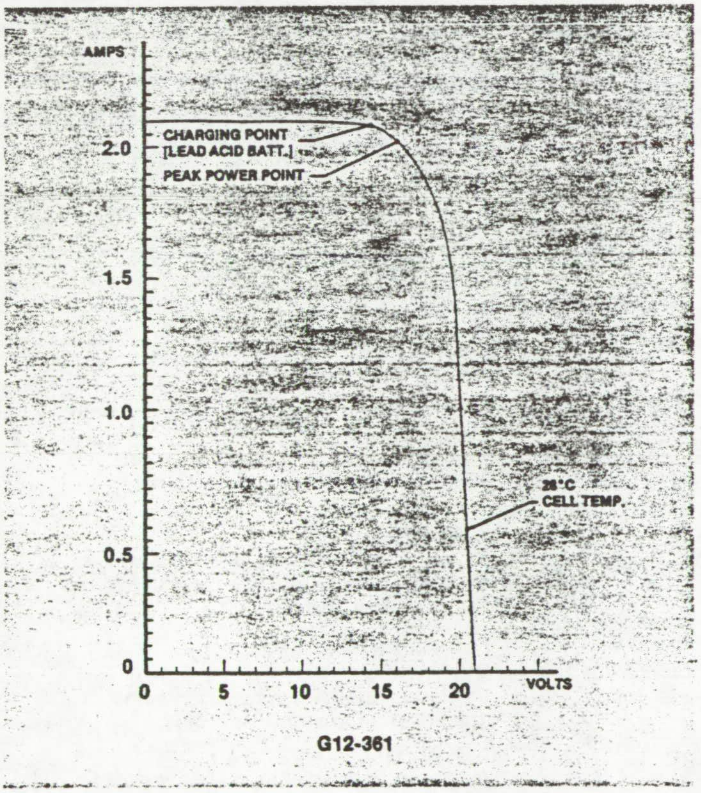
Solar Insolation Effect

VOLTAGE:
Operating voltage attained approximately 10m/w sq cm (dark overcast sky)

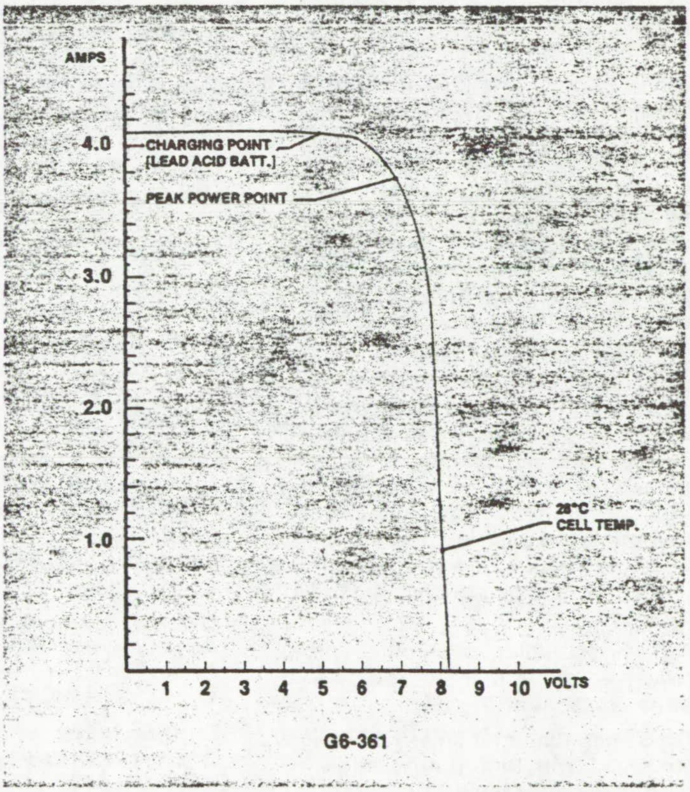
CURRENT:
Proportional to solar insolation: e.g. at 50mW/sq cm, output current would be 50% of rated current.



Typical four-module array.



G12-361

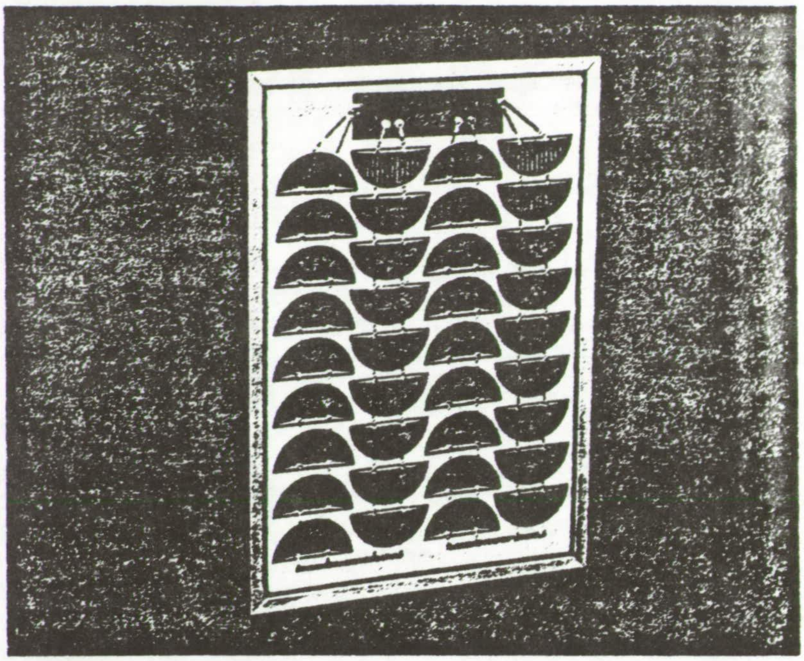


G6-361

Printed in U.S.A.

Solar Power Corporation **Affiliate of EXXON Enterprises, Inc.**

SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES: Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 •, Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126



Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

G-Series

PRODUCT DATA

G12-3672 Solar Electric Generators

The Model G12-3672 solar module consists of thirty-six (36), 75mm diameter silicon solar half cells connected in series in a module package that features a glass top module surface. The top module surface material is a low iron, high transmission, 1/8" thick, tempered glass that provides a smooth and durable cover. The glass surface gives the module the capability to withstand salt spray, sand storms, hail stones, and attack by vermin with minimal degradation of electric performance.

Low iron glass was selected for its characteristically high light transmittance. Tempering increases the impact strength of the glass. The top surface of the glass module is smooth, thus preventing the buildup of debris on the module.

The solar cells are bonded to the glass sheet with silicone rubber. The silicone seals the solar cells and the electrical interconnections from the environment. Silicone has been chosen for various reasons including high light transmission, long term environmental stability, excellent electrical insulation properties, and the ability to resist degradation due to UV radiation.

The silicone/solar cells combination is coverered at the rear surface by a white plastic film.

The 75mm diameter solar half cells are produced from high purity, single crystal silicon wafers. The wafer initially doped with an "n", or negative, charge donor impurity has a "p", or positive, charge donor impurity diffused into the top layer of the wafer to form the p-n junction.

Electrodes are attached to the top and bottom surfaces of the solar cell to collect the electrical energy. The bottom surface is completely covered by an electrode. The electrode pattern used on the top surface of the 75mm solar half cell consists of a number of small conductor "fingers" criss-crossing the wafer and connecting to a tapering main bus. This pattern has been designed to provide maximum surface area for light collection while providing a low resistance, and efficient electrical conductor.

Individual modules are supplied with an output cable and blocking diode, or bypass diode, or both as required. The diodes and the connectors to the output cable are sealed in a glass reinforced phenolic junction box located in the rear of the module.

The module is supplied with an anodized aluminum support frame. The glass, solar cell, and silicone assembly is cushioned in the support frame by a one-piece gasket. The gasket isolates the glass assembly from shocks transmitted through the frame.

SPECIFICATIONS

Electrical

	Battery Charging Point	Peak Power Point
Current:	0.62 Amps ±10%	0.59 Amps ±10%
Voltage:	13.8 Volts	16.5 Volts
Power:	8.4 Watts ±10%	9.7 Watts ±10%

Output rated at 28°C cell temperature and 100mW/sq. cm incident sunlight. Charging point based on 12-volt lead-acid battery near full charge. Peak power values do not include cable and blocking diode losses.

Structural

WEIGHT: excluding supporting legs
5.5 lbs (2.3 Kg)

OVERALL DIMENSION: excluding supporting legs.
20" x 13" x 0.8"
51 cm. x 33.0 cm. x 2 cm.

Environmental

OPERATING TEMPERATURE:
-55°C to + 60°C

HUMIDITY:
0 to 100%

ALTITUDE:
to 25,000 feet (7,620m)

WIND LOADING:
Module with supporting legs built to withstand sustained winds in excess of 175 mph (280 Km/hour) (90 lbs/sw.ft.)

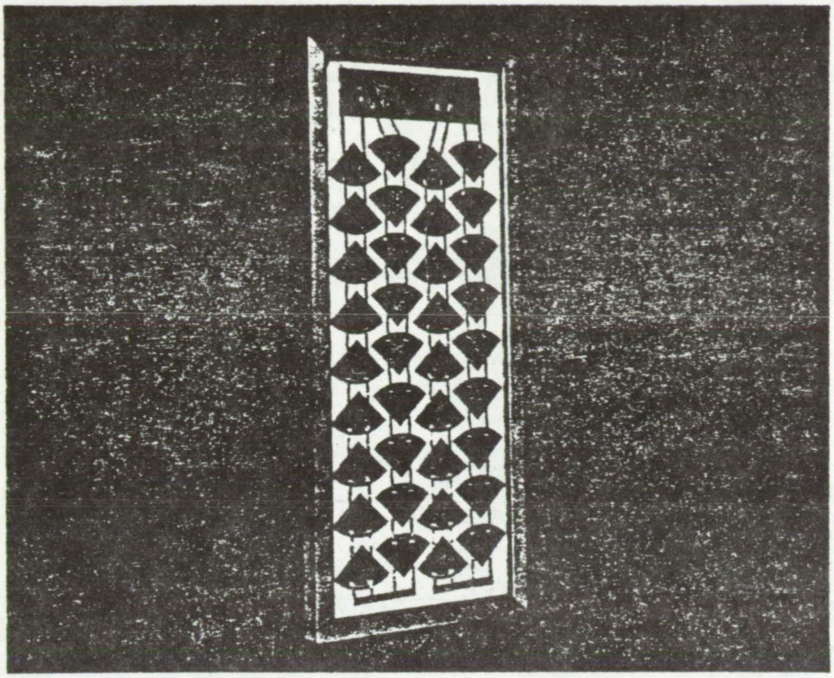
Solar Insolation Effect

VOLTAGE:
Operating voltage attained approximately 10mW/sq cm (dark overcast sky)

CURRENT:
Proportional to solar insolation; e.g. at 50mW/sq cm, output current would be 50% of rated current.

SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES. Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 • Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126

April 79



Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

G-Series

PRODUCT DATA

G12-3674 Solar Electric Generators

The Model G12-3674 solar module consists of thirty-six (36), 75mm diameter silicon solar quarter cells connected in series in a module package that features a glass top module surface. The top module surface material is a low iron, high transmission 1/8" thick, tempered glass that provides a smooth and durable cover. The glass surface gives the module the capability to withstand salt spray, sand storms, hail stones, and attack by birds and vermin with minimal degradation of electric performance.

Low iron glass was selected for its characteristically high light transmittance. Tempering increases the impact strength of the glass. The top surface of the glass module is smooth, thus preventing the buildup of debris on the module.

The solar cells are bonded to the glass sheet with silicone rubber. The silicone seals the solar cells and the electrical interconnections from the environment. Silicone has been chosen for various reasons including high light transmission, long term environmental stability, excellent electrical insulation properties, and the ability to resist degradation due to UV radiation.

The silicone/solar cell combination is covered at the rear surface by a white, plastic film.

The 75mm diameter solar quarter cells are produced from high purity, single crystal silicon wafers. The wafer initially doped with an "n", or negative, charge donor impurity has a "p", or positive, charge donor impurity diffused into the top layer of the wafer to form the p-n junction. Electrodes are attached to the top and bottom surfaces of the solar cell to collect the electrical energy. The bottom surface is completely covered by an electrode. The electrode pattern used on the top surface of the 75mm solar quarter cell consists of a number of small conductor "fingers" criss-crossing the wafer and connecting to a tapering main bus. This pattern has been designed to provide maximum surface area for light collection while providing a low resistance, and efficient electrical conductor.

Individual modules are supplied with an output cable and blocking diode, or bypass diode, or both as required. The diodes and the connectors to the output cable are sealed in a glass reinforced phenolic junction box located in the rear of the module.

The module is supplied with an anodized aluminum support frame. The glass, solar cell, and silicone assembly is cushioned in the support frame by a one piece silicone gasket. The gasket isolates the glass assembly from shocks transmitted through the frame.

SPECIFICATIONS

Electrical

	Battery Charging Point	Peak Power Point
Current:	0.31 Amps ±10%	0.29 Amps ±10%
Voltage:	13.8 Volts	16.5 Volts
Power:	4.2 Watts ±10%	4.8 Watts ±10%

Output rated at 28°C cell temperature and 100mW/sq. cm incident sunlight. Charging point based on 12-volt lead-acid battery near full charge. Peak power values do not include cable and blocking diode losses.

Structural

WEIGHT: excluding supporting legs
4.70 lbs (2.1kg.)

OVERALL DIMENSIONS: excluding supporting legs
20" x 9" x 0.8" (51 cm x 22.9 cm. x 2 cm)

Environmental

OPERATING TEMPERATURE:
-55°C to + 60°C

HUMIDITY:
0 to 100%

ALTITUDE:
to 25,000 feet (7,620m)

WIND LOADING:
Module with supporting legs built to withstand sustained winds in excess of 175 mph (280 Km/hour) (90 lbs./sq. ft.)

Solar Insolation Effect

VOLTAGE:
Operating voltage attained approximately 10mW/sq. cm (dark overcast sky)

CURRENT:
Proportional to solar insolation; e.g., at 50mW/sq cm, output current would be 50% of rated current.

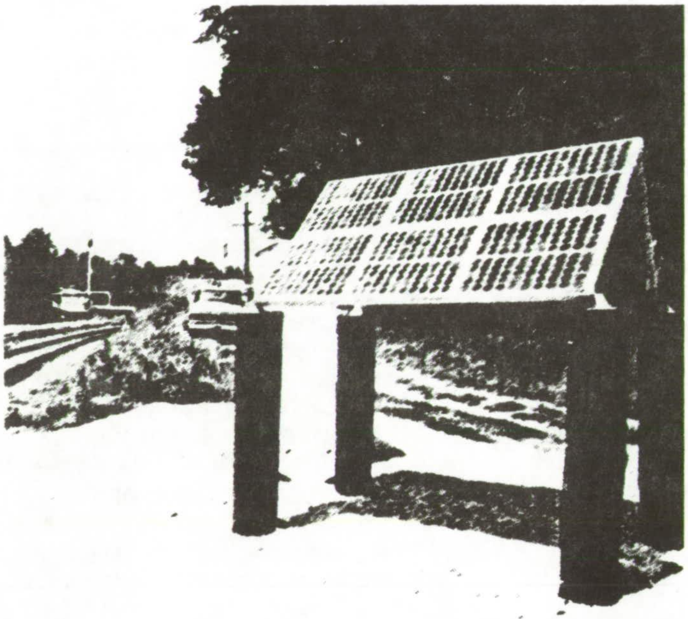
SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES: Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 •. Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126

April 79

Solar Power Corporation
AFFILIATE OF EXXON ENTERPRISES INC.

APPLICATION BULLETIN
No. 52

RAILROAD



MODEL 1002

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fueling requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commericial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

APPLICATION: Railroad Grade Crossing
LOCATION: Atlanta, Georgia
VOLTAGE: 12 V.D.C. Nominal
LOAD: Crossing Unoccupied — 2.0 Amps for 23 hours
Crossing Occupied — (lights and bells) 6.0 Amps for 1 hour
TOTAL LOAD: 52 AH/DAY

SOLAR ARRAY: Model 12-119-10.2; Battery Charging Point
13.8 V.D.C.
10.2 Amps
140 Watts
DIMENSIONS: 98" x 58" x 3.5"
WEIGHT: 298 Lbs.
BATTERY: 835 AH, 12 V.D.C. (6 cells); stationary
Lead-calcium cells
INSTALLED: Summer, 1974

SOLAR POWER CORPORATION/20 CABOT ROAD/WOBURN, MA 01801/TEL: (617)935-4600/TWX: 710-348-0602
BRANCH OFFICES: Solar Power Limited, 220 Grand Buildings, Trafalgar Square, London WC2N 5HB • Tel: 01 930-0873/4 •, Telex: 21221
Solar Power Corporation, One Kingwood Place, Suite 200, Kingwood, Texas 77339 • Tel: (713)358-3126

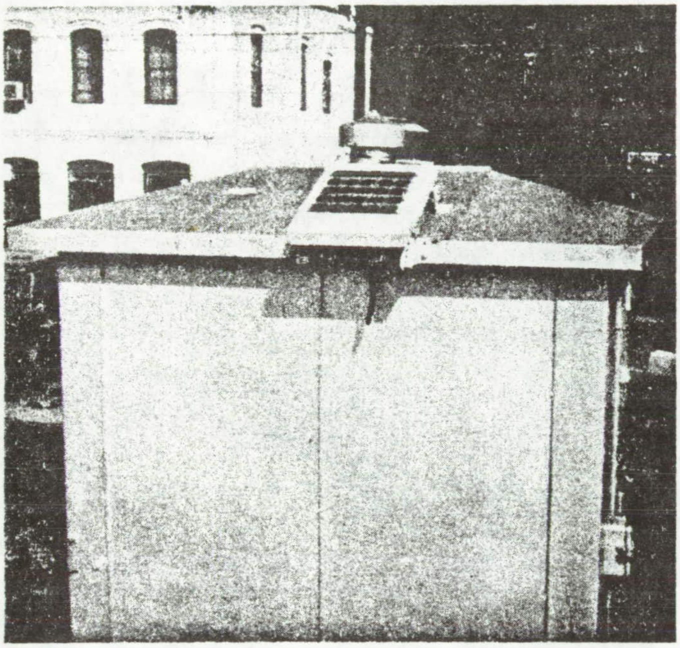
April 1979

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

20 Cabot Road, Woburn, MA 01801 Tel. (617)935-4600 TWX 710 348-0602

RAILROAD
APPLICATION BULLETIN — No. 50



MODEL 1002

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fueling requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commericial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

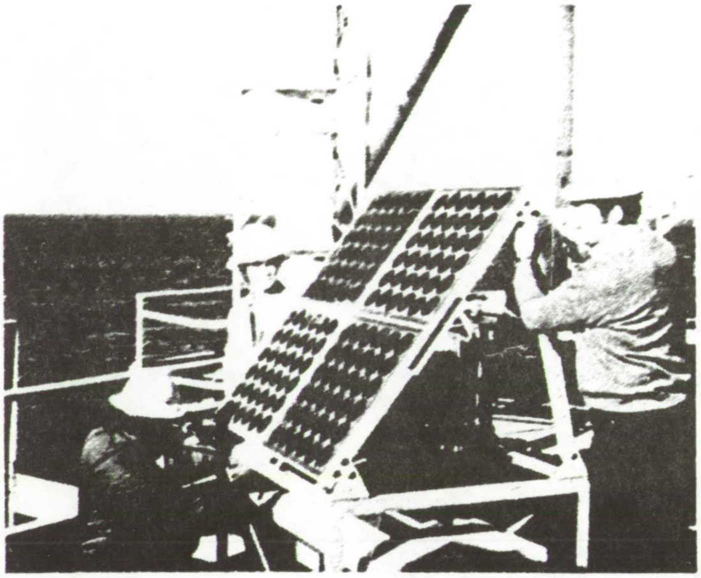
APPLICATION: Railroad Track Circuit (using Lead Acid Batteries)
LOCATION: Montreal, Canada
VOLTAGE: 2.0 Volts D.C. Nominal
LOAD: Track unoccupied—240 mA for 23 hours—5.5 AH
Track occupied —1.0 A for 1 hour —1.0 AH
TOTAL—6.5 AH / Day

SOLAR ARRAY: Model 2—6—1.95; Battery Charging Point
2.3 V.D.C.
1.95 Amps
4.5 Watts
DIMENSIONS: 23.5" x 16.5" x 3.5"
WEIGHT: 15 lbs including mounting hardware
BATTERY: 230 AH, 2.0 V.D.C., Lead-Acid type with lead-calcium plates
INSTALLED: Fall, 1974

August 1978

NAVIGATIONAL-AIDS
APPLICATION BULLETIN — No. 55

20 Cabot Road, Woburn, MA 01801 TEL. (617) 935-4800 TWX 710 348-0602



MODEL "SERIES E"

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fueling requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

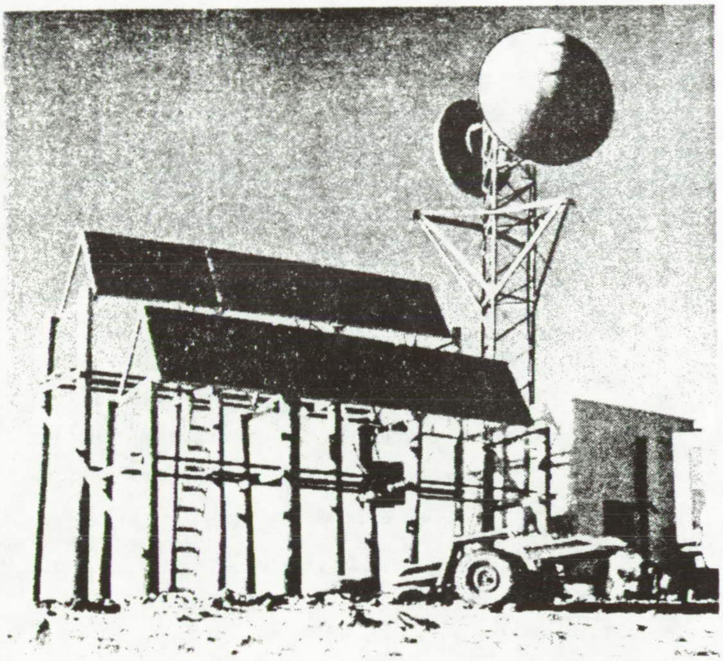
APPLICATION:	Aids to Navigation
LOCATION:	Offshore oil platform, Gulf of Mexico
VOLTAGE:	24 V.D.C. Nominal
LOAD:	Horn—4 Amps, 10% duty cycle; 0.06 Amp, 90% duty cycle; 24 hour operation TOTAL LOAD: 10.9 AH/DAY
SOLAR ARRAY:	Model E24-04369-3.0; Battery Charging point 26.4 V.D.C. 3.2 Amps 84.5 Watts
DIMENSIONS:	50" x 50" x 2"
WEIGHT:	130 Lbs.
BATTERY:	335 AH, 24 V.D.C. (12 cells); stationary Lead Calcium cells
INSTALLED:	Summer, 1975

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

COMMUNICATIONS APPLICATION BULLETIN - NO. 54

20 Cabot Rd., Woburn, Ma. 01801 TEL.(617)935-4600 TWX 710-348-0602



MODEL "SERIES E"

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fueling requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are impervious to environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

APPLICATION:	Microwave Repeater Station
LOCATION:	Challis, Idaho
VOLTAGE:	24 VDC Nominal
LOAD:	5.0 Amps Continuous
	TOTAL LOAD: 120 AH / DAY
SOLAR ARRAY:	Model E24-36369-27; Charging Point
	27.6 VDC
	30 Amps
	816 Watts
DIMENSIONS:	Six separate arrays, each measuring 75" x 50" x 2"
WEIGHT:	1130 Lbs.
BATTERY:	2190 AH, 24 VDC (12 cells); stationary
	Lead-calcium cells.

Cost of Assembled Solar Array Ready for Installation......Under $19,000.00

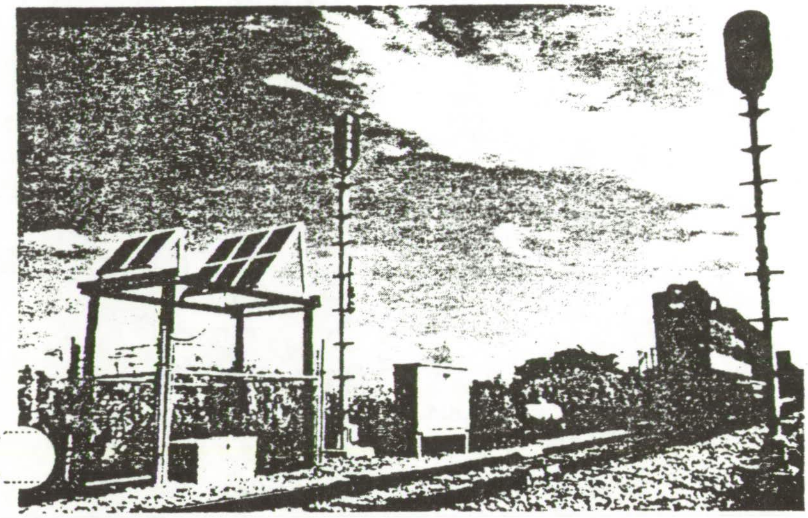
June 1978

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

RAILROAD
APPLICATION BULLETIN — No. 60

20 Cabot Road, Woburn, MA 01801 Tel. (617)935-4600 TWX 710 348-0602



"P" SERIES SOLAR POWER SYSTEM

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fuel requirement, and no pollution producing waste materials. Solar powered systems are completely self-contained, require no commercial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

	Application #1	Application #2
APPLICATION:	Railroad Track Circuit	Railroad Signal Lamp
LOCATION:	Lake Pontchartrain, Louisiana	Lake Pontchartrain, Louisiana
VOLTAGE:	2.8 Vdc nominal	12 Vdc nominal
LOAD:	40 Ah/day; track occupied 6 hours/day, 5 days/week	30 Ah/day; track occupied 6 hours/day, 5 days/week
SOLAR ARRAY:	Model P2-281002	Model P12-841002
ELECTRICAL SPECIFICATIONS: (At Battery Charging Point)	3 Vdc, 9.1 A, 27.3 W	13.8 Vdc, 7.8 A, 108 W
DIMENSIONS:	48" x 32" x 3"	62" x 51" x 3"
WEIGHT:	70 lbs., including hardware	210 lbs., including hardware
BATTERY:	786 Ah, 2.8 Vdc, nickel-cadmium type	554 Ah, 12 Vdc, lead-acid type
INSTALLED:	Summer 1976	Summer 1976

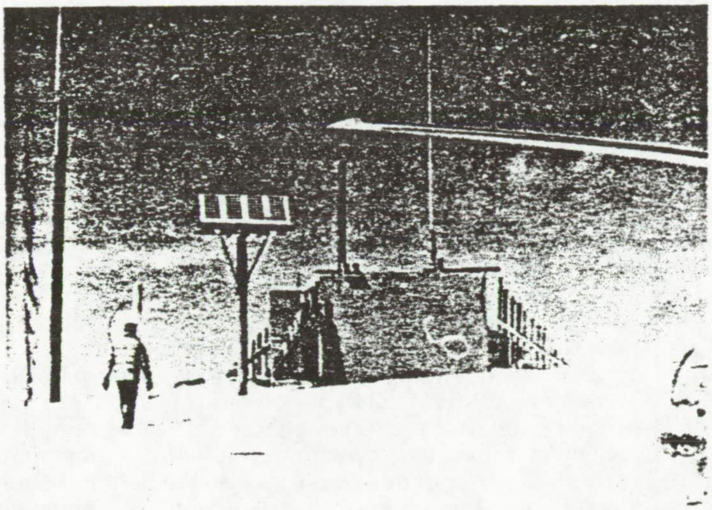
September 1978

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

COMMUNICATIONS
APPLICATION BULLETIN — No. 56

20 Cabot Road, Woburn, MA 01801 Tel. (617)935-4600 TWX 710 348-0602



"P-1002" SOLAR POWER SYSTEM

Solar Electric Generator systems are the most economical and reliable of all remote power sources. Solar energy boasts maintenance free operation, no fuel requirement, and no pollution producing waste materials. Solar power systems are completely self-contained, require no commercial power and are highly resistant to all environmental and climatic elements. A well designed solar "cell" system is a solid state device with unlimited life expectancy.

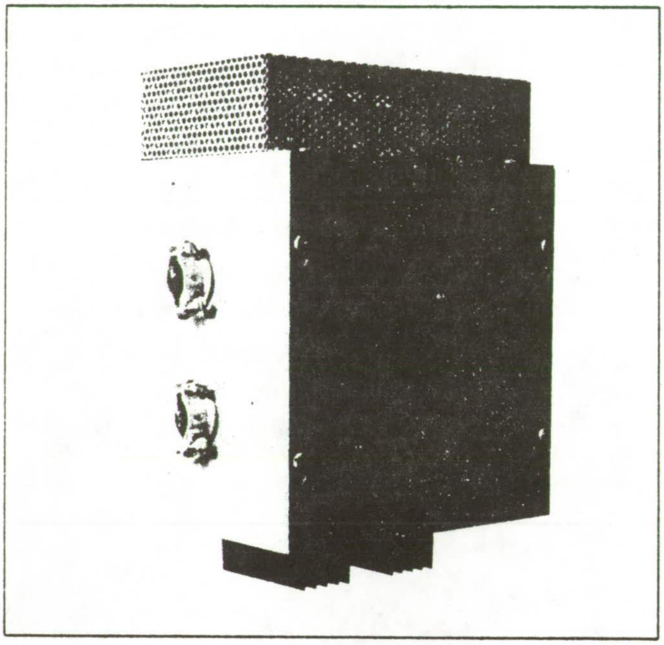
APPLICATION:	VHF Radio Repeater Station
LOCATION:	Eaglehead Mountain, Gallatin County, Montana
VOLTAGE:	12 Vdc nominal; 14.5 Vdc max., 11.2 Vdc min.
LOAD:	90 mA continuous standby 4.2 A for 1.5 hours/day transmit; 8.46 Ah/day total load (50% excess power capability supplied for future system expansion)
SOLAR ARRAY:	Model 12-35-3 (New Model No. P12-351002)
ELECTRICAL SPECIFICATIONS: **(At Battery Charging Point)**	13.8 Vdc, 3.0 A, 41.4 W
DIMENSIONS:	70.5" x 33.5" x 3.5"
WEIGHT:	87.5 lbs. net
BATTERY:	500 Ah, 12 Vdc, lead-acid type with lead-calcium plates
INSTALLED:	Fall 1973

September 1978

Solar Power Corporation

Affiliate of EXXON Enterprises, Inc.

BVR
Battery Voltage Regulators



Solar Power Corporation's BVR series Battery Voltage Regulators are designed to provide exacting battery voltage control, low quiescent power consumption and reliable, long service life.

Available in weather-resistant or nonweather-resistant configurations, the BVR series Battery Voltage Regulators are of shunt design. Once the regulating voltage is set, the BVR series regulators allow only enough current to flow into the battery as needed to maintain a full state of charge. Additional solar array output current is then diverted through power dissipation devices in the battery voltage regulator. In cases where the battery falls below full charge, the regulator circuit draws only enough power to operate the terminal voltage level detector (typically 1mA or less). The low "off" state power drain of the BVR series Battery Voltage Regulator prevents unnecessary waste of valuable solar-generated power in the regulator circuits when the battery is below full charge. The battery voltage upper limit is selected to minimize electrolysis of water in the electrolyte. In addition to preventing unnecessary electrolyte loss, BVR series Battery Voltage Regulators protect against equipment or battery damage due to excessive voltage.

Battery Voltage Regulator Specifications

MODEL NUMBER	[3] TYPICAL REGULATING VOLTAGE [VOLTS D.C.]	[4] CURRENT [AMPS]	DIMENSIONS [IN.]			WEIGHT [LBS.]	
			LENGTH	WIDTH	DEPTH	NET	SHIPPING
[2] BVR12-0.3	14.4	0.3	3	1.5	1	1	N/A
BVR12-0.7	14.4	0.8	7	8	4	3	8
BVR12-2.0	14.4	2.4	7	9	4	4	9
BVR12-6.0	14.4	7.2	9	13	6	7	12
BVR12-12*	14.4	14.4	14	13	6	13	20
BVR24-0.7	28.8	0.8	7	8	4	3	8
BVR24-2.0	28.8	2.4	7	9	4	4	9
BVR24-6.0	28.8	7.2	14	13	6	13	20

*Supersedes Model BVR 12-10

Notes:
1. The regulators listed above are supplied in non-weather resistant enclosures. Optional weather resistant enclosures are available.
2. BVR12–0.3 regulator is designed for use with the E12—3652 solar module. It is supplied in a weather resistant enclosure and is mounted on the rear of the module. This model is not adjustable.
3. Regulating Voltage Range ±1% for Lead Acid Battery.
4. Maximum Value.

All BVR series Battery Voltage Regulators use solid state devices. A MIL STD 723 integrated circuit is used as the heart of each voltage regulator.

Precision metal film resistors are used in voltage level detection circuits. Reverse polarity protection and the system blocking diodes are incorporated into the unit. All power handling devices are derated to assure long life, even at constant maximum power dissipation levels. Connections to printed circuit boards are made via terminal blocks capable of handling up to #10 AWG wire, and provide a solid gas-tight seal. Either weather-resistant feedthroughs or strain relieving cable clamps are offered.

BVR series Battery Voltage Regulators are available in standard voltage ranges shown in the specification table. If other voltages are required, please contact the Technical Service Department at Solar Power Corporation.

Installation and adjustment

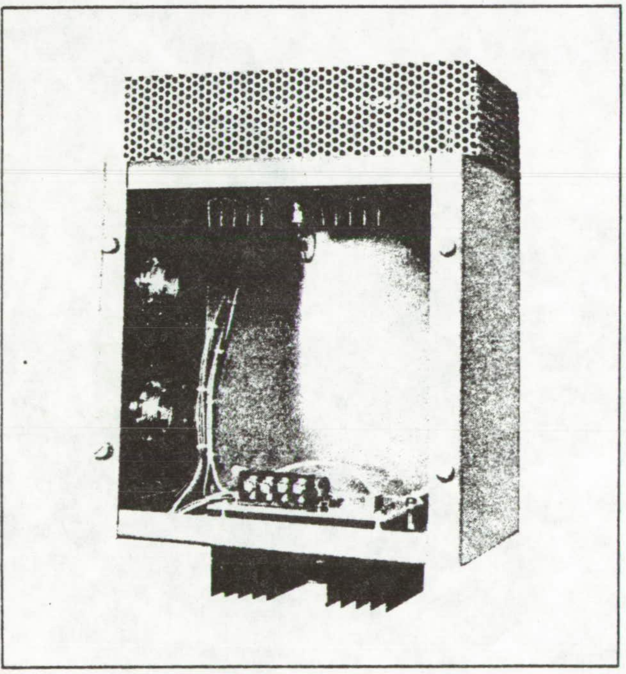
Neither weather-resistant nor nonweather-resistant models of the BVR series Battery Voltage Regulators should be installed in areas exposed to extreme weathering. Weather-resistant BVR Battery Voltage Regulators may be mounted external to an equipment cabinet or hut, although it may be desirable to mount weather-resistant regulators behind the solar panel for increased protection. Nonweather-resistant models must be installed within an enclosure. In both instances, air flow around the heat sinks and resistor cage must not be impeded.

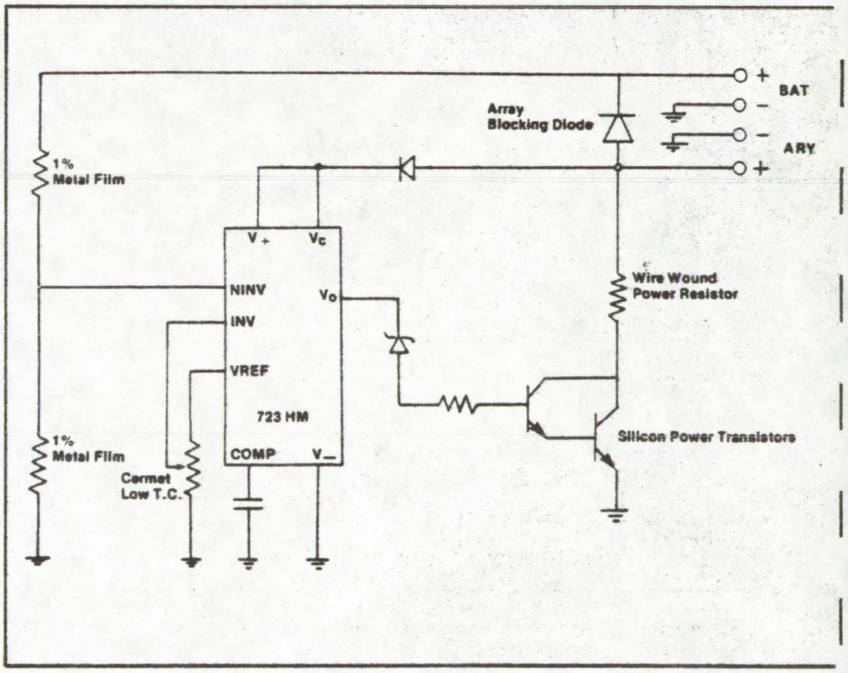
Connect as follows:

1) Connect the solar array leads to the terminals marked "ARY" observing correct polarity.
2) Connect the battery to the terminals marked "BAT" observing correct polarity.
3) The BVR series Battery Voltage Regulator is now completely installed.

To adjust the regulating voltage level:

1) Disconnect the battery cable from the battery.
2) Connect a suitable high impedence voltmeter across the battery cable.
3) Adjust the regulating voltage via the small potentiometer on the PC board; clockwise to increase, counterclockwise to decrease the voltage level.
4) Reconnect the battery cable to the battery terminals, observing correct polarity.





Solar Power Corporation **Affiliate of EXXON Enterprises, Inc.**

20 CABOT ROAD, WOBURN, MASSACHUSETTS, TELEPHONE (617)935-4600, TWX 710-348-0602

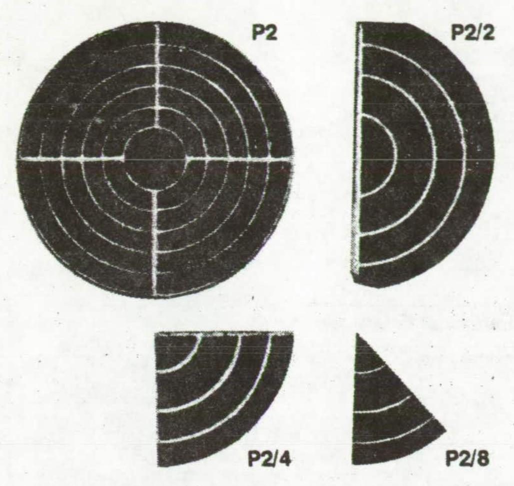
Branch Offices: Solar Power Limited 220 Grand Buildings, Trafalgar Square, London WC2N SHB Tel. 01-930-0873/4

Solar Power Corporation One Kingwood Place Suite 200 Kingwood, Texax 77339 Tel.# 713-358-3126

Sollos

Silicon Solar Cells & Solar Electrical Modules

Silicon Solar Cells & Solar Electrical Modules



Design Features:
Standard Sollos silicon solar cells are produced in 2 inch (5 cm) diameter, 0,012–0,015 inch (0,03–0,04 cm) thick discs.

The cell structure is P+/N, achieved by a closely controlled gaseous diffusion process to obtain maximum conversion efficiencies. Low resistance ohmic contact optimizes the collection efficiency and the geometry of the contact is chosen to simplify interconnection between individual cells in uniform and symmetrical patterns.

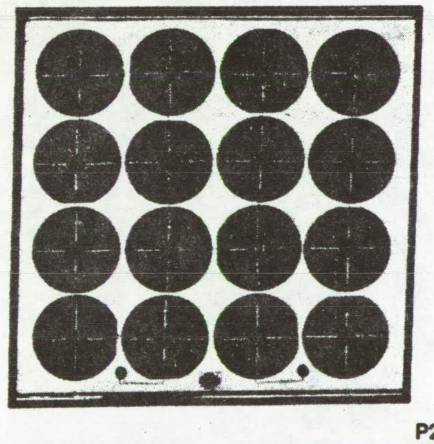
Tin (63%)-lead (37%) eutectic alloy contact allows for an easy lead attachment and cell interconnection by common soldering techniques. Halves, quarters and eighths of the standard cells are produced as individual cells or in assemblies.

Module cost per watt -- $12.
Delivery time -- 6-8 w

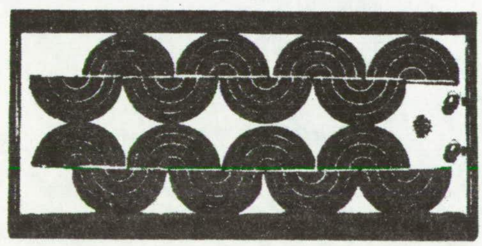
Cell Type	Power Output*	
	Vmax (Volts)	Imax (mAmps)
P2	0.4–0.45	350–500
P2/2	0.4–0.45	170–250
P2/4	0.4–0.45	80–125
P2/8	0.4–0.45	40–65

*Test data relates to 1 sun (1 kW/m²) insolation.

6 Volt Battery Chargers & Solar Electric Generators



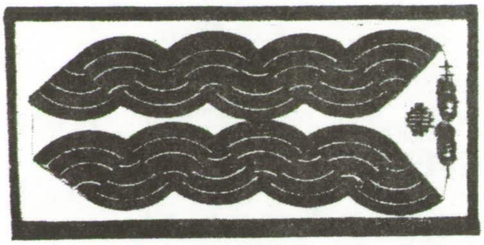
P2(16)



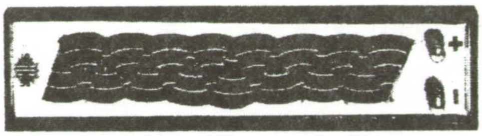
P2/2(16)

Design Features:
- □ Hermetically sealed, environmentally stable assemblies
- □ Screw type, noncorrosive terminals
- □ Light weight
- □ Mechanical strength greater than 100 lbs/ft² (500 kg/m²)
- □ Optical reflectivity on the active side and black body emissivity on the back side minimize thermal degradation

Suggested Applications:
Radios, tape recorders, television, toys, battery chargers (in boats, campers, for lights, etc.), science projects



P2/4(16)

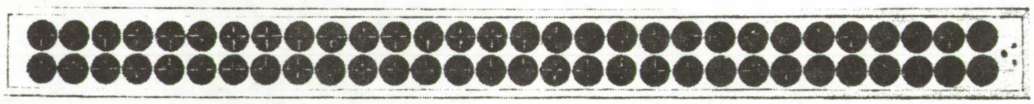


P2/8(16)

Physical Characteristics			Electrical Characteristics*			
Array Type	Size	Max. Weight	Initial Charging		Power Output	
			V_{in}(Volts)	I_{in}(mAmps)	V_{max}(Volts)	I_{max}(mAmps)
P2(16)	9.25x9.25x0.375 (in) 23.5x23.5x1.0 (cm)	26 oz (750 gms)	8.6–8.2	550–450	6.8–6.4	500–350
P2/2(16)	10.25x4.75x0.375 (in) 26x12x1.0(cm)	14 oz (400 gms)	8.6–8.2	280–225	6.8–6.4	250–170
P2/4(16)	6.25x3.5x0.375 (in) 16x9x1.0 (cm)	6 oz (175 gms)	8.6–8.2	140–120	6.8–6.4	125–80
P2/8(16)	7x1.75x0.375 (in) 18x4.5x1.0 (cm)	3 oz (90 gms)	8.6–8.2	70–60	6.8–6.4	55–40

*Test data relate to 1 sun (1kW/m²) insolation

12 Volt Battery Chargers & Solar Electric Generators

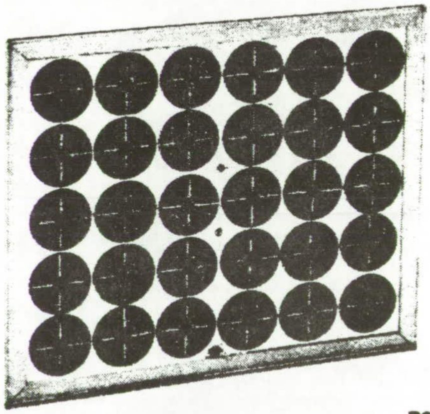


P2(60)

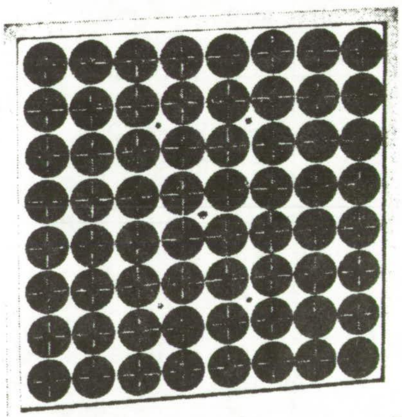
P2(30) module is designed for charging 12 Volt batteries on boats and in campers. It can be either mounted within a standard window frame or on the floor, as it withstands the weight of walking persons.

P2(60) module is designed for charging 12 Volt batteries for bill board lights. Two rows of 30 cells in series are connected in parallel.

P2(64) module consists of two discrete 12 Volt arrays. This feature provides versatility of interconnections to meet specific design requirements. It is used either for charging 12 Volt or 24 Volt batteries or directly for generating power in water irrigation systems.



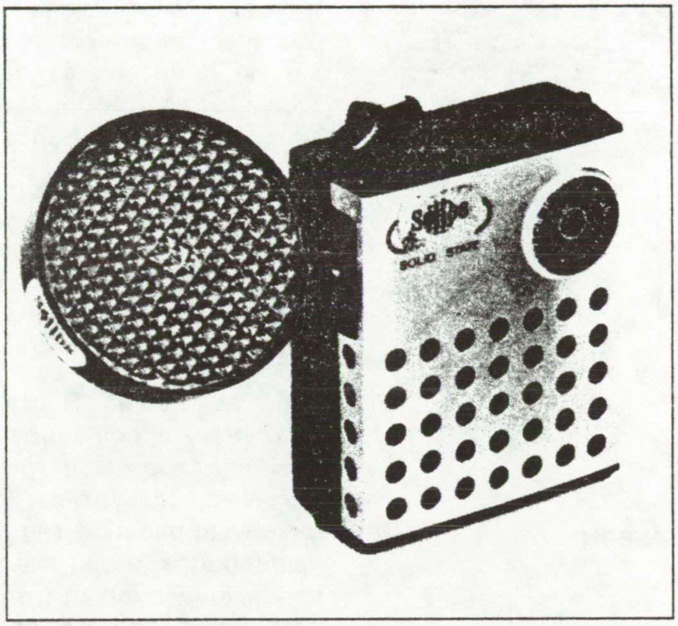
P2(30)



P2(64)

Physical Characteristics			Electrical Characteristics*			
Array type	Size	Max. Weight	Initial Charging		Power Output	
			V_{in}(Volts)	I_{in}(mAmps)	V_{max}(Volts)	I_{max}(mAmps)
P2(30)	14x12x0.375 (in) 35.5x30.5x1.0 (cm)	[illegible] oz (1020 gms)	[illegible]–16.5	[illegible]–450	12–12.5	500–350
P2(60)	66x5.5x0.375 (in) 168x14x1.0 (cm)	90 oz (2550 gms)	15.8–16.5	1100–900	12–12.5	1000–700
P2(64)	18x18x0.5 (in) 46x46x1.25 (cm)	92 oz (2600 gms)	a) 33.5–34.5 b) 16.75–17.25	550–450 1100–900	23.5–27.0 12.75–13.5	500–350 1000–700

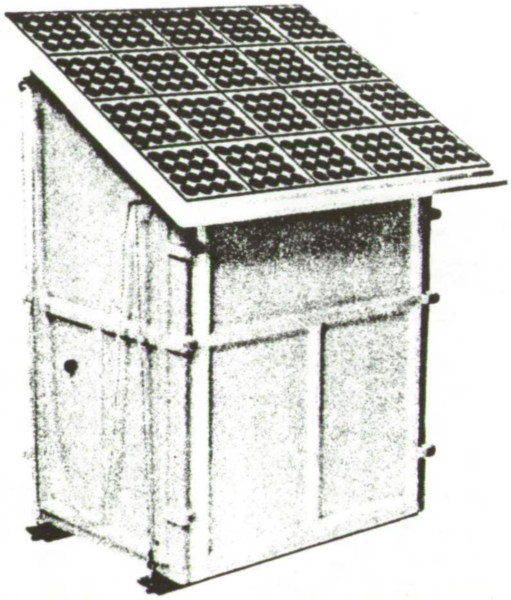
*Test data relate to 1 sun(1kW/m²) insolation a) in series b) parallel



The encapsulations of individual cells or cell assemblies are custom designed to comply with specific requirements.
6 Volt assemblies are structurally identical with 12 Volt assemblies. They are basic units for a wide range of terrestrial applications.

Sollos Inc.
2231 S. Carmelina Ave.
Los Angeles, CA 90064
Phone: (213) 820-5181

SolaViva® Solar Power Stations



SV-60U

Present day solar cell installations of good design convert sunlight into electrical energy utilizing highly efficient silicon transducers and modern packaging techniques. Limited numbers of terrestrial solar cell installations have been in operation for more than 10 years. Improvements required for long-term reliability resulted in two main accomplishments: production of cells which respond in the red portion of the light spectrum at .7 to .9 microns to penetrate the earth's atmosphere, and improvement in the packaging of the cells to survive long-term service in terrestrial application. Tideland has introduced SolaViva solar power systems which incorporate both these improvements.

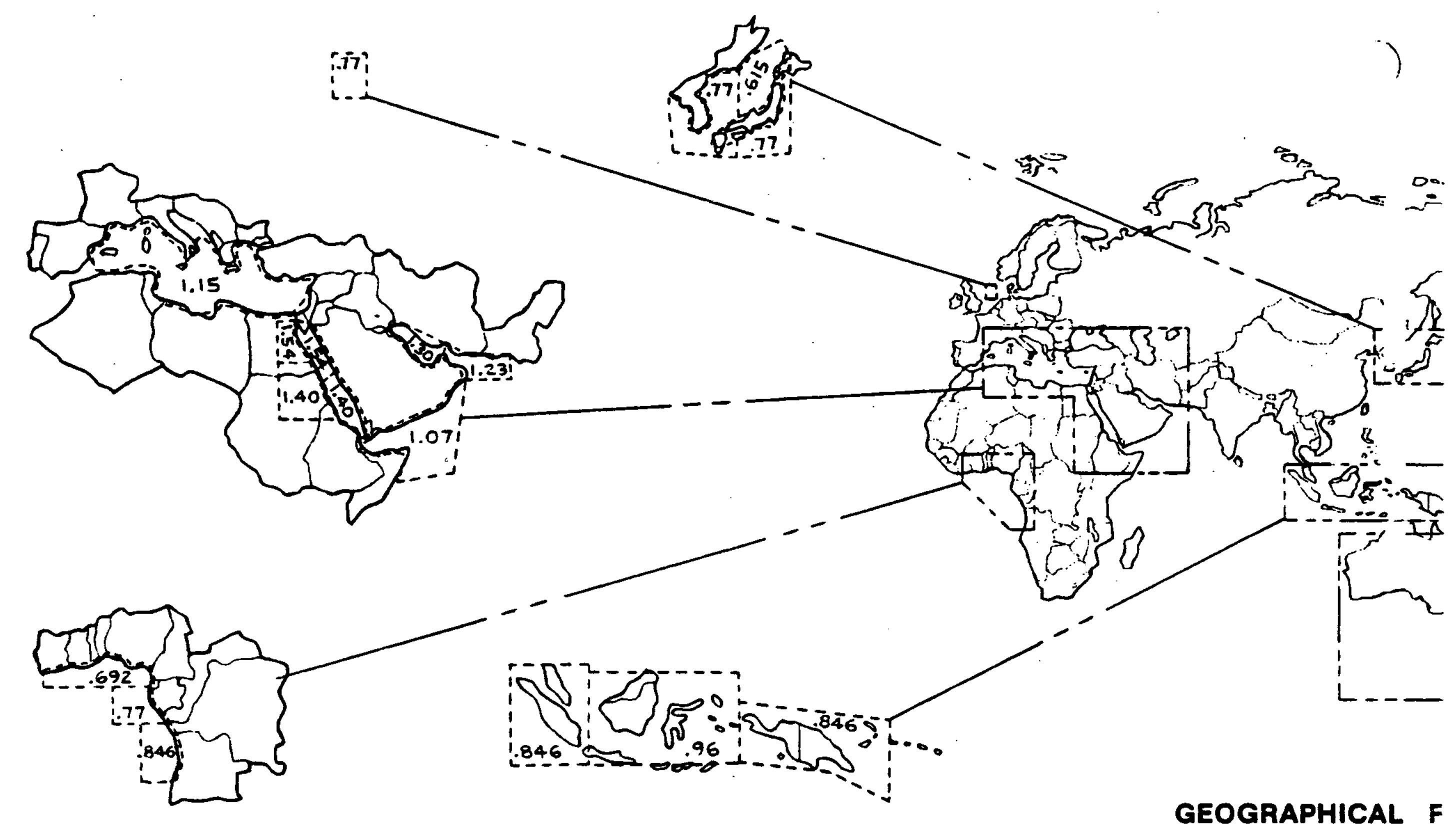
The first SolaViva system for powering aids to navigation equipment was installed in December 1972 in the Gulf of Mexico. At this writing more than 1000 SolaViva power stations of various sizes have been operating on offshore locations throughout the world with outstanding success.

SolaViva Power Stations incorporate Tideland's proprietary specification for solar cells and charge-retaining deep-discharge storage batteries of the very low self-discharge type. SolaViva is an excellent choice for any application requiring remote power; routine maintenance requirements are reduced to a semi-annual inspection visit, and the costly practice of transporting heavy primary batteries or gas cylinders, or the exchange of secondary batteries required for many remote power systems is no longer necessary.

DESCRIPTION OF OPERATION

The SolaViva Power Station responds to the overall sky brightness as a source of power rather than an image of the sun. Sunlight falling on the solar cells is silently converted into electrical energy during the sunlight hours. This energy is accumulated in a storage battery and is used at night by visual signal lights and throughout the 24-hour day by audible fog signals. The systems are designed to provide a quantity of ampere-hours per day at the operating voltage which is equal to the load placed on the system. Conversion of the solar energy does not use up or wear out any portion of the SolaViva system. Life expectancy is only limited by the capacity of the battery to accept charges and the durability of the system's packaging. The solar cells are not affected by thin dust or minute surface scratches.

The Tideland SolaViva Power Station incorporates an array of modules consisting of multiple solar cells that are connected in series/parallel arrangement to produce the proper charging voltage to the battery with the inherent ability to supply current as required by the internal resistance changes in the battery. The SolaViva system and its charge-retaining deep-discharge storage battery are correctly matched so that the battery is kept properly charged without the use of a power-consuming regulator. The high degree of efficiency of this carefully matched system ensures that at least eight days of power to the aids to navigation is always present even during the lowest charging periods of winter. In the event of severe storm damage or loss of the solar array this reserve power is necessary to assure standby requirements of federal regulations.



GEOGRAPHICAL F

SELECTION PROCEDURE

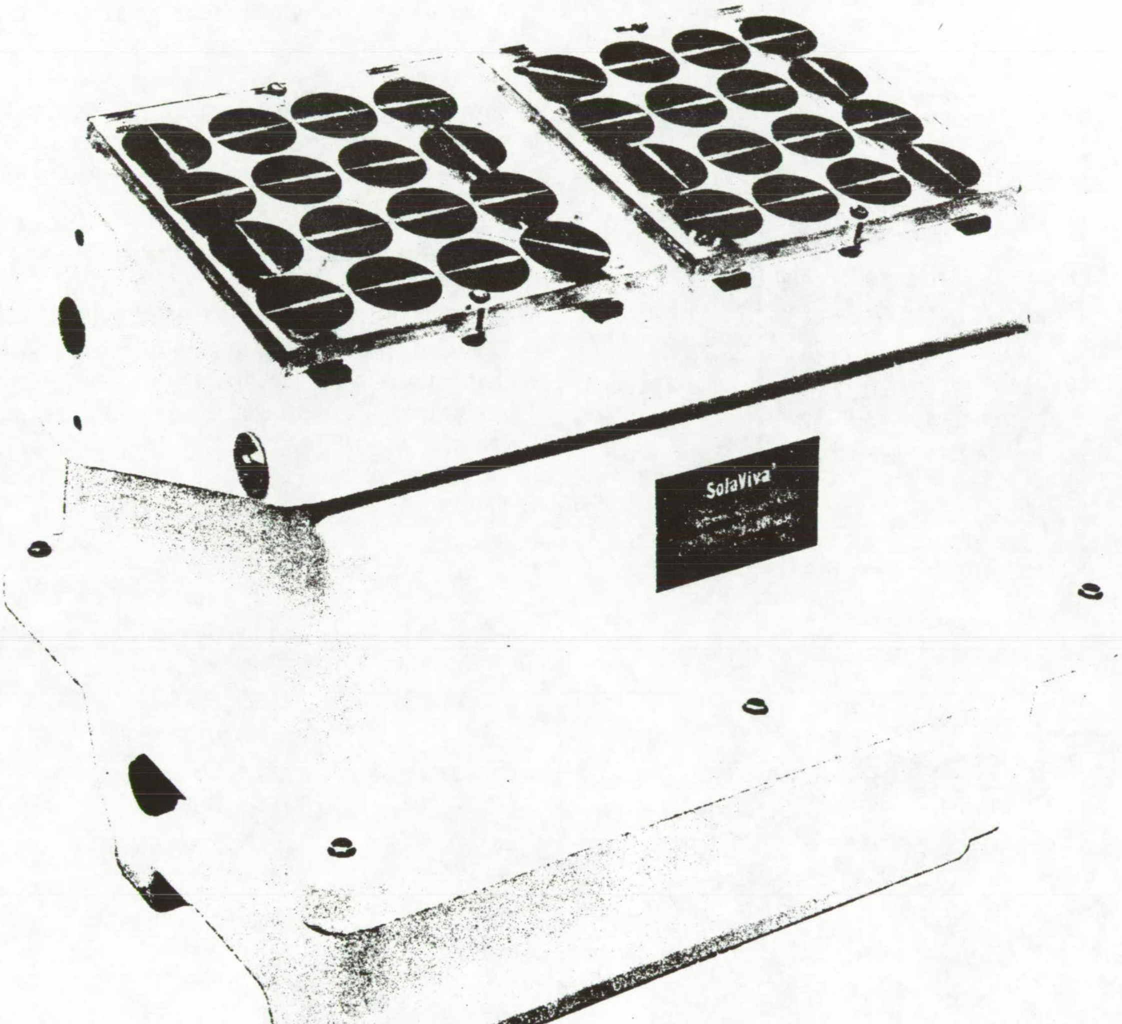
Selection of the proper size SolaViva Power Station for a typical application is determined from the voltage and ampere-hours per day required by the load of the aids to navigation devices to be operated. The geographical location of the installation must also be known due to variations in weather conditions throughout the world. Typically, the weather on the shoreline in any area location is not as favorable as weather farther offshore for the required amount of annual sunshine hours available. The procedure to follow in determining the proper size SolaViva is to first determine the location of the installation on the Geographical Factor Chart and identify the location factor, and then select from the Selection Table a power station model which shows the ampere-hour value per day nearest the load requirement of the installation. Multiply this value by the location factor. If the resulting ampere-hours are less than the load requires, select the next larger size power station and multiply this value by the location factor. If the result meets your load requirement use it. If it is too large, select the next smaller size power station.

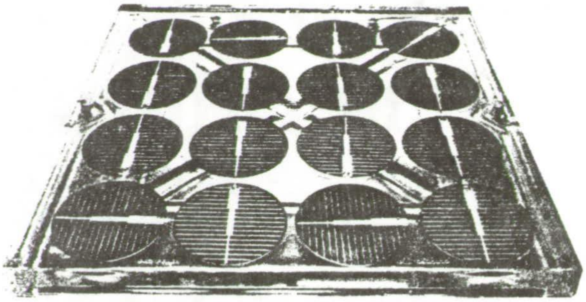
POWER STATION MODEL For 12V Operation	COMPREHENSIVE PART NUMBER	CON· ·URA
SV-6M	042.4110.120601 (Weight: 62 kg)	Fiberglass panel to m···nt un
SV-18MU	042.2117.121802 (Weight: 177 kg)	Fiberglass panel in str ural chion, TI-5 box c/w batteries
SV-24U	042.1112.122403 (Weight: 242 kg)	Single-lift FG-15 fiberglass en·
SV-30MU	042.2114.123004 (Weight: 320 kg)	Fiberglass panel in str ural chion, TI-10 box c/w b· ·ries
SV-30U	042.1112.123004 (Weight: 320 kg)	Single-lift FG-15 fiberglass en·
SV-36U	042.1113.123605 (Weight: 375 kg)	Single-lift FG-30 fiber· s en·
SV-42U	042.1113.124206 (Weight: 439 kg)	Single-lift FG-30 fiberglass en·
SV-48MU	042.2115.124806 (Weight: 514 kg)	Fiberglass panel in st· ural chion, TI-15 box c/w · eries
SV-60U	042.1213.126007 (Weight: 499 kg)	Single-lift FG-30 fiberglass en·
POWER STATION MODEL For 6V Operation		
SV-3MU	042.4110.060401 (Weight: 35 kg)	Fiberglass panel to mount unc· illustration of Sola-Chan 155).
SV-15MU	042.2116.061602 (Weight: 143 kg)	Fiberglass panel in st· ural chion, B-5 box c/w ba· ies

BASE MOUNTING SPECIFICATIONS
SV-4M and SV-6M Panel: 200mm bolt circle (See ML-155 lantern pub. no. 3M030274.); Stanchion base bolt hole center: 560mm x 406mm; TI-5 box bolt hole centers: 839mm x 406mm; TI-10 box bolt hole centers: 1245mm x 406mm; TI-15 box bolt hole centers: 1245mm x 647mm; FG-15, FG-30 enclosures bolt hole centers: 1125mm x 400mm.

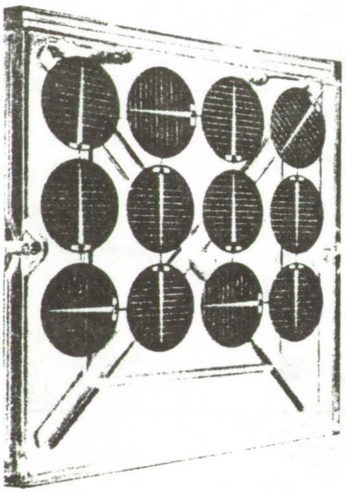
This page has been removed because of copyright information. For information on the design of Tideland Solar Power Stations contact Tideland Signal Corporation, P. O. Box 52430, Houston, Texas 77052.

Tideland SVC Series SolaViva® Electric Generators

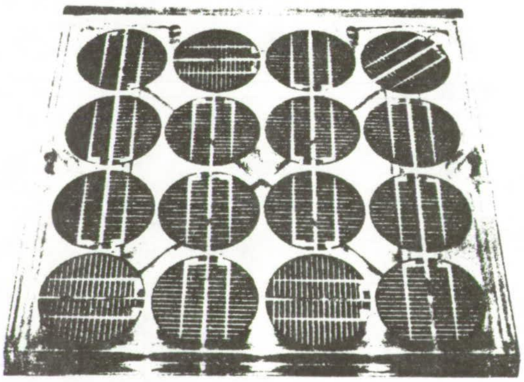




MG-600 MODULE



MG-600/4 MODULE
MG-1200/2 MODULE *



MG-300/12 MODULE

*Identical in appearance to MG-600/4. Internal wiring difference only.

U.S. Patent No. 4,097,308. Additional patents pending.

TIDELAND SVC SERIES SOLAVIVA® ELECTRIC GENERATORS

Description

The SolaViva SVC Series comprises a variety of units, each one of which is a complete, self-contained solar electric generator. Components for a unit are the FG-4 fiberglass battery box with adjustable fiberglass head on which an array of one or two SolaViva energy modules of the MG-600 type is mounted. The battery box contains the required number of VIVA® V6CR charge-retaining batteries and is reinforced by two galvanized steel channel mounts on the bottom. The batteries are protected from shock by polystyrene packing material. A NavGrip® cable gland bushing is provided on one end of the battery box for cable entry. All additional hardware used in assembly of the unit is stainless steel.

The generator is fully factory wired and tested under actual sunlight conditions. A blocking diode is included within the interior wiring from the array modules to the batteries to protect the photovoltaic cells from reverse current at nighttime. Self-regulation, a unique feature of

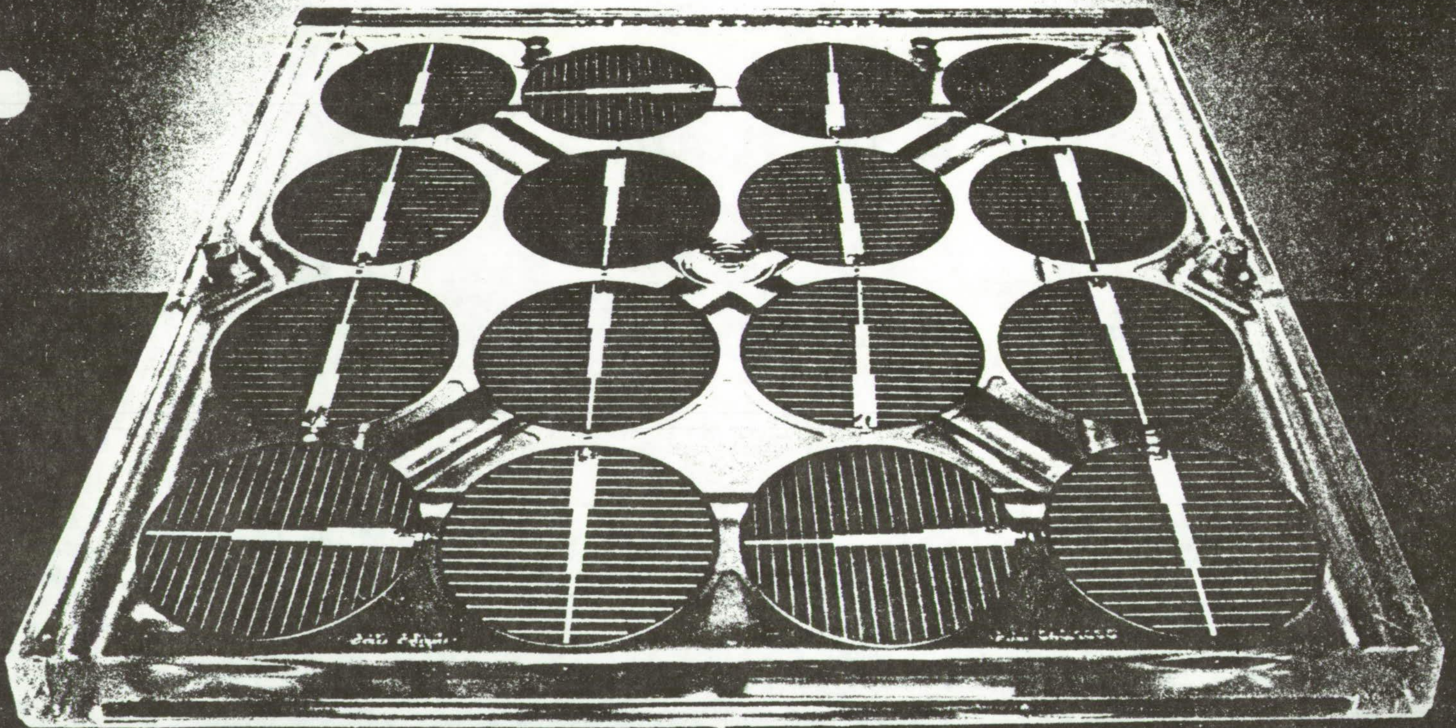
DOUBLE MODULE UNITS

MODEL NO. & PART NO.	CONFIGURATION	VOLTAGE
SVC-24/2 044.1001-1	2 MG-1200/2 Modules 2 V4CR Batteries	2
SVC-12/4 044.1001-2	2 MG-600/4 Modules 2 V4CR Batteries	4
SVC-12/6 044.1001-3	2 MG-600 Modules 2 V6CR Batteries	6
SVC-6/12 044.1001	2 MG-600 Modules 2 V6CR Batteries	12
SVC-3/24 044.1001-5	2 MG-300/12 Modules 4 V6CR Batteries	24

Annual lightfall data for an installation site within any area of the wor
Signal Corporation through its exclusive arrangement with the Institute
national meteorological authority headquartered in Houston, Te is.

This page has been removed because of copyright information. For information on the MG-600 SolaViva energy modules contact Tideland Signal Corporation, P. O. Box 52430, Houston, Texas 77052.

Now, a remarkable design for a solar energy generator that assures reliable, long-term performance

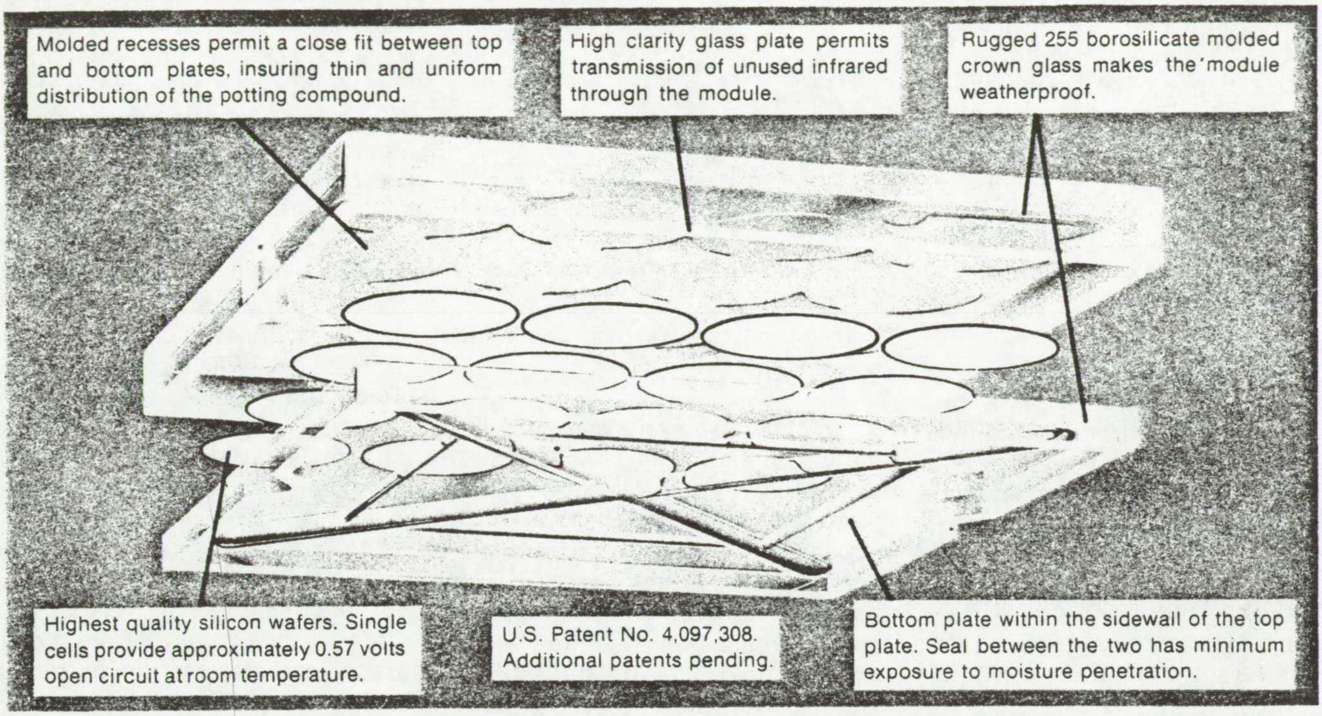


TIDELAND MG-600 SOLAVIVA® ENERGY MODULE

TIDELAND

Tideland Signal Corporation

Tideland designed and engineered the MG-600 in glass to meet the most severe environmental requirements



Solar modules of plastic can generally perform well in clean, dry environments such as desert areas and mountain elevations. But in marine environments, exceptionally harsh deteriorating influences can drastically shorten the service life of these modules.

Included among these influences: humidity, salt water, atmospheric pollutants, chemical agents, drilling muds, sulfur compounds, bird droppings, degrading sunlight (both ultraviolet and infrared) and extreme temperature changes.

Records show that failures of solar modules have been most often due to *failure of the module package* rather than cell failure.

The Tideland solution—molded glass

Tideland Signal's MG-600 SolaViva solar energy module is an assembly of sixteen silicon photovoltaic cells positioned, not in a plastic enclosure, but in two closely fitting plates molded of Special 255 borosilicate crown *glass*, offering these solid advantages:

1. Excellent protection for cells and potting compounds—the top glass plate reduces transmission of ultraviolet radiation.
2. Reduced mechanical stresses—glass and commonly used solar photovoltaic cells have similar thermal expansion characteristics.
3. Cooler, more efficient operation—glass plates permit transmission of unused infrared radiation all the way through the module.
4. Excellent resistance to corrosive organic and inorganic agents—glass is inert to almost all chemicals.
5. No cracking of cells due to package flexure.
6. Physically stable in presence of eroding materials—module is unaffected by windborne sand and spindrift.
7. Self-cleaning—the glass surface is easily washed by rain.
8. Low maintenance—paint or any other undesirable coating can be easily removed.

These pluses add up to exceptional durability and dependability in harsh environments.

Detail of module construction

Tideland engineered refinements of design and construction into the MG-600 that are further assurance of dependability:

- Both the top and bottom plates of the MG-600 have downwardly directed sidewalls. The bottom plate is positioned beneath and within the sidewall of the top plate. This reduces the exposure of the seal to moisture and other degrading agents.
- Silicone adhesive binds the interface of the two plates along the entire lip where they meet. This adhesive provides an almost impervious bond to the "sandwich" of glass plates.
- Solar cells fit into molded recesses in the top plate. This reduces plate separation to a very thin and uniform space to contain the cell potting compound. This, in turn, solves the thermal expansion problem while insuring more uniform stress distribution.
- The potting compound has been selected to eliminate reflection of the inner surfaces of the glass.
- Texturized interior surfaces of the top and bottom glass plates increase adhesion of the potting compound by increasing the effective bonding area.
- Terminals are of naval brass, coated with tin for the utmost in durability.

Tideland's refinements of reliability of SolaViv

A Tideland SolaViva Electric Generator incorporates an array of MG-600 modules which supply electrical energy to a bank of charge-retaining batteries during periods of sunshine. The sizes of the array and the battery are carefully matched to the electrical load and the geographic location to assure a constant supply of electric energy to the rated requirement of the load.

System operation

Six years of extensive, in-the-field research have led Tideland scientists to the observation that the most common system failures are of three kinds:

a) failure of the module package;

b) failure of external voltage regulation systems;

c) failure of batteries due to overcharging in the high-radiation summer months.

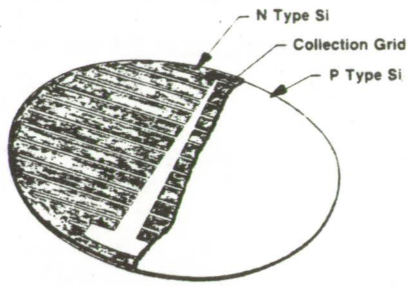
The MG-600 package was developed in direct response to the first type failure. Current experience approaches or exceeds the observed lifetime expectancy of previous solar modules without a single known electrical failure due to package failure. Indeed, one array is in service delivering its rated power after three and a half months of accidental submersion in sea water!

To address the latter two failure modes, Tideland has taken a pioneering approach, that of sizing the MG-600 module for self-regulation.

Several design considerations lead in this practical direction:

1. Properly designed systems with fewer parts have greater reliability.

2. SolaViva Electric Generators are used as isolated power sources and, as such, should not be designed to provide maximum power during periods of peak solar radiation, but instead to provide power at an essentially constant rate over the annual solar cycle.



SOLAVIVA PHOTOVOLTAIC CELL

3. For maximum system reliability and battery lifetime, the charge state of the batteries must be carefully nurtured between nominal minimum and maximum levels. The minimum charge state in winter must provide adequate reserve for weather anomalies, while the maximum charge state achieved in the late summer months must not exceed the rated battery capacity lest the electrolyte be evaporated due to overcharge. A properly designed array will have maximum current generation when the battery is partially discharged (winter) and will reduce current when the battery is near full charged (late summer).

The keys to self-regulation

The vital question in design of the self-regulating system is "How many solar cells are enough?" This raises a second question, "What cells?"

Three quantities in combination indicate the quality of solar cells:

1. Conversion efficiency (the amount of electrical energy generated in relation to the incident solar energy);

2. The open circuit voltage (the voltage produced across the cell with no load);

3. The fill factor (the ability of the cell to provide current as the reverse voltage across it increases).

Generally, the higher these numbers, the better the cells. It was decided to specify the best state-of-the-art terrestrial cell in the MG-600 solar module. Using these cells, it is possible to use the minimum number of cells, a result consistent with all of the above considerations. Careful studies showed that the optimum number is 16 **provided first quality silicon solar cells are used**. For lower grade cells, it would be necessary to use as many as 20 to achieve nominal charge efficiency and this necessitates external regulating devices since the module continues to supply current to the battery at reduced levels even though the battery is fully charged.

The blue curves on the graph show the current delivering capacity of the MG-600 module at "standard solar conditions" at two different cell surface temperatures versus the terminal voltage of the 6 volt (nominal) battery. Note that the 27°C curve shows that the module delivers nearly constant current up to a battery voltage of 8 volts. At this point, the current capacity of the cell drops sharply reaching zero just over 9 volts.

The red curve shows the charge state of the battery versus the terminal voltage. Note that for reduced charge states the terminal voltage is near 6 volts, rising gradually until the full charge state is reached. At this point, a rapid increase is seen, rising to about 7.8 volts as the battery is charged to 120% of its rated capacity. At first glance, it would appear that the battery would be overcharged. Several factors mitigate against this:

1. During the summer months, when the operating temperatures are greatest, current delivering capacity is reduced in accord with the 60°C curve. (The operating temperature will be about 25°C above ambient in full sun.)

2. The charging efficiency of the batteries decreases as the full charge state is neared. This means that the fractional energy stored in relation to

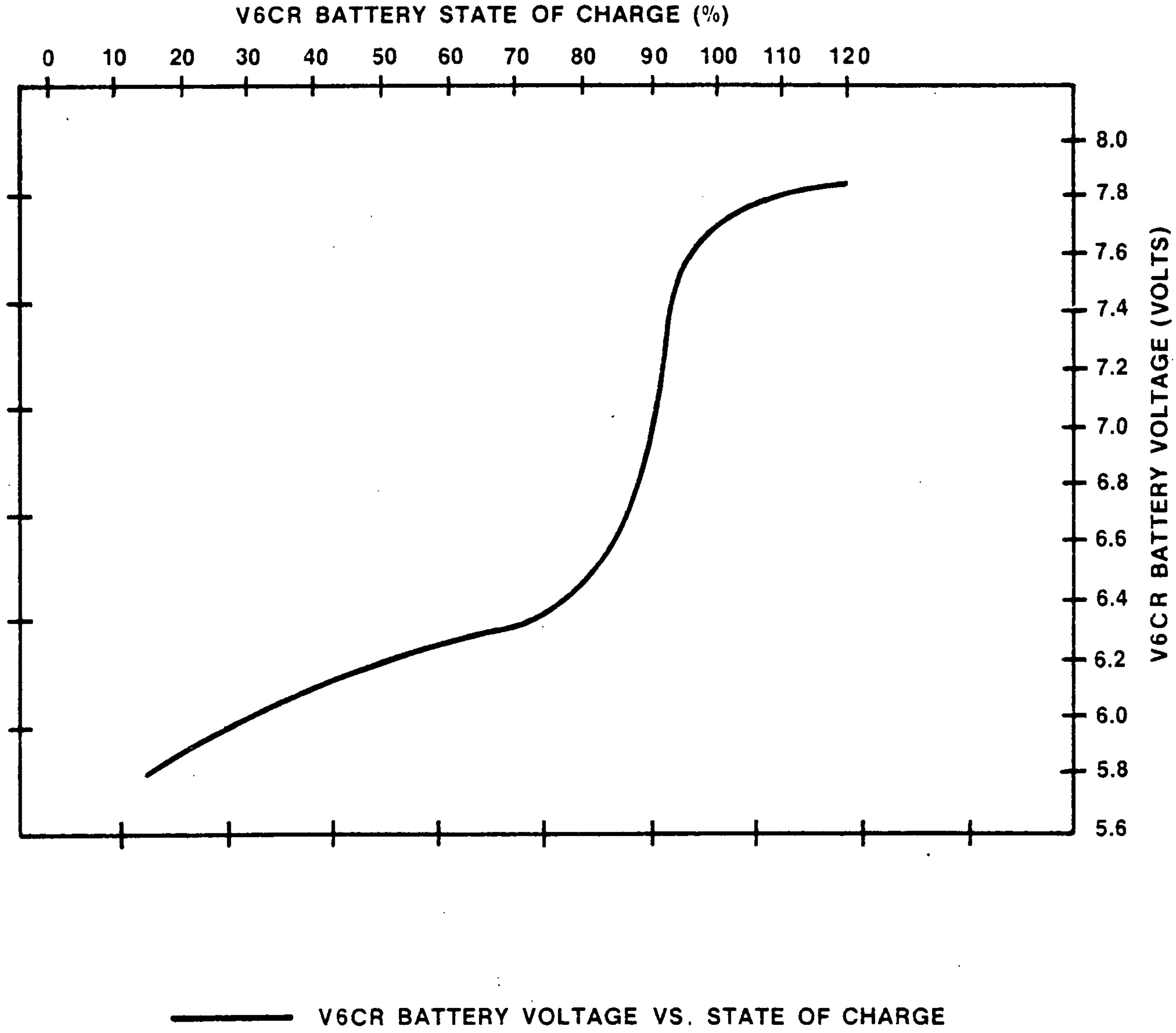
proven technology assure
a Electric Generators

the energy delivered to the battery by the solar array decreases.

3. For protection of the solar array from reverse currents during dark periods, a diode is placed in series with the array. This effectively causes the blue curves to shift approximately 0.3 volts to the left.

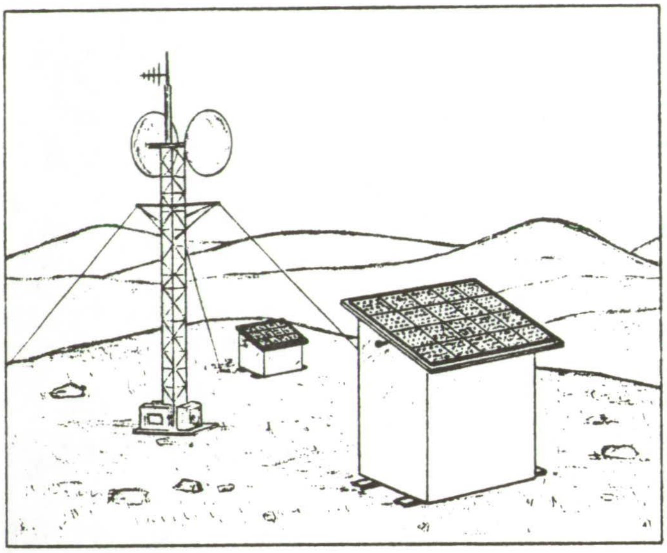
Experience has shown a remarkable system reliability provided the system is properly sized for the load demand and is properly installed.

SELF-REGULATION RELATIONSHIPS OF MG-600 AND V6CR LOW SELF-DISCHARGE LEAD ACID BATTERY



Annual lightfall data for an installation site within any area of the world is available from Tideland Signal Corporation through its exclusive arrangement with the Institute for Storm Research, an international meteorological authority headquartered in Houston, Texas.

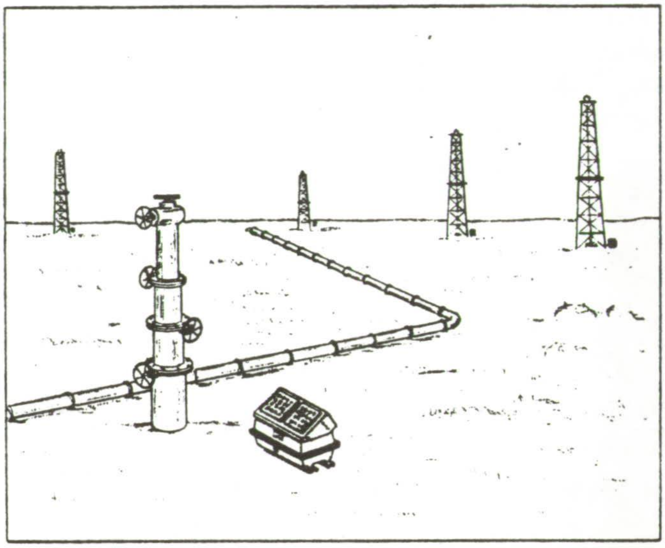
Tideland arrays of MG-600 modules offer dependable power for a wide range of applications



COMMUNICATIONS

SolaViva Electric Generators provide dependable, economical power for unmanned VHF, UHF, TV and broadcast transmitters subject to the most severe temperature and weather conditions. These generators offer solid-state reliability. No moving parts. Noiseless and ripple-free. Maintenance costs are low and service life is 10 years.

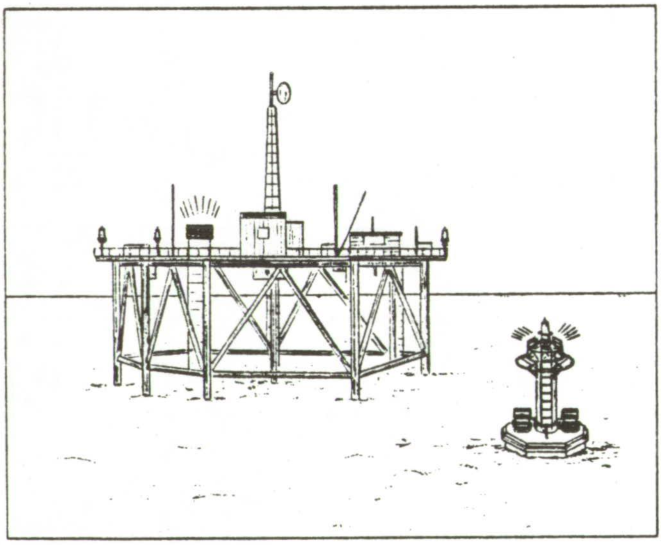
Shown: SV-60U SolaViva Electric Generator (foreground) and SV-30U SolaViva Electric Generator (background).



AUTOMATION OR CATHODIC PROTECTION

Completely self-contained, SolaViva Electric Generators are a simple, effective method of powering automation or corrosion prevention systems. They will activate remote control devices which measure flow rates or monitor control equipment operations. SolaViva Electric Generators, used in impressed current applications, provide cathodic protection for pipelines, well casings and other structural assemblies.

Shown: SVC-6/12 SolaViva Electric Generator.

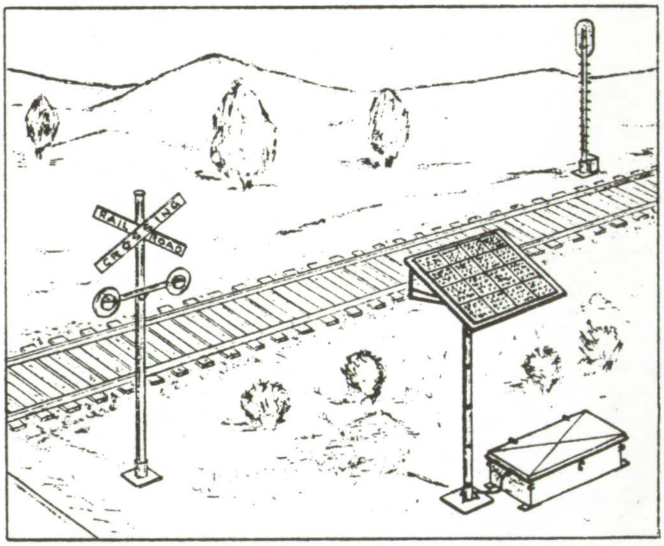


AIDS TO NAVIGATION

For seven years Tideland has conducted on-site observation of a variety of cell sizes and packaging techniques used in solar arrays deployed on several hundred offshore locations. This has prepared Tideland for its present role of worldwide leadership in solar energy used to power marine aids to navigation.

SolaViva systems, utilizing the unique and proprietary MG-600 photovoltaic module, dependably supply power for signal lanterns, fog signals, radar and radio beacons. They operate round the calendar and round the world, despite the sea's hostile environment.

Shown: SV-60AU SolaViva Electric Generator on platform, SVB-6M SolaViva Electric Generator (2 units) on buoy.



RAILROADS

SolaViva Electric Generators can reduce the hazards of unprotected railroad crossings by providing the ultimate dependable power for lights, gates and bells round the clock, 12 months a year. Other possible applications include communications, automatic controls, signals, packaged power for rolling stock. SolaViva systems are sized for the job, matched to specific requirements to give reliable service.

Shown: SV-48MU SolaViva Electric Generator.

This page has been removed because of copyright information. For information on the MG-600 Sola Viva energy module contact Tideland Signal Corporation, P. O. Box 52430, Houston, Texas 77052.

MOTOROLA
SOLAR
SYSTEMS

USER'S
MANUAL

SAMPLE

FOR
WHITECAP MOUNTAIN, MAINE
REPEATER 11-VHF 4
SSP0093

417512

Prepared by Linda Marcy

Approved by Bob Hammond
7/23/79

WARNING:

HAZARDS TO HEALTH:

LARGE SERIES STRINGS OF SOLAR PHOTOVOLTAIC CELLS CAN PRODUCE HIGH VOLTAGES AND THUS COULD BE A HUMAN SHOCK HAZARD.

THE ELECTROLYTE SUPPLIED WITH THE SYSTEM'S STORAGE BATTERIES CONTAINS STRONG ACID OR STRONG CAUSTIC MATERIAL. CARE MUST BE TAKEN IN HANDLING AND INSTALLING THE STORAGE BATTERIES.

HAZARDS TO EQUIPMENT:

FAILURE TO FOLLOW THE ELECTRICAL ASSEMBLY OF THE SYSTEM COULD RESULT IN SERIOUS DAMAGE TO THE SYSTEM COMPONENTS AND ELECTRICAL LOAD EQUIPMENT. CAREFULLY READ AND UNDERSTAND ELECTRICAL ASSEMBLY STEPS BEFORE PROCEEDING WITH EACH INSTRUCTION.

SEE PART 1, SECTION 2 FOR FURTHER SAFETY PRECAUTIONS.

TABLE OF CONTENTS

ATTACHMENT A

LIST OF FIGURES

Pg

PART 1

LIST OF TABLES

Pg

PART 2

PART 1
GENERAL INFORMATION

PART 1

GENERAL INFORMATION

SECTION 1 INTRODUCTION

1.1 FUNCTIONAL DESCRIPTION OF SYSTEM AND COMPONENTS

The Motorola solar power system is a complete (direct-current) power source which has been configured for specific customer requirements from a selection of modularized components.

In general, a solar power system is comprised of three basic building blocks: an array of photovoltaic solar modules which produce electrical power, a power conditioning block that includes storage capability (batteries) and a load. A typical solar battery charging system is shown in Figure 1.1.

When the solar array is exposed to sunlight, electrical energy is generated. This electrical power is used directly by the system load, and/or stored in the battery for later use by the system load.

The voltage regulator insures that the battery is not subjected to excess charging potentials (which can reduce battery life) and protects the load equipment from excess voltages. The need for the voltage regulator can be seen in Figure 1.2, which shows the array output voltage and the desired charging voltage for lead acid batteries in a typical 12 volt system at various temperatures. The voltage regulator limits the battery charging potential to the proper level over the operating temperature range. The blocking diode prevents the battery from discharging through the solar array during non-sunshine periods. The battery is sized to provide ample energy storage capacity for periods when sunlight is not available (cloudy, nocturnal and seasonal).

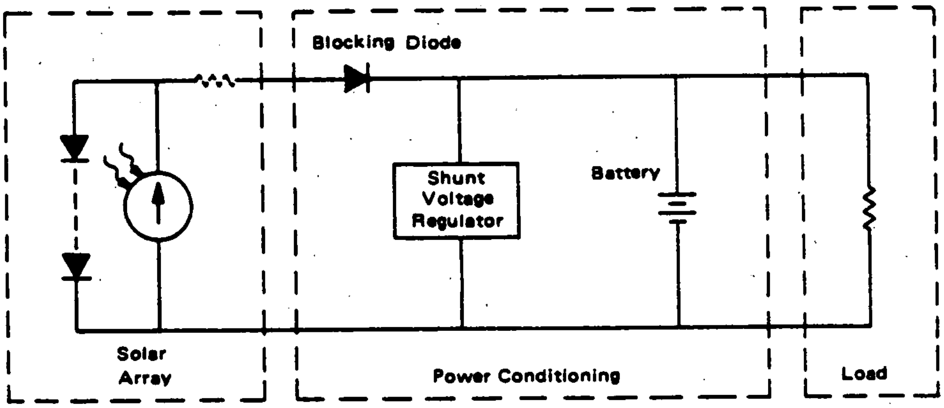


Figure 1.1 Typical Solar Battery Charger

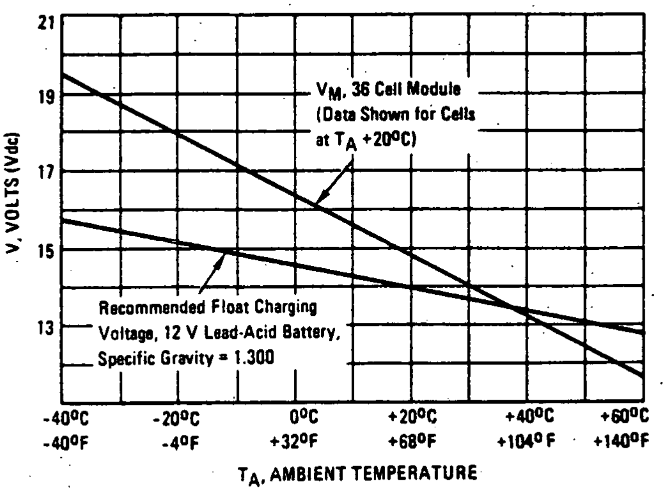


Figure 1.2 Array Output Voltage vs Desired Battery Voltage

1.2 SOLAR SYSTEM DESIGN FEATURES

The dependable solar photovoltaic cell is the only device capable of converting sunlight directly into electricity. The unique solar cell is light weight, has no moving parts to wear out, is totally noiseless, generates no waste by-products or pollution and comes with a theoretical lifetime far exceeding any other power supply. But, best of all, the solar cell requires no other energy source, no fuel other than sunlight--which is cost-free--to provide instant electricity.

Interconnected in modules and integrated into solar power systems, these unique solar cells provide an automatic, maintenance free, unfailing source of primary or standby power under even the most severe weather conditions and man-made or environmental stresses.

Motorola incorporates state-of-the-art cell design, interconnection and encapsulation techniques to tap and transform the sun's radiant energy at the highest levels of performance.

The solar cells are interconnected by means of a flexible copper-conductor printed circuit laminate located beneath the cells (Figure 1.3). The use of multiple contacts significantly enhances overall reliability of the Motorola modules.

The interconnect is then completely encased in a clear silicone gel within a peripherally-sealed, glass-and-stainless-steel case. This not only protects the cells from shock and vibration, but also locks out the corrosive effects of any moisture which might otherwise seep into the system. The net effect is a mass produced, rugged, reliable maintenance-free solar module.

The Motorola voltage regulator features 100% solid state reliability. The unit is completely weatherproof for outdoor mounting and has the blocking diode internally built-in. The regulator also incorporates internal protection against polarity reversal during installation. A temperature sensing

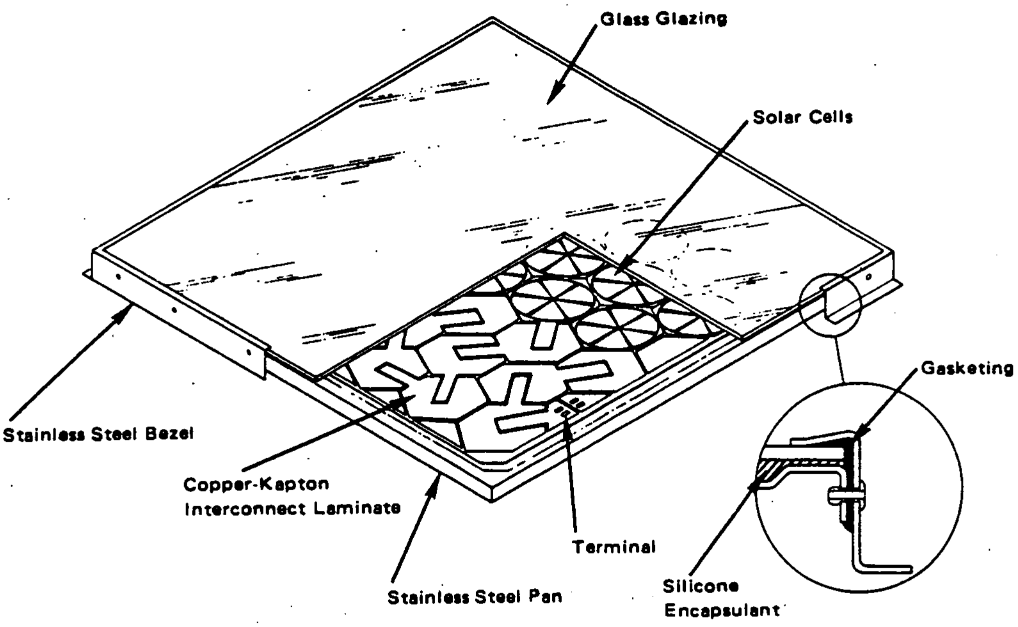


Figure 1.3 Module Construction Cross Section

thermistor is part of the master regulator circuitry and is used to measure the ambient temperature in the vicinity of the batteries, thus approximating the temperature of the battery electrolyte. As was shown in Figure 1.2, the desired charging voltage of the batteries changes with temperature. As the temperature varies, the thermistor controls the output voltage of the regulator to conform to the desired battery charging voltage.

With the aid of a highly sophisticated system-sizing computer program, Motorola solar systems are tailored to specific site locations and load conditions. This computer program performs thousands of calculations in determining the optimum array tilt angle, the number of modules in series and parallel required, and the amp-hour battery capacity needed for a specific application. (See Section 8.5 for this application). The result of all these calculations is maximum performance at minimum cost.

1.3 SOLAR SYSTEMS STANDARD WARRANTY

Seller warrants that the Motorola manufactured components of its Solar Systems sold hereunder will, at the time of shipment, be free and clear of all liens and encumbrances and will be free from defects in material and workmanship and will conform to Seller's applicable specifications or, if appropriate to specifications accepted by Seller therefor, non-Motorola manufactured products (e.g., batteries) are subject to the warranties, if any, provided by their manufacturers. Seller's obligation hereunder shall be limited to either refunding the purchase price or repairing or replacing any products for which written notice of nonconformance hereunder is received by Seller within one year following the date of delivery, provided such nonconforming products are with Seller's written authorization, returned F.O.B. Seller's plant within thirty (30) days after such one year period. This warranty shall not apply to any products which Seller determines have, by Buyer or otherwise, been subjected to testing for other than specified electrical characteristics or to operating and/or environmental conditions in excess of the maximum values established therefor in the applicable specifications, have been the subject of mishandling misuse, neglect, improper testing, repair, alteration, damage, assembly or processing that alters physical or electrical properties, or which have been subject to Acts of God.

IN NO EVENT WILL SELLER BE LIABLE FOR ANY INCIDENTAL OR CONSEQUENTIAL DAMAGES. THIS WARRANTY EXTENDS TO BUYER ONLY AND NOT TO BUYER'S CUSTOMERS OR USERS OF BUYER'S PRODUCTS AND IS IN LIEU OF ALL OTHER WARRANTIES WHETHER EXPRESS, IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS.

1.4 WHO TO CONTACT IN CASE OF DIFFICULTY

Should any questions or problem areas arise during the installation, operation or maintenance of the solar photovoltaic power supply, please contact the agency which installed your system, the nearest authorized Motorola service representative listed on the following page, or the Motorola factory at the following location:

Solar Product Marketing
Motorola Semiconductor Group
P. O. Box 2953
Phoenix, Arizona 85062
602-244-5459
TWX #910-951-1334

AUTHORIZED MOTOROLA SEMICONDUCTOR DISTRIBUTORS

ALABAMA, Huntsville	Hall-Mark Electronics	(205) 837-8700
ALABAMA, Huntsville	Pioneer-Standard Electronics	(205) 837-9300
ARIZONA, Phoenix	Hamilton/Avnet Electronics	(602) 275-7851
ARIZONA, Phoenix	Liberty Electronics	(602) 249-2232
CALIFORNIA, Costa Mesa	Avnet	(714) 754-6111 (213) 558-2345
CALIFORNIA, Culver City	Hamilton Electro Sales/L.A.	(213) 558-2000
CALIFORNIA, El Segundo	Liberty Electronics Corp.	(213) 322-8100
CALIFORNIA, Irvine	Cramer/Los Angeles	(213) 771-8300
CALIFORNIA, Mountain View	Elmar Electronics, Inc.	(415) 961-3611
CALIFORNIA, Mountain View	Hamilton/Avnet Electronics	(415) 961-8600
CALIFORNIA, Palo Alto	Kieruiff Electronics, Inc.	(415) 968-6292
CALIFORNIA, San Diego	Hamilton/Avnet Electronics	(714) 279-2421
CALIFORNIA, San Diego	Liberty Electronics	(714) 565-9171
***CALIFORNIA**, Sunnyvale	Western Microtechnology Sales	(408) 737-1660
COLORADO, Commerce City	Elmar Electronics, Inc.	(303) 287-9611
COLORADO, Denver	Hamilton/Avnet Electronics	(303) 534-1212
CONNECTICUT, Danbury	Schweber Electronics	(203) 792-3500
CONNECTICUT, Georgetown	Hamilton/Avnet Electronics	(203) 762-0361
CONNECTICUT, North Haven	Cramer/Connecticut	(203) 239-5641
FLORIDA, Ft. Lauderdale	Hall-Mark Electronics	(305) 971-9280
FLORIDA, Ft. Lauderdale	Hamilton/Avnet Electronics	(305) 971-2900
FLORIDA, Hollywood	Schweber Electronics	(305) 927-0511
FLORIDA, Orlando	Cramer/Orlando	(305) 894-1511
FLORIDA, Orlando	Hall-Mark Electronics	(305) 855-4020
GEORGIA, Atlanta	Schweber Electronics	(404) 449-9170
GEORGIA, Norcross	Hamilton/Avnet Electronics	(404) 448-0800
ILLINOIS, Chicago	Newark Electronics Corp.	(312) 638-4411
ILLINOIS, Elmhurst Industrial Park	Semiconductor Specialists, Inc./Chicago	(312) 279-1000
ILLINOIS, Elk Grove Village	Pioneer/Chicago	(312) 437-9680
ILLINOIS, Elk Grove Village	Schweber Electronics	(312) 593-2740
ILLINOIS, Mt. Prospect	Cramer/Chicago	(312) 593-8230
ILLINOIS, Schiller Park	Hamilton/Avnet Electronics	(312) 678-6310
INDIANA, Indianapolis	Graham Electronics Supply, Inc.	(317) 634-8202
INDIANA, Indianapolis	Pioneer/Indianapolis	(317) 849-7300
KANSAS, Overland Park	Hamilton/Avnet Electronics	(913) 888-8900
KANSAS, Shawnee Mission	Hall-Mark Electronics	(913) 888-4747
LOUISIANA, Metairie	Sterling Electronics	(504) 887-7610
MARYLAND, Gaithersburg	Cramer/Washington	(301) 948-0110
MARYLAND, Gaithersburg	Pioneer/Washington Electronics	(301) 948-0710
MARYLAND, Hanover	Hamilton/Avnet Electronics	(301) 796-5684
MARYLAND, Rockville	Schweber Electronics	(301) 881-3300
MARYLAND, Savage	Pyttronic Industries, Inc.	(301) 953-9850
****MASSACHUSETTS**, Burlington	Zeus Components	(617) 273-0750
MASSACHUSETTS, Lexington	Harvey Electronics	(617) 861-9200
MASSACHUSETTS, Newton	Cramer Electronics, Inc.	(617) 969-7700
MASSACHUSETTS, Newton	Impact Sales Co., Inc.	(617) 964-7740
MASSACHUSETTS, Waltham	Schweber Electronics	(617) 890-8484
MASSACHUSETTS, Woburn	Hamilton/Avnet Electronics	(617) 933-8000
MICHIGAN, Livonia	Hamilton/Avnet Electronics	(313) 522-4700
MICHIGAN, Livonia	Pioneer-Standard Electronics	(313) 525-1800
MICHIGAN, Livonia	R S Electronics	(313) 525-1155
MINNESOTA, Bloomington	Hall-Mark Electronics	(612) 884-9056
MINNESOTA, Eden Prairie	Schweber Electronics	(612) 941-5280
MINNESOTA, Edina	Cramer-Minnesota	(612) 835-7811
MINNESOTA, Edina	Hamilton/Avnet Electronics	(612) 941-3801
MISSOURI, Earth City	Hall-Mark Electronics	(314) 291-5350
MISSOURI, Hazelwood	Hamilton/Avnet Electronics	(314) 731-1144
NEW JERSEY, Cedar Grove	Hamilton/Avnet Electronics	(201) 239-0800
NEW JERSEY, Mt. Laurel	Hamilton/Avnet Electronics	(609) 234-2133
NEW JERSEY, Pennsauken	RESCO Electronics	(609) 662-4000 (215) 925-6900
NEW JERSEY, Somerset	Schweber Electronics	(201) 469-6008
NEW MEXICO, Albuquerque	Hamilton/Avnet Electronics	(505) 765-1500
*****NEW YORK**, Elmsford	Zeus Components	(914) 592-4121
NEW YORK, Farmingdale	Harrison Radio Corporation	(516) 293-7979
NEW YORK, Hauppauge, L.I.	Cramer/Long Island	(516) 231-5600
NEW YORK, Rochester	Cramer/Rochester	(716) 275-0300
NEW YORK, Rochester	Hamilton/Avnet Electronics	(716) 442-7820
NEW YORK, Rochester	Schweber Electronics	(716) 461-4000
NEW YORK, Syracuse	Cramer/Syracuse	(315) 437-6671
NEW YORK, East Syracuse	Hamilton/Avnet Electronics	(315) 437-2642
NEW YORK, Westbury, L.I.	Schweber Electronics	(516) 334-7474
NEW YORK, Woodbury, L.I.	Harvey Electronics	(516) 921-8700
NORTH CAROLINA, Greensboro	Pioneer/Washington	(919) 273-4441
NORTH CAROLINA, Raleigh	Hall-Mark Electronics	(919) 832-4465
NORTH CAROLINA, Winston-Salem	Cramer/Winston-Salem	(919) 725-8711
OHIO, Beachwood	Schweber Electronics	(216) 464-2970
OHIO, Cleveland	Hamilton/Avnet Electronics	(216) 461-1400
OHIO, Cleveland	Pioneer-Standard Electronics, Inc.	(216) 587-3600
OHIO, Dayton	Hamilton/Avnet Electronics	(513) 433-0610
OHIO, Dayton	Pioneer/Dayton	(513) 236-9900
OHIO, Solon	Cramer/Cleveland	(216) 248-8400
OKLAHOMA, Tulsa	Hall-Mark Electronics	(918) 835-8458
PENNSYLVANIA, Horsham	Pioneer/Washington	(215) 674-4000
PENNSYLVANIA, Montgomeryville	Pyttronic Industries	(215) 643-2850
PENNSYLVANIA, Pittsburgh	Pioneer-Standard Electronics	(412) 782-2300
SOUTH CAROLINA, Columbia	Dixie Electronics	(803) 779-5332
TEXAS, Austin	Hall-Mark Electronics	(512) 837-2814
TEXAS, Austin	Sterling Electronics	(512) 836-1341
TEXAS, Dallas	Hall-Mark Electronics	(214) 234-7400
TEXAS, Dallas	Hamilton/Avnet Electronics	(214) 661-8661
TEXAS, Dallas	Schweber Electronics	(214) 661-5010
TEXAS, Dallas	Sterling Electronics	(214) 357-9131
TEXAS, El Paso	Midland Speciality Co.	(915) 533-9555
****TEXAS**, Dallas	Trevino Electronics, Inc.	(214) 358-2418
TEXAS, Houston	Hall-Mark Electronics	(713) 781-6100
TEXAS, Houston	Hamilton/Avnet Electronics	(713) 780-1771
TEXAS, Houston	Sterling Electronics, Inc.	(713) 627-9800
UTAH, Salt Lake City	Hamilton/Avnet Electronics	(801) 972-2800
WASHINGTON, Bellevue	Hamilton/Avnet Electronics	(206) 746-8750
WASHINGTON, Bellevue	Liberty Electronics Corp.	(206) 453-8300
WASHINGTON, Seattle	Almac/Stroum Electronics	(206) 763-2300
WISCONSIN, Milwaukee	Marsh Electronics	(414) 475-6000
WISCONSIN, New Berlin	Hamilton/Avnet Electronics	(414) 784-4510

CANADA

CALGARY, Alberta	L. A. Varah, Ltd.	(403) 276-8818
DOWNSVIEW, Ontario	Zentronics, Ltd.	(416) 635-2822
EDMONTON, Alberta	Bowtek Electric Co., Ltd.	(403) 426-1072
HAMILTON, Ontario	L. A. Varah, Ltd.	(416) 561-9311
LONDON, Ontario	C. M. Peterson Co., Ltd.	(519) 434-3204
MISSISSAUGA, Ontario	Hamilton/Avnet Int'l Canada Ltd.	(416) 677-7432
MONTREAL, Quebec	Cesco Electronics Ltd.	(514) 735-5511
OTTAWA, Ontario	Zentronics, Ltd.	(613) 232-3591
OTTAWA, Ontario	Hamilton/Avnet Int'l Canada Ltd.	(613) 626-1700
QUEBEC CITY, Quebec	Cesco Electronics, Ltd.	(418) 524-4641
ST. LAURENT, Quebec	Hamilton/Avnet Int'l Canada Ltd.	(514) 331-6443
TOWN OF MOUNT ROYAL, Quebec	Zentronics, Ltd.	(514) 735-5361
VANCOUVER, B.C.	Intek Electronics, Ltd.	(604) 324-6831
VANCOUVER, B.C.	L. A. Varah, Ltd.	(604) 873-3211
WILLOWDALE, Ontario	Electro Sonic, Inc.	(416) 494-1555
WINNIPEG, Manitoba	L. A. Varah, Ltd.	(204) 633-6190

***Power Products**
****Military Products**
***LS TTL, M2900 Series, TTL RAMs**

MOTOROLA SEMICONDUCTOR SALES OFFICES

MOTOROLA SEMICONDUCTOR AMERICAS DISTRICT OFFICES

ALABAMA, Huntsville 35805, 2611 Artie St., Suite 4	(205) 533-1650
ARIZONA, Phoenix 85018, 4350 E. Camelback Road, Suite 230F	(602) 994-6326
CALIFORNIA, Encino/Sherman Oaks 91403, 15355 Morrison St., Suite 105 Mail to: P.O. Box 9031, Van Nuys, CA 91409	(213) 986-8850
CALIFORNIA, Orange 92668, One City Blvd. West, Bank of America Tower Bldg., Suite 722 ...(Orange Exch.) Mail to: P.O. Box 11987, Santa Ana CA 92711 ..(L.A. Exch.)	(714) 634-2844 (213) 885-9552
CALIFORNIA, San Diego 92111, 7071 Convoy Court, Suite 210	(714) 560-4644
CALIFORNIA, San Jose 95117, 4000 Moorpark Ave., Suite 216	(408) 985-0510
COLORADO, Denver 80237, 3515 S. Tamarac, Suite 330	(303) 773-6800
CONNECTICUT, New Haven/Hamden 06518, 3074 Whitney Avenue, Building C, Room 1 & 2	(203) 281-0771
FLORIDA, Pompano Beach/Ft. Lauderdale 33309, 1001 N.W. 62nd Street, Suite 310	(305) 491-8141
FLORIDA, Altamonte Springs/Maitland 32701, 253 Whooping Loop	(305) 831-3422
FLORIDA, St. Petersburg 33702, 9720 Executive Center Drive North, Suite 108	(813) 576-6030
GEORGIA, Atlanta 30328, 6085 Barfield Rd., Suite 114	(404) 394-6627
ILLINOIS, Chicago/Park Ridge 60068, 1460 Renaissance Drive, Suite 310	(312) 576-2600
INDIANA, Fort Wayne 46808, Franklin National Life Insurance Bldg. 2100 Goshen Road, Suite 208	(219) 484-0436
INDIANA, Indianapolis 46250, 6525 East 82nd Street, Suite 106	(317) 849-7060
IOWA, Cedar Rapids 52402, 206 Collins Road N.E.	(319) 377-9439
KANSAS, Kansas City/Mission 66202, 6700 W. Squibb Road, Suite 104	(913) 384-3050
MASSACHUSETTS, Boston/Lexington 02173, 2 Militia Drive	(617) 861-1350
MICHIGAN, Benton Harbor/Douglas 49406, 36 South Center Mail to: P.O. Box 567, Saugatuck, MI 49453	(616) 857-2159
MICHIGAN, Detroit/Westland 48185, Holiday Park Plaza, Suite 210 8623 N. Wayne Road	(313) 261-6200
MINNESOTA, Minneapolis 55426, 6950 Wayzata Blvd., Suite 405	(612) 545-0251
MISSOURI, St. Louis 63141, 760 Office Parkway	(314) 872-7681
NEW JERSEY, River Edge 07661, 337 Johnson Avenue	(201) 488-1200
NEW YORK, Poughkeepsie/Fishkill 12524, Route 9	(914) 896-8970
NEW YORK, Long Island/Hauppauge 11787, 350 Vanderbilt Motor Parkway	(516) 231-9000
NEW YORK, Rochester 14618, 3380 Monroe Avenue	(716) 381-7220
NEW YORK, Syracuse 13211, 123 Pickard Bldg., E. Molloy Road	(315) 454-9373
NORTH CAROLINA, Raleigh 27612, 3716 National Dr., Suite 101	(919) 782-7604
OHIO, Cleveland 44143, 840 Brainard Road	(216) 461-3160
OHIO, Dayton 45439, 3490 South Dixie Drive, Room 130	(513) 294-2231
OHIO, Columbus/Worthington 43085, 933 High Street, Suite 116	(614) 846-9480
OKLAHOMA, Tulsa 74145, 4833 South Sheridan, Suite 406	(918) 664-5227
OREGON, Portland 97221, 1730 S.W. Skyline Blvd., Suite 228	(503) 297-2235
PENNSYLVANIA, Philadelphia/Ft. Washington 19034, 501 Office Center Drive, Suite 128	(215) 643-4500
TENNESSEE, Knoxville 37919, 9041 Executive Park Drive, Building 400, Suite 403	(615) 690-5592
TEXAS, Austin 78752, 7715 Chevy Chase 4, Suite 125	(512) 452-7673
TEXAS, Dallas 75234, 4825 LBJ Freeway, Suite 140	(214) 661-9829
TEXAS, Ft. Worth 76118, 6335 Grapevine Highway (Ext. 855)	(817) 284-4861
TEXAS, Houston 77016, 2010 North Loop West, Suite 111	(713) 688-4583
VIRGINIA, Charlottesville 22901, 400 Preston Ave., Suite 300	(804) 977-3691
WASHINGTON, Seattle/Kirkland 98033, 10604 N.E. 38th Place, Suite 119	(206) 827-4681
WASHINGTON, D.C./MARYLAND, Lanham 20801, 5900 Princess Garden Parkway, Suite 804	(301) 577-2600
WISCONSIN, Milwaukee/Wauwatosa 53226, 909 North Mayfair Road	(414) 476-5554

Field Applications Engineering Available Through All Sales Offices

MOTOROLA SEMICONDUCTOR INTER-COMPANY OFFICES

ARIZONA, Scottsdale 85251, 8201 E. McDowell Road, Room 3195	(602) 949-3811
FLORIDA, Ft. Lauderdale 33313, 8000 W. Sunrise Blvd.	(305) 473-6000
ILLINOIS, Franklin Park/Schaumburg 60196, CONSUMER/1229 E. Algonquin Road, Room 2024	(312) 576-2788
ILLINOIS, Schaumburg 60196, INDUSTRIAL/1301 E. Algonquin Road, Room 2707	(312) 576-5518

MOTOROLA SEMICONDUCTOR INTERNATIONAL SALES OFFICES

ARGENTINA, Buenos Aires Uruguay 485, Floor 6th, Office "C"	Motorola International, Inc.	46-9797
AUSTRALIA, Sydney 37-43 Alexander St., Suite 204 Crow's Nest, N.S.W. 2065	Motorola Semiconductor Products Div. Motorola Australia Pty. Ltd.	43-4409/4299
DENMARK, DK2800 Lyngby Bredebovej 23	Motorola Semiconductors	(01) 88 44 55
BRAZIL, Sao Paulo Caixa Postal 8718	Motorola Semiconductores do Brazil, Ltd.	70-2395 or 70-7286
CANADA, Ontario, Downsview, M3N 1Y4 490 Norfinch Drive	Motorola Semiconductor Products, Canada	(416) 661-6400
CANADA, Ontario, Ottawa K1Z 6A6 1007 Merivale Road, Room 106	Motorola Semiconductor Products, Canada	(613) 729-4361
CANADA, Quebec, Montreal H4T 1G1 7800 Cote de Liesse Road	Motorola Semiconductor Products, Canada	(514) 731-6881
CANADA, North Vancouver, B.C. 706 E. 7th Street	Motorola Semiconductor Products, Canada	(604) 985-4818
ENGLAND, Wembley, Middlesex York House, Empire Way	Motorola Semiconductors Ltd.	01-902-8836
ENGLAND, Manchester, 2. Lancashire M2 5WS Television House, 10/12 Mount Street	Motorola Semiconductors Ltd.	061-833-0731
FRANCE, Paris 75007 15-17 Avenue de Segur Mail: Boite Postale 101-07, 75326 Paris Cedex 07	Motorola Semiconducteurs, S.A.	551-50-61 551 50 61
GERMANY, 3012 Langenhagen/Hannover Hans-Boeckler-Strasse 30	Motorola GmbH, Geschaftsbereich Halbleiter	(0511) 77-20-37
GERMANY, 8043 Munich, Unterfoehring Muenchner Strasse 18	Motorola GmbH, Geschaftsbereich Halbleiter	089-95-1041
GERMANY, Nurnberg Virnsberger Strasse 43	Motorola GmbH, Geschaftsbereich Halbleiter	(0911) 65761
GERMANY, 7032 Sindelfingen Stralsunder Strasse 1, P.O.B. 450	Motorola GmbH, Geschaftsbereich Halbleiter	(07031) 83074
GERMANY, 6200 Wiesbaden A. Lincoln Strasse 28	Motorola GmbH, Geschaftsbereich Halbleiter	(06121) 76-1921
HOLLAND, Utrecht Emmalaan, 41	Motorola N.V.	030 510207
HONG KONG, Hunghom, Kowloon 10th Floor Eldex Building, Block C-21 Matauwei Road	Motorola Semiconductors Hong Kong Ltd.	3-69 4717
ISRAEL, Tel Aviv 67-899 16, Kremenetski Street	Motorola Israel, Ltd.	03-38973
ITALY, 40137 Bologna Via Portanova	Motorola Semiconduttori S.p.A.	266905
ITALY, 20129 Milan Via Ciro Menotti 11	Motorola Semiconduttori S.p.A.	738-6141
ITALY, 00162 Rome Via Constantino Maes 68	Motorola Semiconduttori S.p.A.	83.14.7.46
JAPAN, Osaka Shin Osaka Chisan Bldg., 7-1-26, Nishinakajima, Yodogawa-Ku	Motorola Semiconductors, Ltd.	06-262-4637
JAPAN, Tokyo 12-16, Jingyu-Mae, 6-Chome, Shibuya-Ku	Motorola Semiconductors Japan Ltd.	03-499-1241
MEXICO, Mexico 20, D.F. Tecoyotitla No. 191-A. Col. Florida	Productos Semiconductores Motorola de Mexico, S.A.	(905) 524-9191
PUERTO RICO, San Juan/Santurce 00907 Sonsid Condominium, 1319 Ashford Avenue	Motorola Americas Inc.	(809) 723-9350
SINGAPORE, 9 Room 520 Plaza Singapora, 68 Orchard Road	Motorola Singapore Pty. Ltd.	361-755
SWEDEN, S-171 40 Solna Vireberjsvagen 19	Motorola Semiconductor AB	08/82 02 95
SWITZERLAND, 1211 Geneva-Montbrillant 20 16, chemin de la Voie-Creuse, P.O. Box 8	Motorola Semiconductor Products Inc.	(022) 33 56 07
SWITZERLAND, 8702 Zollikon-Zurich 101, Alte Landstrasse – P.O. Box 62	Motorola Semiconductor Products Inc.	(C51) 65 56 56/07
TAIWAN, Taipei Hsietsu Building, Room 604 47 Chung Shan North Road, Sec. 3	Motorola Asia, Ltd.	594-7172/6

MOTOROLA SEMICONDUCTOR HEADQUARTER SALES

ARIZONA, Phoenix 85036, P. O. Box 20912 .... (602) 244-3952

MOTOROLA *Semiconductor Products Inc.*

PRINTED IN U.S.A • C.O.L. PUBLISHING INC., PHOENIX, ARIZONA

The solar array will always produce electrical energy when the sun is shining on it. Therefore, it is suggested that the power output terminals of the modules be electrically shorted together during module handling and array assembly. (Note: The shorting material must be removed during final electrical assembly in order to provide proper system performance).

The storage batteries supplied with the system contain strong acid electrolyte (lead acid and lead calcium batteries) or strong caustic electrolyte (nickel cadmium batteries). Care must be taken in their installation and interconnection.

The following general precautions for the safe handling of the storage batteries should be observed. More detailed safety precautions are included in the battery installation instructions (See Part 2, Section 2).

a) In the operation of an acid battery, hydrogen gas is liberated, which may be explosive if ignited. Keep open flames, burning material, and spark-producing sources away from the batteries.

b) The battery area should be well ventilated to prevent hydrogen gas build-up, particularly at the ceiling.

c) Cells connected in series can produce high voltages and thus could be a human shock hazard.

d) The electrolyte of the battery should be handled only when wearing plastic or rubber gloves and apron and safety goggles. Have fresh water available so that if electrolyte does come in contact with the skin, it can be rinsed off immediately. If electrolyte comes in contact with the eyes, flush liberally with water and consult a physician. A mixture of 1 lb. bicarbonate of soda in one gallon of water can be used to neutralize acid spills. Apply the solution until bubbling stops, then thoroughly rinse the area with water. A mixture of 1 lb. of boric acid in 1 gallon of water can be used to neutralize caustic spills. Apply the solution in the above manner, being careful to thoroughly rinse any affected galvanized steel surfaces.

e) When diluting an electrolyte, always add electrolyte to water slowly, with constant stirring. Explosive reactions can occur if this procedure is not followed.

During normal operation of the solar array, the voltage regulators may be quite <u>hot</u>. Care should be taken to avoid burns when working in the vicinity of the voltage regulators.

The mechanical and electrical assembly of Motorola solar systems is straightforward and requires a minimum of special tools. A standard selection of wrenches, screwdrivers, pliers, etc., should be available at the installation. Refer to the Parts List (Part 2, Section 1.4) for a complete list of assembly hardware and fasteners. Basic tools for the assembly of this type hardware are required. Your tool selection should include, but not be limited to, the following:

Standard spade blade screwdrivers
Standard Phillips head screwdrivers
Standard socket wrenches
Standard box wrenches
Ratchet socket wrench drive
Wire cutters (dikes)
Wire stripper (for #18, #10 and #4 wire)
Crimping tool (for #18 and #10 terminals)
16 oz. steel hammer
Pliers or vise grips
Work gloves
Torque wrench (with drive to fit socket wrenches)
Drill (hand or power - with portable supply)
Metal drill bits
Metal files, rat tail and flat
Hacksaw and blades
Soldering iron (with portable power supply)
Syringe filler
3 ft. jumper cables, #10 wire or larger with alligator clamps
Tilt meter (to measure array tilt angle) or level and protractor
Wire crimp connectors or wire nuts, #18 and #10
2 Hydrometers high - s.g. 1.150 to 1.300
low - s.g. 1.050 to 1.250
Gallon jugs of potable water
Plastic mixing bucket
Plastic apron
Safety goggles
Rubber or plastic gloves
Glass thermometer
½ pt. rust preventative paint and applicator
1 lb. box boric acid or bicarbonate of soda (See Safety Instructions, Part 1, Section 2)

It is recommended that this manual be thoroughly read and understood and any necessary adjustments be made to the tool selection before departing for the job site. Check the Parts List thoroughly to be sure all parts have been received. It is recommended that extra nuts, bolts, washers, etc., of the appropriate sizes and lengths be included in the tool selection.

In addition to the above supplies, the following special test equipment is recommended:

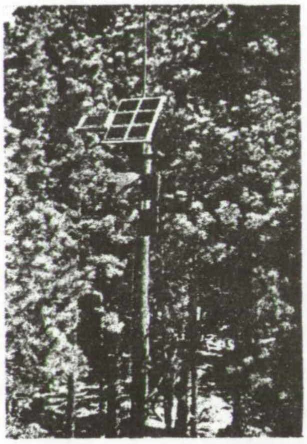
Simpson Model 260 Volt-ohm meter or equivalent
Simpson Model 6709 external, portable 50 amp shunt or equivalent
Fluke Model 8020A Multimeter or equivalent
(Optional) Matrix Solameter Model MK1GM solar radiometer or equivalent (to measure solar irradiation).

SECTION 4
ASSEMBLY AND INSTALLATION INSTRUCTIONS

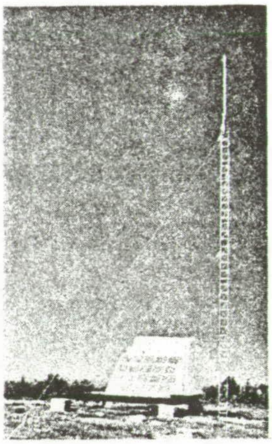
4.1 GENERAL OVERVIEW OF TYPICAL SYSTEM

Pictured below (Figure 4.1) are typical system installations showing a variety of installation alternatives.

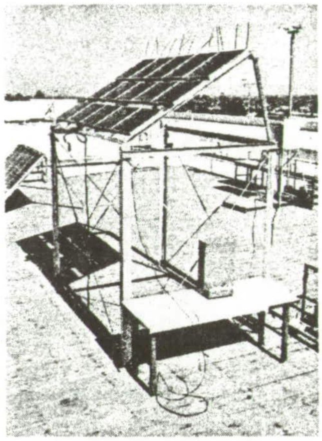
Before beginning installation of the system, it is suggested that all the members of the support frame (and scaffold, if used) be laid out in the proper positions and orientations in an assembly "dry run" to gain familiarity with the structure.



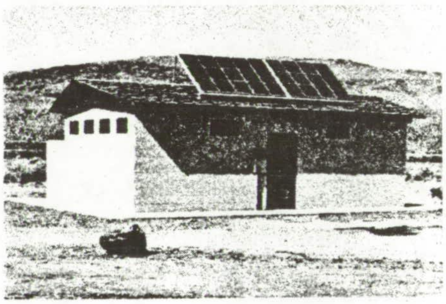
Single Pole Mount



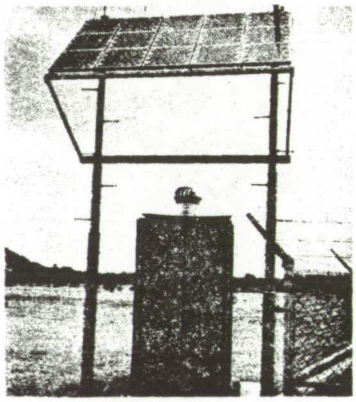
Ground Mount



Scaffold Mount



Roof Mount



Double Pole Mount

Figure 4.1 Typical System Installations

Carefully read through the assembly instructions making sure each step is understood. (BE SURE TO REFER TO PART 2, SECTION 8.1 TO DETERMINE IF THERE ARE ANY UNIQUE ASSEMBLY INSTRUCTIONS FOR YOUR SYSTEM). Make note of these changes in the appropriate locations in this section. As you read through the directions, carefully check that each structural member and the associated hardware called out in the instructions and itemized in the systems Part List, Part 2, Section 8.4 has been delivered to the site.

After the assembly "dry run" has been completed, the actual step-by-step assembly and installation of the system can be accomplished with a minimum of effort.

In the Northern hemisphere, the solar array must be tilted toward <u>true</u> South and vice versa <u>(true</u> North) in the Southern hemisphere. Special attention must always be given to determine <u>true</u> North or <u>true</u> South, rather than magnetic North/South at the application site.

4.2 MECHANICAL ASSEMBLY

4.2.1 ASSEMBLY OF THE SUPPORT STRUCTURE

Refer to the assembly and fastener detail drawing(s) in Part 2, Section 8.2 and Parts List, Part 2, Section 8.4.

The installer must provide adequate provisions and hardware for anchoring the array mounting brackets (feet) and, if desired, shelter for the storage batteries to minimize environmental exposure. Part 2, Section 8.5 details the extreme minimum and maximum temperatures for which your system was designed. Provisions should be made to protect the batteries such that the temperature of the battery electrolyte does not exceed these temperature limits.

Below are sketches of typical anchoring techniques for a variety of array mountings. (Figure 4.2) These are provided as suggested mountings only

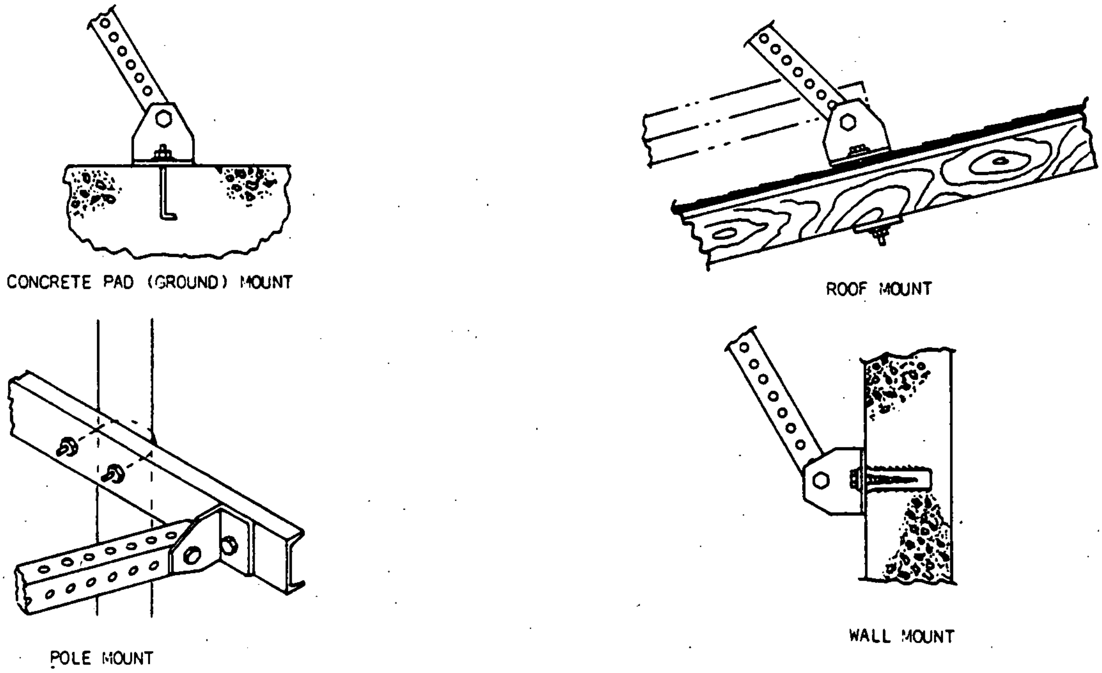


Figure 4.2 Typical Anchoring Methods

and any equivalent mounting can be utilized. Also, in order to reduce the area occupied by the array, the mounting brackets (feet) can be located on the inside of the framework (pointing inward). The center-hole spacing for the anchor bolts indicated on the assembly drawing is for the normal (outside) mounting.

NOTE: When assembling a structure, fasteners should be hand tightened only, until the complete structure is in place.

4.2.1.1

Locate the four mounting brackets, Parts List (P/L) #5, on existing anchor bolts (customer supplied) and attach each with hex nut and lockwasher (customer supplied). Hand tighten only.

4.2.1.2

Attach rail (horizontal member), P/L #2, to the southern-most brackets if array is located in northern hemisphere, or the northern-most brackets if array is located in the southern hemisphere. Use fasteners as called out and shown in Detail "G" on Fastener Detail Drawing. Hand tighten only.

4.2.1.3

Attach spreader (vertical member), P/L #1, to one end of the rail. Each end spreader can only be assembled in one position. See electrical schematic, Part 2, Section 8.3, for regulator bracket location, since the spreaders with the regulator bracket mounted between them must be "open" to each other as shown on array assembly drawing (not applicable to 1 module wide arrays). See Detail "D". Assemble spreaders to rail flat on ground and hand tighten only.

4.2.1.4

Attach the remaining rail, P/L #2, to the top of each spreader and hand tighten only.

4.2.1.5

With array frame still on the ground, attach the outer support braces, P/L #37, to the upper rail, P/L #2, according to Detail "A" and hand tighten only.

4.2.1.6

Attach inner support brace, P/L #36, if supplied, to outer support brace, as shown in Detail "B" and hand tighten only.

4.2.1.7

Raise the array frame by the top rail and attach the free end of each support brace to the two remaining mounting brackets, as shown in Detail "C". Hand tighten only. Adjust the array angle initially to allow easy module and wiring attachment (generally the most vertical angle possible). This is accomplished by telescoping the inner and outer support braces to their longest fastenable length. Proceed with module attachment.

4.2.2 MECHANICAL ATTACHMENT OF MODULES AND REGULATORS

4.2.2.1

Attach solar module(s), P/L #35, to the array frame from bottom to top and from left to right where applicable. CAUTION: Voltage is being generated whenever modules are exposed to light.

Module terminals should be in the upper right corner when viewed from below (Figure 4.3). See Detail "E" for fastener details. Hand tighten only.

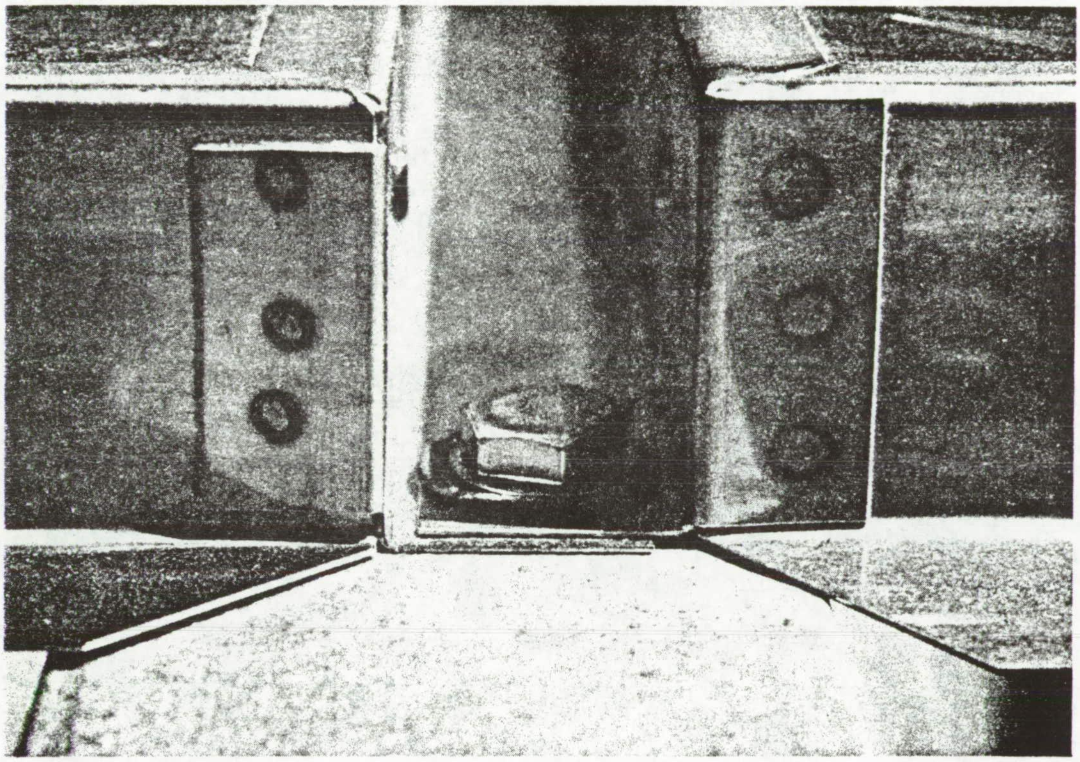


Figure 4.3 "Shingling" of Module Flanges During Assembly

4.2.2.2

Refer to Drawing for Regulator and Bracket Fastener Details. Determine the type of regulator mounting bracket, P/L #6 a, b or c, and using the appropriate fasteners, attach the master regulator, P/L #16, and slave regulator(s), P/L #38, if required, to the mounting bracket (if not already done). Tighten securely. The regulator connectors should face down when the bracket is installed. For multiple regulator mounting brackets, P/L 6a only, attach the insulator block, P/L #31, and buss bars, P/L #7, to the mounting bracket (if not already done) using the appropriate fasteners. Tighten securely.

If the regulator panel is to be located under the array, attach the mounting bracket to the array frame spreaders in the location indicated on the system electrical schematic, Part 2, Section 8.3, and as shown in the above referenced drawing using the appropriate fasteners.

If the regulator panel is to be located in the battery/equipment shelter (i.e., remote from the array), attach it to a vertical wall of the shelter using the appropriate fasteners.

4.2.2.3

Tighten all fasteners for the entire structure in the reverse order of installation. Tighten securely but do not overstress. Do not exceed the following torque figures:

Bolt Size	Tightening Torque
1/4-20	20 in-lbs
3/8-16	250 in-lbs
1/2-12	550 in-lbs

4.2.3 BATTERY AND THERMISTOR - MECHANICAL INSTALLATION

4.2.3.1

Refer to the installation instructions for the storage batteries supplied in Part 2, Section 9. Follow the safety precautions in Part 1, Section 2 when handling and installing the batteries.

4.2.3.2

The thermistor should be located in the immediate area of the batteries to sense the battery temperature. The thermistor housing should be firmly attached to the battery support rack, or banded or taped to the side of a battery. See Figure 4.4. If not already done, the thermistor lead wires should be lengthened appropriately to reach the regulator panel. Use the #18 wire supplied (25 feet) and solderless crimp connectors.

4.3 ELECTRICAL ASSEMBLY

Refer to the electrical schematic for the system, Part 2, Section 8.3. Also, refer to the regulator and bracket fastener detail drawing Part 2, Section 8.2.

Before beginning the electrical assembly of the system, it is suggested that all the instructions be thoroughly read and understood. Be sure to refer to Part 2, Section 8.1 to determine if there are any unique electrical assembly instructions for this system. Make note of these changes (if any) in the appropriate locations in this section.

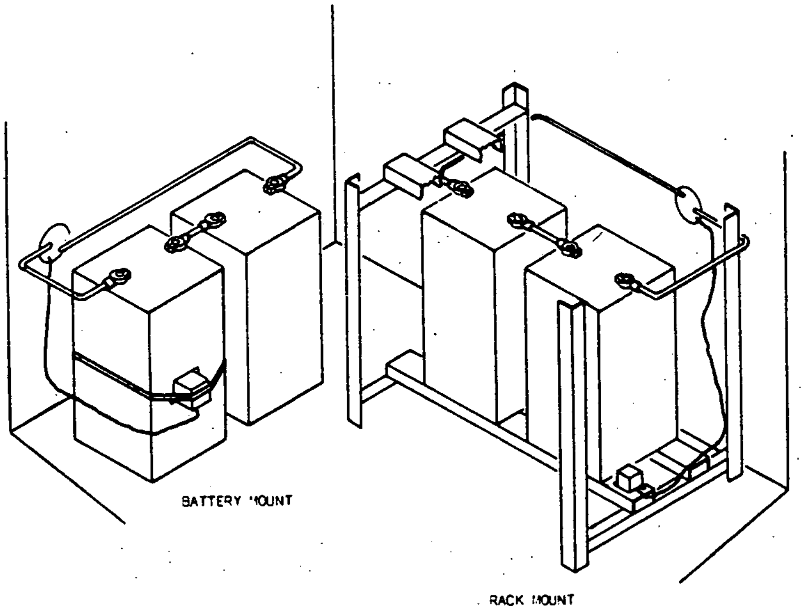


Figure 4.4 Typical Thermistor Mountings

After the electrical "dry run" has been completed, the actual step-by-step electrical assembly can be accomplished with a minimum of effort and a minimum risk of possible electrical damage to the system or its components.

4.3.1 ELECTRICAL ASSEMBLY - SOLAR MODULES

CAUTION: Electrical power is being produced whenever the modules are exposed to sunlight.

4.3.1.1

Using the #10 AWG white terminated wires (P/L #39), connect the module terminals as indicated in the electrical schematic and described in Note 1 of the schematic. Single module systems do not require #10 AWG white interconnects. Do not exceed 15-in pounds tightening torque on terminal nuts or severe damage to the module terminals could result. Do not slide the weather protection boots into place until all wiring is complete and system function has been verified. See Figure 4.5.

4.3.1.2

Connect the #10 AWG red terminated wire(s) to the positive (+) terminal(s) of the module(s) as shown in the electrical schematic and described in Note 2 of the schematic. Do not over tighten.

4.3.1.3

Connect the #10 AWG black terminated wire(s) to the negative (-) terminal(s) of module(s) as shown in the electrical schematic and described in Note 3 of the schematic. Do not over tighten.

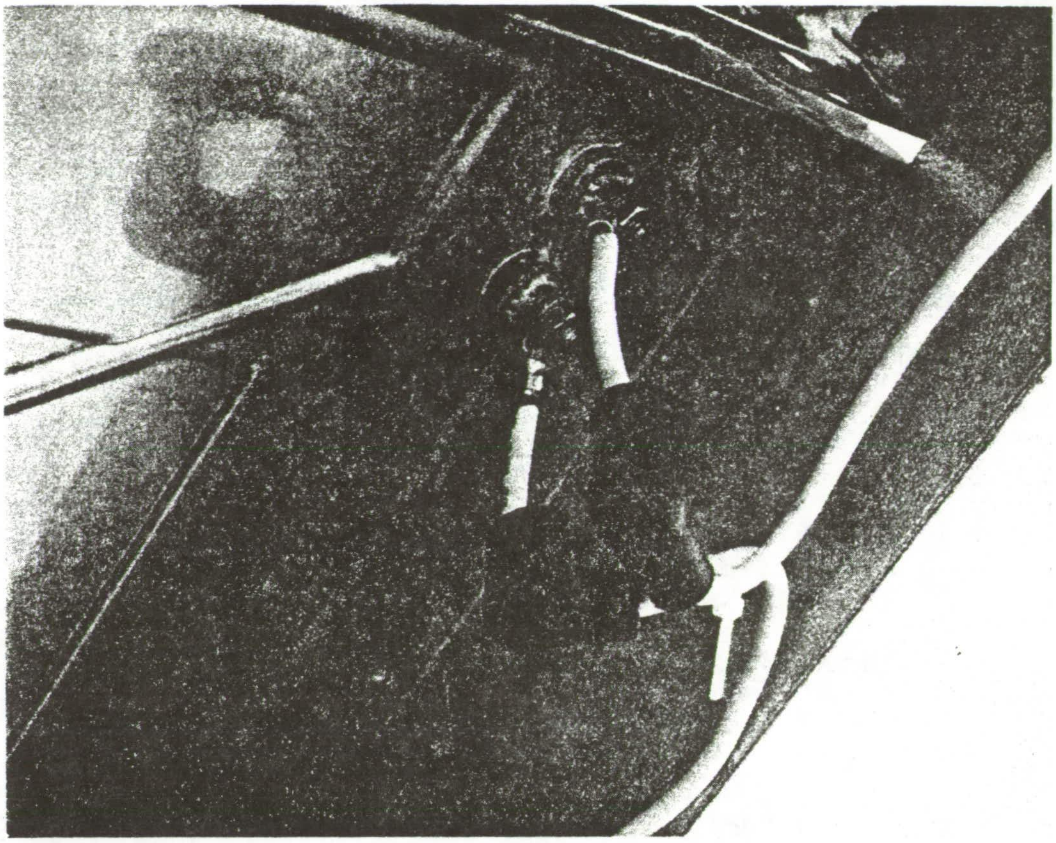


Figure 4.5 Typical Series Connection of Solar Modules

4.3.1.4

Electrically check the module or module strings for the proper power output. Measure the open circuit voltage of each module string, using a voltmeter capable of 2% accuracy at the measured voltage.

Measure the short circuit current of each module string using a current meter with a sufficiently low resistance (i.e., its terminal voltage drop does not exceed 10% of the nominal system voltage). Connect the meter directly across the output leads of each module string to make the measurement. When disconnecting the meter, the connection should be broken rapidly as there will be a tendency of large dc currents to draw an arc and burn the leads. Also, the operator should not touch both sides of the connection while it is being broken as there may be an inductive kick which could be dangerous.

The open circuit voltage and the short circuit current should fall within the ranges indicated in the system performance specifications in Part 2, Section 8.5, Table 1: Module String Output.

If any measurement falls outside the range indicated, review the above wiring steps for completeness and accuracy. If, after checking the wiring, there is still a problem, refer to the fault isolation and correction activities in Part 1, Section 7.

4.3.2 ELECTRICAL ASSEMBLY - REGULATOR PANEL FOR SYSTEMS WITH MULTIPLE REGULATOR MOUNTING BRACKETS ONLY

NOTE: For systems with single regulator mounting bracket, skip to Paragraph 4.3.3.

4.3.2.1

Connect the free end(s) of the #10 AWG red wire(s) from the array to the positive input buss bar on the regulator mounting bracket. If a clamp type terminal strip buss bar is supplied, all wire ends should be tinned before inserting in the terminal block. Tighten securely. If the regulator panel is located in the battery/equipment shelter (i.e., remote from the array), all the red and black leads from the array should be bundled and routed appropriately from the array to the vicinity of the regulator panel. Care should be taken to insure that wire insulation is not gouged or scarred if wires are pulled through electrical conduit or pipe, etc. It is also important to protect the wiring insulation at any point where a wire bundle goes through a wall or panel.

The red wire(s) should then be attached to the positive input buss bar as described above.

4.3.2.2

Connect the free end(s) of the #10 AWG black wire(s) from the array to the common (middle) buss bar on the regulator mounting bracket. Tighten securely

4.3.2.3

The electrical output of the entire array should now be checked for proper performance. The open circuit voltage and the short circuit current should fall within the ranges indicated in the system performance specifications in Part 2, Section 8.5, Table 1: Total <u>Unregulated</u> Array Output. The measurements should be made as in Paragraph 4.3.1.4.

If either measurement falls outside the range indicated, review the above wiring steps for completeness and accuracy. If, after checking the wiring, there is still a problem, refer to the fault isolation and correction activities in Part 1, Section 7.

4.3.2.4

Using #10 AWG jumper cable (or larger) with alligator clips or equivalent, electrically short the positive input buss bar to the common (middle) buss bar.

4.3.2.5

Check the fuse(s) on the master regulator and on each slave regulator (if supplied) to verify that each fuse is functional.

4.3.2.6

Connect the #18 AWG wire(s) from the master regulator and slave regulator(s) if supplied, to the positive input buss bar using the appropriate fasteners. Tin the wire ends if necessary. Tighten securely.

4.3.2.7

Connect the blue #18 AWG wire(s) from the master regulator and slave regulator(s) if supplied, to the common (middle) buss bar using the appropriate fasteners. Tin wire ends as necessary and tighten securely.

4.3.2.8

Connect the green #18 AWG wire(s) from the master regulator and slave regulator(s) if supplied, to the positive output buss bar using the appropriate fasteners. Tin wire ends as necessary and tighten securely. Note that prior to this step, the positive output buss bar is the one with no wires connected to it.

4.3.2.9

For systems with slave regulators - Using the 3 - wire #18 AWG jumper connector(s) supplied, connect the master regulator to its adjacent slave regulator and that slave regulator to the next adjacent slave regulator and so forth until all regulators are appropriately interconnected. The remaining open socket on the last slave regulator should be filled with RTV or other suitable sealant. This socket is not used.

4.3.2.10

Connect the black #18 AWG wire from the thermistor assembly to the black #18 AWG wire from the master regulator, if not already done, using a wire nut or solderless crimp connector. The end(s) of the connector should be filled with RTV or other sealant to prevent moisture ingression.

4.3.2.11

Connect the blue #18 AWG wire from the thermistor assembly to the common (middle) buss bar of the regulator mounting panel.

4.3.2.12

Disconnect the #10 AWG temporary jumper cable from the shorted buss bars detaching in a quick, clean motion to minimize arcing and possible damage to the buss bar.

4.3.2.13

The regulated electrical output of the array should now be checked. Measure the short circuit current of the array between the output buss bar and common buss bar using the technique described in Paragraph 4.3.1.4.

Next measure the open circuit voltage across the common buss bar and the output buss bar.

These measurements should fall within the ranges indicated in the system performance specifications in Part 2, Section 8.5, Table 1: Total Regulated Array Output. If either measurement falls outside the range indicated, review the above wiring steps for completeness and accuracy. If, after checking the wiring, there is still a problem, refer to the fault isolation and correction activities in Part 1, Section 7.

4.3.2.14

Connect the #4 AWG black wire to the common (middle) buss bar using the appropriate grounding lug (P/L #13). Tighten securely.

4.3.2.15

Connect the #4 AWG red wire to the positive output buss bar using a grounding lug. Tighten securely. Do not allow the free ends of these battery leads to short together.

4.3.2.16

Connect the remaining #4 AWG black wire (the ground wire) to any module attach bolt using a grounding lug and an appropriate lockwasher and nut as shown in the regulator mounting bracket detail drawing in Part 2, Section 8.2. Connect the free end to the system ground.

4.3.2.17

All wires should now be properly attached to local supporting members wherever possible and to each other using the small cable ties (P/L #11) provided. This will minimize movement of the wires during windy periods and prevent abrasion failures of the wiring insulation.

The system is now ready to be connected to the storage batteries. Skip to paragraph 4.3.4.

4.3.3 ELECTRICAL ASSEMBLY - REGULATOR ASSEMBLY FOR SYSTEMS WITH SINGLE REGULATOR MOUNTING BRACKET ONLY.

4.3.3.1

Connect the free end of the #10 AWG red wire from the array to the #18 AWG red wire of the master regulator using a wire nut (P/L #17) or a solderless crimp connector. The end(s) of the connector should be filled with RTV or other equivalent sealant to prevent moisture ingression.

4.3.3.2

Connect the free end of the #10 AWG black wire from the array to the #18 AWG blue wire from the thermistor assembly, the #18 AWG blue wire from the master regulator and the #10 black wire from the negative battery terminal. Use a wire nut or solderless crimp connector and seal with RTV, as necessary. NOTE: Do not connect the battery yet.

4.3.3.3

Connect the #18 AWG green wire from the master regulator to the #10 AWG red wire from the positive battery terminal using a wire nut or solderless crimp connector and seal with RTV as necessary. Care should be taken to see that the free ends of the battery leads are not permitted to short together. NOTE: Do not connect the battery yet.

4.3.3.4

Connect the #18 AWG black wire from the master regulator to the #18 AWG black wire from the thermistor assembly, if not already done, using a wire nut or solderless crimp connector and seal with RTV as necessary.

4.3.3.5

The regulated electrical output of the array should now be checked. The open circuit voltage and short circuit current of the array should fall within the ranges indicated in the system performance specifications in Part 2, Section 8.5, Table 1: Total Regulated Array Output. These measurements are made at the free ends of the #10 AWG battery leads. Measure the open circuit voltage using a voltmeter capable of 2% accuracy at the measured voltage.

Measure the short circuit current using a current meter with a sufficiently low resistance (i.e., its terminal voltage drop does not exceed 10% of the nominal system voltage). Connect the meter directly across the battery leads to make the measurement. When disconnecting the meter, the connection should be broken rapidly as there will be a tendency to draw an arc and burn the leads. Also, the operator should not touch both sides of the connection while it is being broken as there may be an inductive kick which could be dangerous.

If either measurement falls outside the range indicated, review the above wiring steps for completeness and accuracy. If, after checking the wiring there is still a problem, refer to the fault isolation and correction activities in Part 1, Section 7.

4.3.3.6

Connect the remaining #10 AWG black wire (the ground wire) to any module attach bolt using an appropriate lockwasher and nut. Connect the free end to the system ground.

4.3.4 ELECTRICAL INSTALLATION OF THE BATTERIES

Refer to the installation instructions for the storage batteries supplied in Part 2, Section 9. Follow the safety precautions in Part 1, Section 2 when handling and connecting the batteries.

4.3.4.1

Using the battery jumper cables or buss bars supplied, the batteries are to be interconnected in the appropriate matrix of series and parallel cells indicated in the computer printout, Part 2, Section 8.5. The manufacturer's suggested procedure for making the connections should be followed.

4.3.4.2

Using a hydrometer, measure the specific gravity of each cell. These initial values should be recorded on the battery maintenance record supplied in Part 2, Section 9. A thermometer should be used to check the battery electrolyte temperature and the specific gravity should be adjusted according to the manufacturer's recommended procedure.

4.3.4.3

Using a suitable voltmeter capable of 2% accuracy at the measured voltage, the open circuit voltage of each cell and each series string of cells should be checked and recorded as above.

4.3.4.5

Using the appropriate hardware, connect the red battery lead from the array to the positive side of the storage battery matrix.

4.3.4.6

Using the appropriate hardware, connect the black battery lead from the array to the negative side of the storage battery matrix.

5.1 WEATHERIZATION

When the photovoltaic power supply is fully assembled and electrically operative, all exposed electrical connections must be carefully weatherized.

5.1.1

Verify that the electrical connections to each module terminal have been properly attached and tightened to the correct torque (do not exceed 15 in-lb).

5.1.2

Coat the connection with silicone RTV (P/L #14) or equivalent and slip the protective boot over the module terminal until it is contacting the back of the module. See Figure 5.1. This procedure should be repeated for all module terminals.

5.1.3

Inspect any wire nut connections or solderless crimp connections which have been made and fill the ends with sealant.

5.1.4

When completed all connections should be inspected visually for the adequacy of their weatherization.

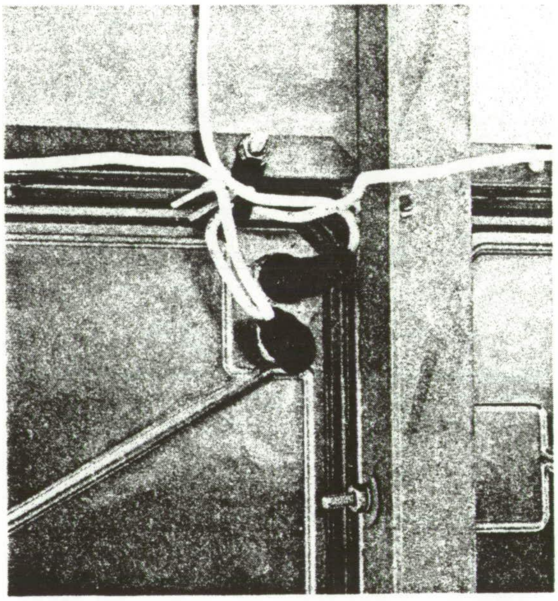


Figure 5.1 Properly Weatherized Terminals

5.2 PROPER ADJUSTMENT OF ARRAY TILT ANGLE

When the final system electricals have been checked and the storage batteries connected, the system is operational. However, to optimize the performance of the system on a year around basis, the array must now be adjusted to the optimum tilt angle. Refer to Part 2, Section 8.6 for the proper procedure in making this adjustment.

5.3 ATTACHMENT OF BIRD DISCOURAGERS

After adjusting the array tilt angle, attach the bird discouragers, P/L #10 to the top row of modules or top module, as appropriate, as shown in Detail F of the Assembly Drawing, Part 2, Section 8.2. Adjust each discourager so that it is pointed vertically. When properly installed, the bird discourager will prevent birds from perching on the top framework and, thereby, minimize droppings on the module surfaces.

This completes the assembly and installation of the solar system and it is now in service to provide the desired electrical power.

5.4 SYSTEM LOAD VERIFICATION

After the installation of the system load equipment, the user should measure the actual load current(s) and duty cycles, as appropriate, and record these values in the maintenance chart provided in Part 2, Section 10. The user should verify that the actual load does not exceed the maximum load for which the system was designed. This maximum design load current is specified in the computer printout in Part 2, Section 8.5

SECTION 6 PREVENTATIVE MAINTENANCE

6.1 GENERAL PERIODIC MAINTENANCE

It is recommended that periodic maintenance on the solar system be performed annually during the springtime. The advantage of springtime maintenance is for the benefit of the storage batteries. If water additions are required, the battery electrolyte level will be topped off just before entering the season of greatest water usage - the summertime. Also, as water is consumed, the proportional acidity or alkalinity of the electrolyte will increase and will achieve its highest level during the winter months, providing additional freeze protection.

6.2 SOLAR ARRAY PERIODIC MAINTENANCE

Solar array periodic maintenance activities are presented below and summarized in Figure 6.1. Additionally, the fault detection procedures presented in Part 1, Section 7 should be referred to if the array electrical output degrades during operation.

6.2.1

Inspect solar modules for dirt, dust, bird droppings, insects or other foreign material on glass. Clean with warm water and a soft cloth as necessary.

6.2.2

Inspect module mounting bolts for tightness and tighten as necessary.

6.2.3

Inspect module label for legibility and adherence. Clean, re-attach or replace as necessary.

6.2.4

Inspect rubber boots, silicone weatherization and terminals of each module for an adequate weatherization. Tighten terminals and repair silicone weatherization as necessary.

6.2.5

Inspect wiring insulation for cracking, peeling or other defects. Replace as necessary.

6.2.6

Inspect installation site for any new growth, weeds, shrubs, trees, etc. which have obscured the exposure of the solar array to the sun and which may cause localized shading of the array. Also inspect voltage regulators for bird or insect nests. All such obstructions should be removed or cleared as necessary.

6.3 STORAGE BATTERY PERIODIC MAINTENANCE

The periodic maintenance requirements of the system's storage batteries are described in detail in the battery manufacturer's installation manual in Part 2, Section 9. This information is summarized in Figure 6.2.

6.4 VOLTAGE REGULATOR PERIODIC MAINTENANCE

The solid state voltage regulator has been designed to require a minimum of maintenance.

Once yearly, the regulator heat sink (and buss bar assembly, if used) should be cleaned of any foreign material. Also, check the connectors for good electrical connection (clean, non-corroded terminals and sockets), and inspect wiring for any defects. Repair or replace as necessary. IT IS IMPERATIVE TO TEMPORARILY SHORT THE REGULATOR INPUT BUSS AND COMMON BUSS BEFORE DISCONNECTING ANY REGULATORS FOR INSPECTION OR REPAIR.

6.5 PERIODIC MAINTENANCE - SYSTEM ELECTRICAL CHECK

6.5.1

The glass surface of each module in the array should be clean and unobstructed.

6.5.2

Note the ambient temperature in the vicinity of the thermistor housing.

6.5.3

Using a voltmeter capable of 2% accuracy at the measured voltage, check the voltage between the positive battery terminal and negative battery terminal. It should be within the limits indicated in Part 2, Section 8.5, Table 1: Total Regulated Array Output.

6.5.4

If the voltage is lower than the stated limit, the battery should be disconnected and the voltage measured again. It should now be within the prescribed limits. (Explanation: if the battery is fully charged, and the array is generating its full output, then the regulator will be operating to clamp the battery voltage at the level required for the particular battery temperature. However, if the battery is accepting a substantial charge current, the output voltage will be lower and it is necessary to disconnect the battery in order to force the regulator into operation).

6.5.5

If the voltage is high, or it is low even with the battery disconnected, then the thermistor control needs readjustment. In this case, the battery should be disconnected (if it is not already disconnected), and the thermistor housing opened to allow access to the adjustment potentiometer. While monitoring the voltage across the battery input leads, adjust the potentiometer so that the voltage is within the limits given in Part 2, Section 8.5, Table 1:

Total Regulated Array Output, for that particular thermistor temperature. Care should be taken to shield the thermistor from drafts or sources of heat (such as the hand), while this adjustment is being made. Reconnect the batteries, as required.

6.5.6

Measure the short circuit current of the array using a current meter with a sufficiently low internal resistance (i.e., its terminal voltage drop does not exceed 10% of the nominal system voltage).

Connect the meter directly across the positive input buss bar and the common (middle) buss bar. For single regulator systems, this measurement should be made across the #10 AWG black and #10 red AWG array output wires.

For method of carrying out this measurement, refer to Part 2, Section 8.5. The short circuit current should be greater than the limit given in Part 2, Section 8.5, Table 1: Total Unregulated Array Output.

6.5.7

If, after the above measurements and any necessary adjustments, either measurement is not within the stated limits, refer to Part 1, Section 7 for further fault isolation and correction procedures.

ITEM	ACTIVITY	FREQUENCY
Solar module cover glass	Inspect, clean as necessary	Yearly*
Solar module mount bolts	Inspect, tighten as necessary	Yearly
All electrical connections**	Inspect, tighten as necessary	Yearly
Solar module electrical terminal weatherization	Inspect, repair as necessary	Yearly
Electrical wiring insulation	Inspect, replace as necessary	Yearly

*Certain environments may require more frequent cleaning, this should be inspected the first few site visits until a reasonable cleaning interval is established.

**If the weatherization on the solar module terminals is intact, it can be assumed that the module electrical connection is still adequate unless obviously defective.

Figure 6.1 Motorola Photovoltaic Array Periodic Maintenance Requirements

Item	Activity	Frequency
Electrolyte level	Check, add distilled or potable water as necessary	Yearly
Terminals	Check, clean as necessary	Yearly
Terminal Connections	Check for tightness adjust as necessary	Yearly

Figure 6.2 General Periodic Maintenance Requirements For Storage Batteries

SECTION 7 FAULT ISOLATION AND CORRECTION PROCEDURES

The following section is a diagnostic procedure to be followed step by step in the given order unless otherwise directed. Following this procedure carefully will insure that the system fault is isolated and corrected properly and that the system is accurately reconnected and commissioned. For easy reference, this procedure is summarized in Figures 7.1 and 7.2.

7.1 SOLAR POWER SYSTEM

7.1.1

Disconnect the electrical output of the array from the busses, and also the battery and load leads from the busses, making sure that the battery leads do not touch each other.

7.1.2

Check the array performance as follows:

7.1.2.1

Short the output of the entire array, and measure the resistance from the shorted output to the array frame. The resistance should be greater than 1000 ohms.

7.1.2.2

Measure the short circuit current of the array using a current meter with a sufficiently low internal resistance that its terminal voltage does not exceed 10% of the nominal system voltage. Connect the meter directly across the output of the array to make the measurement. When disconnecting the meter, the connection should be broken rapidly as there will be a tendency for the large dc current to draw an arc and burn the leads. Also, the operator should not touch both sides of the connection while it is being broken as there may be an inductive kick which can be dangerous.

7.1.2.3

Measure the open circuit voltage of the array using a voltmeter capable of 2% accuracy at the measured voltage.

7.1.2.4

Check if the short circuit current and the open circuit voltage fall within the limits specified in Part 2, Section 8.5, Table 1; Total Unregulated Array Output. If both measurements are within limits, continue at Step 7.1.7. If either measurement is out of limits, proceed with the next step.

7.1.3

Locate which string is faulty.

7.1.3.1

This is essentially a repeat of Steps 7.1.2.1 to 7.1.2.3, except that they are carried out on each string separately. This can be accomplished by disconnecting all series strings from the array (-) and array (+) busses, and measuring the short circuit current and open circuit voltage of each of the series strings by itself. One or more of the individual series strings will be found to have the same type of fault as the total array showed in Steps 7.1.2.1 to 7.1.2.3. Use the electrical limits of Part 2, Section 8.5, Table 1: Module String Output.

7.1.4

Locate which module is faulty.

7.1.4.1

This is a repeat of Step 7.1.3.1, on an individual module basis. The faulty string should be open circuit during these tests, and it is necessary to disconnect each individual module of the string. This test will locate one or more defective modules in the defective string. Use the electrical limits of Part 2, Section 8.5, Table 1: Module Output.

7.1.5

Check connections and surface of faulty modules.

7.1.5.1

Inspect the condition of the connections to the module. Poor connections can cause both low short circuit current and low open circuit voltage. Foreign material on the front surface of the module can also cause either short circuit current or open circuit voltage to be low.

7.1.5.2

If all modules in the string test out within limits the fault must be in the connectors. Test the resistance of each interconnecting wire of that string. Each interconnect wire should have a resistance of less than .2 ohms. Replace defective interconnects. Loose connections between the interconnect and the module terminals can have the same symptoms as poor interconnects. If all modules and all interconnects of the faulty string appear to be within limits, the fault is probably a loose connection. Reconnect all modules of the string, making sure all connections are properly tightened, and retest the string.

7.1.6

Any faulty modules should be replaced.

7.1.6.1

Reconnect the string, retest, and if still defective, return to Step 7.1.4. If the string is within limits, reconnect the strings together and return to the array testing at Step 7.1.2.

7.1.7

Reconnect the array to the busses.

7.1.8

Measure the temperature in the vicinity of the thermistor housing.

7.1.9

Measure the voltage across the battery busses (battery (+) to battery (-).

7.1.9.1

Compare the measured bus voltage with the desired voltage range as given in Part 2, Section 8.5, Table 1: Total Regulated Array Output for that particular temperature (use the value of temperature near the thermistor housing).

7.1.9.2

If the voltage is within limits, proceed to Step 7.1.16.

7.1.10

Adjust the control in the thermistor housing.

7.1.10.1

Remove the cover from the thermistor housing by inserting a screwdriver blade, or equivalent, into the slot and twisting.

7.1.10.2

Attach a voltmeter to the battery (+) and battery (-) busses.

7.1.10.3

Adjust the control in the thermistor housing to the desired voltage, as given in Part 2, Section 8.5, Table 1: Total Regulated Array Output for that temperature.

7.1.10.4

If this step can be carried out satisfactorily, proceed to Step 7.1.16.

7.1.11

Temporarily short array busses.

7.1.11.1

Put a temporary short across the array busses, from array (-) buss to the array (+) buss, using a jumper which is capable of carrying the full array current.

7.1.12

Replace blown fuses in the regulators.

7.1.12.1

Check the fuses in the master regulator and in each of the slaves.

7.1.12.2

Replace all blown fuses with similar types and ratings. Do not use slow blow fuses.

7.1.12.3

Proceed to Step 7.1.13, whether fuses were blown or not.

7.1.13

Remove the temporary short from across the array busses.

7.1.14

Readjust control in thermistor housing.

7.1.14.1

This is a repeat of Steps 7.1.10.1 to 7.1.10.4.

7.1.14.2

If successful, proceed to Step 7.1.16.

7.1.15

Replace regulators one at a time.

7.1.15.1

Starting with the master regulator, each regulator should be replaced in turn until the faulty one is replaced. After each replacement, go back to Step 7.1.9 and continue from there. (IT IS IMPORTANT, WHILE REPLACING ANY REGULATOR, TO PUT A TEMPORARY SHORT ACROSS THE ARRAY BUSSES). If this is not done, the other regulators will take the full load which could cause overloading and burnout of one or more regulators.

7.1.16

Measure the battery voltage, using a voltmeter capable of 2% accuracy at the nominal system voltage.

7.1.17

Measure the specific gravity of the battery electrolyte.

7.1.17.1

In most cases, an automotive type hydrometer will be satisfactory for measuring the specific gravity of the battery electrolyte. However, if the battery state of charge is particularly low, it may be necessary to use a low range hydrometer.

7.1.17.2

Check the battery state of charge from the battery information in Part 2, Section 9 for that specific gravity.

7.1.17.3

If the state of charge of the battery is satisfactory, proceed to Step 7.1.19.

7.1.18

Recharge low batteries.

7.1.18.1

If the measurement in Step 7.1.17 shows that the batteries are in an unsatisfactory state of charge, they should be recharged according to the manufacturer's instructions with whatever means are appropriate.

7.1.18.2

In the event that the battery needs charging and there is no other source of power available, the array can be used. The load should be removed from the batteries so that the total array output is utilized for charging the battery. This will typically require a period of time equal to the number of no-sun days capability of the batteries, in clear sunny weather. Thus, several weeks may be required to fully charge the batteries if they have been allowed to discharge completely. Partially discharged batteries will, of course, take proportionately shorter periods using this method.

7.1.19

Reconnect batteries.

7.1.19.1

When the batteries have reached a suitable state of charge, they should be reconnected to the battery busses. Care should be taken to ensure that the positive side of the battery is connected to the positive battery buss, and the negative side of the battery to the negative battery buss. Connecting the battery with the wrong polarity will, at the least, burn out all the fuses, and may cause damage to the regulators.

7.1.19.2

The system is now operational.

Step # 7.1	OK	NOT OK
1.	Disconnect array and batteries from busses	
2.	Check array performance (Isc, Voc)	
3.	OK ↓	Locate which string is faulty
4.	↓	Locate which module is faulty
5.	↓	Check condition of module connection and surface
6.	↓	Correct fault or replace module
	↓	Return to Step 2.
7.		Reconnect array to busses
8.		Measure temperature near thermistor housing
9.		Measure voltage across battery busses
10.	OK ↓	Adjust control in thermistor housing
11.	↓	OK ↓ — Temporarily short array busses
12.	↓	↓ — Replace blown fuses in regulators
13.	↓	↓ — Remove temporary short
14.	↓	↓ — Readjust control in thermistor housing
15.	↓	↓ — OK ↓ — Replace regulators,* one at a time
	↓	↓ — ↓ — Repeat Step 9-14 after each
16.		Measure battery voltage
17.	OK ↓	Measure battery specific gravity and determine its state of charge
18.	↓	OK ↓ — Recharge low batteries
	↓	↓ — Return to Step 16
19.		Reconnect batteries to buss.
		System is now operational

*temporary array short

Figure 7.1 Summary of Fault Isolation & Correction Procedures

PROBLEM	FAULT DETECTION ACTIVITY
Low Voltage	Inspect all electrical connections for proper contact
	Refer to wiring instructions for proper connection of wiring harness
	Internal short in one or more modules. See Section 7.1
Low Current	Remove any obstruction from solar module surfaces
	Clean solar module surfaces
	Inspect all electrical connections for proper contact
	Refer to wiring instructions for proper connection of wiring harness
	Insufficient sunlight/incorrect array angle
Reverse Polarity	Refer to electrical assembly instructions for correct color coding
Discharged Battery w/Low Electrolyte	Inspect thermistor connections and leads for shorting, repair if necessary.
	Verify correct voltage regulator output potential
Discharged Battery w/Normal Electrolyte Level	See "Low Current" activities
	Recent period of unusually bad weather
	Verify correct voltage regulator output potential

Figure 7.2 Solar Array Electrical Output Fault Detection Activities

7.2 ANALYSIS OF MOST PROBABLE REGULATOR FAILURE MODES

7.2.1 OUTPUT TRANSISTOR SHORTED

If the output transistor of any regulator should short out, the fuses in all regulators will blow causing an immediate stop to any battery charging. The batteries will then discharge within a few days depending on their state of charge and the load current.

The faulty regulator should be replaced and the fuses in each regulator should be checked and replaced as described in Steps 7.1.11 through 7.1.15.

7.2.2 OUTPUT TRANSISTOR OPEN

If the output transistor of any regulator should fail in an open circuit mode, the current and power dissipation in the other transistors will increase proportionally and perhaps cause premature failure in another unit, leading to eventual run-away failure.

Addition of an extra slave regulator would provide indenfinite protection from one, or even two transistors failing in this mode.

7.2.3 THERMISTOR OPEN CIRCUIT

If the thermistor has failed in an open circuit mode, the regulator will clamp at a much reduced voltage (typically half, or less, of the normal operating voltage). This condition will blow all the fuses or at least the master fuse. However, if the array continues to put out appreciable current, all the fuses would now blow.

7.2.4 THERMISTOR SHORT CIRCUIT

If the thermistor should fail in a short circuit mode, the regulated voltage will increase to a value well above the normal operating range and the batteries will become overcharged with time.

However, this mode of failure is very unlikely unless the thermistor lead wires have been shorted together.

7.2.5 SHORTED SURGISTOR

Should the surgistor fail in a short circuit mode, the failure has the same effect as a shorted output transistor described in paragraph 7.2.1.

7.2.6 DRIVE CIRCUIT FAILURES

Failure of the drive Darlington, reference circuit or op-amp circuit will cause the drive to the output transistors to go to zero or to maximum. This will have the same effect as having both the output transistors in the regulator fail short or go open at the same time. These cases are covered in paragraphs 7.2.1 and 7.2.2 above respectively.

PART 2
SPECIFIC INSTALLATION DETAILS

SECTION 8 SPECIFIC INSTALLATION DETAILS & DRAWINGS

8.1 UNIQUE ASSEMBLY INSTRUCTION

The general assembly and installation instructions in Part 1, Sections 4.2 and 4.3 of this manual should be followed with the exception of these specific instructions for your unique system:

Mechanical Assembly:

1. This system uses an array configuration of one module high by three modules wide. (Array structure MSPL1H3W).

Electrical Assembly:

1. The electrical configuration is three modules in parallel and one in series.

8.2 ASSEMBLY DRAWINGS

The following are the specific mechanical assembly drawings for your system.

The mechanical drawings; P-0233-78-1, P-0220-78-5C and P-0217-78-3, were deleted due to Motorola's confidential. For above drawings contact Motorola Inc, P. O. Box 20912, Phoenix, AZ 85036.

8.3 ELECTRICAL SCHEMATIC

The following is the specific electrical schematic for your system.

The electrical drawing, P-0236-78-9, was deleted due to Motorola's confidential. For drawing, P-0236-78-9, contact Motorola Inc., P.O. Box 20912, Phoenix, AZ 85036.

8.4 PARTS LIST

The following is a listing of parts required for the proper assembly and installation of your system. Unless otherwise noted, it is the requirement of the installer to provide provisions and hardware for achoring the array feet (see Part 1, Section 4.1) and anchoring and/or enclosing the system's storage batteries.

Before installation, carefully check the parts received with the parts specified on the attached list. If you do not have all the parts specified, or there is some discrepancy between the parts received and the parts listed, please contact your Motorola Service Representative or the Motorola Factory. (See Part 1, Section 1.4).

MOTOROLA
Solar Systems
PHOENIX, ARIZONA

FINAL RELEASE

TITLE:

2VDC WHITECAP MOUNTAIN, MAINE (REPEATER 11-VHF 3) 69° 1HX3W ARRAY

FIND. NO.	SYSTEM NO. REQUIRED PUR.	SYSTEM NO. REQUIRED FAB.	ARRAY NO. REQUIRED PUR.	ARRAY NO. REQUIRED FAB.	NAME - DESCRIPTION	MOTOROLA PART NO.
1				4	SPREADER 1, HIGH	07DSB84510A001
2				2	RAIL 3, WIDE	07DSB82180A001
3				2	SPACER, INNER 1.25" LG	43CSB84810A001
4				6	SPACER, OUTER 1.50" LG	43CSB84810A002
5				4	MOUNTING BRACKET	07CSB84508A001
6a	/		/	1	REGULATOR MOUNTING BRACKET	07DSB88101A001 (MUL.)
6b	/		/	/		07DSB88713A001 (1/2-3/4)
6c	/		/	/		07DSB (SNOW)
8			12		TERMINAL, RING TONGUE #10	29ASB90021A002
9			3		TERMINAL, RING TONGUE #18-22	29ASB90021A001
10			9		CABLE TIE, 14½" LG (BIRD DISCOURAGER)	42ASB90024A002
11			15		CABLE TIE, 4" (HARNESS)	42ASB90024A001
12			6		BOOT, ANGLE DIST. NIPPLE	14ASB90025A001
13			3		GROUND LUG	29ASB90022A001
14			1		TUBE, RTV SEALANT 3OZ.	11ATB03170002
15				/	BIRD DISCOURAGER HOLDER	
16				1	VOLTAGE REGULATOR, MASTER	MSPR125L-12
17			/		WIRE NUT	

DRAWN BY: F. J. MOSNA

DATE:

SHEET 1 OF 4

DRAWING NO. SSP0093

MOTOROLA Solar Systems

TITLE:

IND. NO.	SYSTEM NO. REQUIRED PUR.	SYSTEM NO. REQUIRED FAB.	ARRAY NO. REQUIRED PUR.	ARRAY NO. REQUIRED FAB.	NAME - DESCRIPTION	MOTOROLA PART NO.
18			10		1/4-20 HEX HD BOLT, 1.25" LG, ZN-PLATED	03ASB90020A005
19			4		" " " " , 3.00" LG, "	03ASB90020A006
20			14		1/4-20 HEX NUT , "	02ASB90019A002
21			24		1/4 FLAT WASHER , "	01ASB90018A002
22			10		1/4 SPRING-LOCK WASHER , "	04ASB90017A002
23			20		3/8-16 HEX HD BOLT, 1.25" LG, " GR8	03ASB90020A001
24			6		" " " " , 2.75" LG, " GR8	03ASB90020A004
25	162		/		10-24 x 1.0 HEX HD BOLT "	
26			/		#10 SPRING-LOCK WASHER "	
27			26		3/8-16 HEX NUT , "	02ASB90019A001
28			44		3/8 FLAT WASHER , "	01ASB90018A001
29			26		3/8 SPRING-LOCK WASHER, "	04ASB90017A001
30				3	BUSS BAR	
31				2	INSULATOR BLOCK	
32		/	/		#8 SELF-TAPPING SCREW, 3/4" LG	
33						
34						

DRAWN BY: F. J. MOSNA

DRAWING NO.

MOTOROLA Solar Systems

TITLE:

FIND. NO.	SYSTEM NO. REQUIRED PUR.	SYSTEM NO. REQUIRED FAB.	ARRAY NO. REQUIRED PUR.	ARRAY NO. REQUIRED FAB.	NAME - DESCRIPTION	MOTOROLA PART NO.
35				3	MODULE, 36 CELL, SOLAR-MSP02A10	
36				2	SUPPORT BRACE, INNER (1½"SQ) 23"LG	07CSB86104A001
37				2	SUPPORT BRACE, OUTER (1¾"SQ) 14"LG	07CSB86103A004
38				/	VOLTAGE REGULATOR, SLAVE	
39				/	WIRE, COPPER STRANDED, #10, WHITE, 3'LG	
40				3	" , " " , " , BLACK, 3'LG	
41				/	" , " " , " , " , 6'LG	
42				/	" , " " , " , " , 8'LG	
43				/	" , " " , " , " , 10'LG	
44				3	" , " " , " , RED, 3'LG	
45				/	" , " " , " , " , 6'LG	
46				/	" , " " , " , " , 8'LG	
47				/	" , " " , " , " , 10'LG	
48				/	" , " " , " , BLACK, 25'LG	
49				/	" , " " , " , RED, 25'LG	
50				2	" , " " , #4, BLACK, 25'LG	
51				1	" , " " , #4, RED, 25'LG	

DRAWN BY: F.J. MOSNA

SHEET 3 OF 4

DRAWING NO.

MOTOROLA Solar Systems

TITLE:

NO.	SYSTEM NO. REQUIRED PUR.	SYSTEM NO. REQUIRED FAB.	ARRAY NO. REQUIRED PUR.	ARRAY NO. REQUIRED FAB.	NAME - DESCRIPTION	MOTOROLA PART NO.
52				1	WIRE, STRANDED, TWISTED PAIR # 18GA x 25ft.	
53						
54						
55						
56						
57						
58						
59						
60						
61						
62						
63						
64						
65						
66		/				
67						
68						

DRAWN BY: F. J. MOSNA   SHEET 4 OF 4   DRAWING NO.

With the aid of the solar industry's most sophisticated system-sizing computer program, this particular system has been tailored to your specific site location and load conditions. As the following printout shows, the computer program has determined the optimum tilt angle, the optimum number of modules required and the proper amp-hour battery capacity needed for your application. In addition to battery capacity for several consecutive sunless days, the program determines the seasonal battery storage capacity, if any, for the accumulated yearly deficit of available power to assure continuous service with an adequate safety factor. The printout also shows the minimum system performance and electrical specifications which can be expected during each month of the year. The actual annual safety factor shows the yearly margin of excess available power. This excess allows for variations in the weather, dirt or dust on the solar modules, battery charging efficiencies and other minor system losses.

The system electrical specifications in Table 1 are to be used to verify proper output of the system during installation and to check the system for proper operation during regular or corrective maintenance. The short circuit current should be greater than the value shown in Table 1 on a clear day within 2 hours of solar noon. Under poor weather conditions or at other times during a clear day, the test can still be performed if a suitable irradiation meter is available (See Part 1, Section 3). The irradiation should be measured with the meter parallel to the array at the same time the short circuit current is measured. The short circuit current will be directly proportional to the solar irradiation level. For example, if the irradiation is only $50mW/cm^2$, or one half of one sun (one sun = $100mW/cm^2$), then the short circuit current, at one sun, will be double that measured at $50mW/cm^2$ (one half sun).

Table 1
System Electrical Specifications

Power Output Of	Open Circuit Voltage V_{OC} Min	Open Circuit Voltage V_{OC} Max	Short Circuit Current I_{sc} Min
Module Only	14.3	18.3	1.0
Module String (Series String)	"	"	"
Total Array, Unregulated	"	"	3.0
Total Array, Regulated*	13.0	15.8	"

*Voltage corrections for regulated voltages are shown in the regulator output voltage graphs on the voltage regulator data sheet, Part 2 Section 8.7. Do not use Table 2.

V_{OC} range is valid for 70°F to 80°F (23°C to 27°C) only. These voltage values can be corrected for the actual ambient temperature using the conversion factors shown in Table 2, Section 8.5.

I_{SC} range is valid for 90% or more clear sky-open sunlight, within 2 hours of solar noon. The table value is good from -30 to +120F (-35 to +48C).

Table 2
Voltage/Temperature Correction Factors

DEGREES F
Multiply Table 1 Values By Appropriate Factor
Below To Obtain Temperature Adjusted Voltage Range

-30 to -20	-20 to -10	-10 to 0	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50	50 to 60	60 to 70	70 to 80	80 to 90	90 to 100	100 to 110	110 to 120
1.25	1.225	1.20	1.175	1.15	1.125	1.10	1.075	1.050	1.025	1.0	.975	.950	.925	.900

DEGREES C
Multiply Table 1 Values By Appropriate Factor
Below To Obtain Temperature Adjusted Voltage Range

-30 to -20	-20 to -10	-10 to 0	0 to 10	10 to 20	20 to 30	30 to 40	40 to 50
1.27	1.22	1.17	1.11	1.05	1.0	.95	.89

The actual measured open circuit voltage should be within the adjusted voltage range.

Example: Table 1: Total array unregulated voltage limits are 15.4V min, 18.4V max. Ambient temperature is 35^0F. Corrected voltage limits for actual measured voltage are

15.4V x 1.10 (correction factor) = 16.9V min
18.4V x 1.10 (correction factor) = 20.2V max

Vitel 321-1262

JUN 28, '79 REVISION 22 4-27-79

17512/MCD/BUZZ ROSENBAUM/DITEL-321-1262/SSP0092
?? ATER 11-VHF3/WHITECAP MOUNTAIN, MAINE/GARET/6/27/79

'STEM LOAD(10.3 + 20% SAFETY FACTOR) = 12.4 AMP-HRS/DAY AT 12.0 VOL
LOAD CURRENT W/O SAFETY FACTOR = .4 AMPS AVERAGE

:ATHER DATA:- CARIBOU MAINE 46:52 N 68:01 W

RECOMMENDED SYSTEM

MODULE TYPE = MSP02A10 (1P X 36S)

3 MODULES IN PARALLEL 1 IN SERIES 3 MODULES TOTAL

.JDULES FACING TRUE SOUTH AT A SLOPE OF 69 DEGREES FROM THE HORIZONTAL

312 AMP-HRS(185 @ -10 F) CAPACITY NEEDED FOR 15 SUNLESS DAYS

300 AMP-HRS(179 @ -10 F) CAPACITY NEEDED FOR SEASONAL VARIATIONS

612 AMP-HRS(364 @ -10 F) TOTAL

SYSTEM PERFORMANCE

MONTH	MWH/SQCM PER DAY ON HORIZONTAL	MWH/SQCM PER DAY ON ARRAY	◆ ARRAY OUTPUT AMP-HRS PER DAY	LOAD AMP-HRS PER DAY	◆ ARRAY OUTPUT TO LOAD RATIO	◆◆ SYSTEM OUTPUT TO LOAD RATIO
JAN	159	397	13.11	10.30	1.27	1.46
FEB	267	504	16.64	10.30	1.62	1.86
MAR	426	576	19.03	10.30	1.85	2.44
APR	464	424	14.01	10.30	1.36	2.02
MAY	550	401	13.26	10.30	1.29	1.95
JUN	557	371	12.26	10.30	1.19	1.85
JUL	591	408	13.48	10.30	1.31	1.96
AUG	522	433	14.29	10.30	1.39	2.05
SEP	386	428	14.13	10.30	1.37	2.03
OCT	244	377	12.46	10.30	1.21	1.87
NOV	127	249	8.22	10.30	.80	1.46
DEC	123	321	10.62	10.30	1.03	1.36

'NNUAL SAFETY FACTOR = 30.7%

◆ INCLUDES 20% SAFETY FACTOR
◆◆ SYSTEM OUTPUT = ARRAY OUTPUT + AVAILABLE SEASONAL BATTERY CAPACITY

ULE TYPE SPECIFIED IS TYPICAL -- OTHER MODULE TYPES MAY BE
S ITUTED OR MIXED SUCH THAT THE FOLLOWING SYSTEM PARAMETERS
GUARANTEED, AT A SUNLIGHT INTENSITY OF 100 MW/SQ.CM :-

JUN 28,'79 REVISION 22 4-27-79

17512/MCD/BUZZ ROSENBAUM/DITEL-321-1262/SSP0092
EATER 11-VHF3/WHITECAP MOUNTAIN,MAINE/GARET/6/27/79

MOTOROLA SOLAR SYSTEMS
SYSTEM DESCRIPTION & COST ANALYSIS WORK SHEET

REQUIREMENTS:
POWER 12.36 AH(W/20% SAFETY FACTOR). TEMP: -10 F MINIMUM
@ 12.0 VOLTS 90 F MAXIMUM
MINIMUM BATTERY CAPACITY 0% SUNLESS DAYS 15
WEATHER DATA:- CARIBOU MAINE 46:52 N 68:01 W

SOLAR ARRAY:
MODULE = MSP02A10 (1PX36S)
ARRAY = 3 PARALLEL MODULES X 1 SERIES MODULES, MINIMUM
= 3 TOTAL MODULES @ $ 461.00 ------------ $ 1383.00

REGULATORS:
(3 MODULES X 18 WATT/MODULE)/(100 WATT/REGULATOR)
= .54 --> 1 MASTER, MSPR125L-12 @ $ 90.00 EACH
0 SLAVES, MSPR125S-12 @ $ 78.00 EACH = $ 90.00

WIRING HARNESS:
3 MODULES X $10.00/MODULE = ---------------------------- $ 30.00

SUPPORT STRUCTURE:
3 MODULES X $57.00/MODULE = ---------------------------- $ 171.00

BATTERIES:
MANUFACTURER --- ESB
10.30 AH X(15 SUNLESS DAYS)/(100% DISCHARGE DEPTH)
+20% SAFETY FACTOR
= 185 AH NO-SUN CAPACITY PLUS 179 AH SEASONAL
= 364 AH TOTAL CAPACITY REQUIRED @ -10 F
= 612 AH TOTAL CAPACITY REQUIRED @ 77 F, @ 12.0 V

BATTERY TYPE DD-5-3 (220 AH @ 77 F @ 6 V)
LENGTH WIDTH HEIGHT WEIGHT
16.12" X 7.06" X 9.50" 76.0 LBS. EACH.
3 PARALLEL X 2 SERIES
= 6 TOTAL BATTERIES @ $ 109.15 EACH
+ 1 BATTERY PALLETS @ $ 30.00 EACH
+ 7 INTERCONNECTS @ $ 1.82 EACH -------- $ 698.00

TOTAL SYSTEM COST -- $ 2372.00

RICES ARE U.S. DOLLARS, F.O.B. PHOENIX, ARIZ, U.S.A.
TTERIES, FOB MANUFACTURERS PLANT.
LIVERY(SHIP DATE) TYPICALLY 30 TO 120 DAYS AFTER RECEIPT OF ORDER.
OTOROLA STANDARD TERMS AND CONDITIONS APPLY.

8.6 DETERMINATION OF PROPER TILT ANGLE

When the correct electrical performance of the array has been verified and the module terminals have been properly weatherized with the protective boots and RTV sealant, the array should be adjusted to its optimum tilt angle. In this application, the optimum angle is given in the computer printout, Part 2 Section 8.5. The accuracy of setting this angle is not critical but should be within plus or minus 5 degrees of optimum to achieve the best annual performance of the system.

8.6.1

The tilt angle is adjusted by altering the total length of the inner and outer support braces where they are joined together. Remove the bolts which hold the support braces together. (Assembly Drawing Detail B, Part 2, Section 1.2) being careful to manually support the weight of the array. Do not allow fingers or clothing to get pinched between the braces as the array is lowered.

8.6.2

Using the tilt meter or a protractor and level, manually adjust each support brace so that the array is set at the optimum tilt angle. Replace the bolts, lockwashers and nuts, as each side is adjusted.

Tighten to 250 in-lbs torque - do not overtighten.

8.6.3

After adjustment is complete, check to see that the actual tilt angle of the array is correct.

8.7 TECHNICAL LITERATURE

The following are the applicable technical data sheets for the various components used in your system:

1. MSP Series Solar Modules
2. MSPR Series Voltage Regulator
3. MSPS Series Support Structures

SECTION 9 STORAGE BATTERY INFORMATION

The battery manufacturer's installation and operating manual included in this section contains all the necessary information for the mechanical and electrical installation, initial start-up, preventative maintenance and repair of the systems storage batteries.

Should there be any discrepancy between the suggested procedures in the Motorola manual and the Battery Manufacturer's manual, the manufacturer's procedure shall apply.

In this system, the batteries are to be electrically connected in a matrix as defined in the computer printout, Part 2 Section 1.5. The open circuit voltage of each cell and each series string of cells should be checked as installation proceeds to verify proper connection.

SECTION 9 STORAGE BATTERY INFORMATION

 SOLAR ARRAY MAINTENANCE REPORT

Date of Installation:	Location:
Installed By:	Phone:
Module Type:	Quantity:
Voltage Regulator Type:	Quantity: Master ______ Slaves
Comments:	

Date	Checked By	Regulated "No Load" Voltage*	Regulated "No Load" Current	Comments

*No Load conditions imply that both the battery and system load are disconnected from the regulator leads to the batteries. Measurements are made across these regulator leads.

Actual System Load Verification

Checked By ______________________	Initial Check Date: ____________	Recheck Date: ______________
First Load Current		
Duty Cycle		
Second Load Current		
Duty Cycle		
Nominal System Voltage		
Total Amp Hour Load Per Day (without Safety Factor)		
Comments:		

SERVICE MANUAL

Installation, Operation and Maintenance

Of

Willard Charge Retaining (CR Type)

Lead-Acid Storage Batteries

ESB Wisco Incorporated
2510 North Boulevard
Raleigh NC 27604
(919) 834-8465

DANGER!

FOR YOUR PERSONAL SAFETY -- READ CAREFULLY!

GASSES PRODUCED BY A BATTERY CAN BE EXPLOSIVE. DO NOT SMOKE, USE AN OPEN FLAME OR CREATE AN ARC OR SPARKS IN THE VICINITY OF ANY BATTERY.

BATTERIES COVERED BY THESE INSTRUCTIONS CONTAIN SULFURIC ACID ELECTROLYTE WHICH MAY CAUSE SEVERE BURNS. DO NOT GET ELECTROLYTE IN THE EYES, ON SKIN OR CLOTHING. IN CASE OF CONTACT, FLUSH IMMEDIATELY AND THOROUGHLY WITH CLEAN WATER. OBTAIN MEDICAL ATTENTION AS SOON AS POSSIBLE WHEN EYES ARE AFFECTED.

SAFETY PRECAUTIONS TO BE OBSERVED WHEN HANDLING BATTERIES ARE GIVEN IN MORE DETAIL ON PAGE 4. BE SURE TO READ THESE CAREFULLY BEFORE PROCEEDING WITH INSTALLATION AND OPERATION OF BATTERIES.

TABLE OF CONTENTS

ATTACHMENT B

LIST OF FIGURES

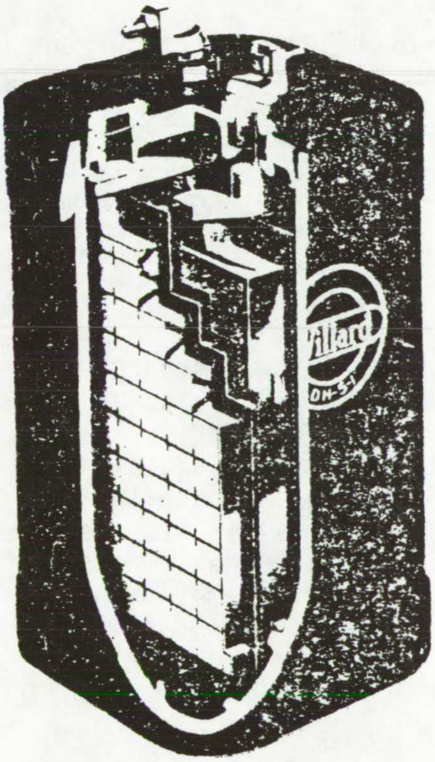
CONSTRUCTION

Willard Charge Retaining Batteries differ radically from conventional lead-acid storage batteries found in automotive or stationary use. Certain materials employed in the construction of such conventional storage batteries, while making them more sturdy physically, actually contribute to their loss in capacity while standing on open circuit.

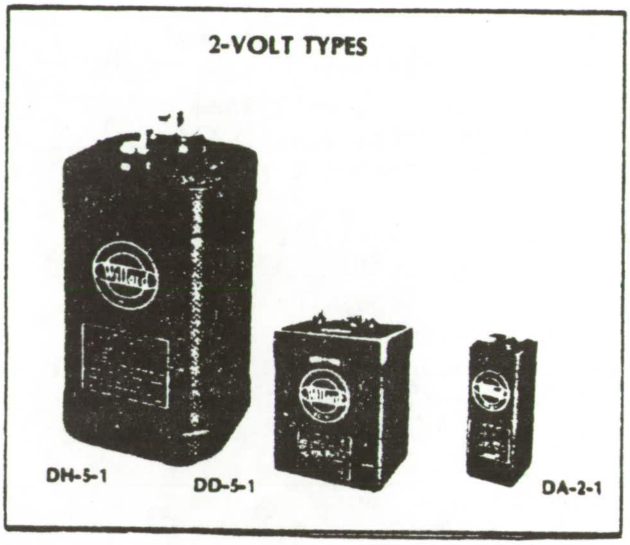
Willard Charge Retaining Batteries are noted for their ability to retain capacity over long periods while standing on open circuit. This is the result of carefully engineered construction which excludes the possible introduction of any foreign substances that might affect this inherent charge retaining characteristic. All components incorporated into Willard CR Batteries are subject to the strictest quality control to assure the extreme purity of materials, such as pure lead grid, straps, oxides and other cell parts.

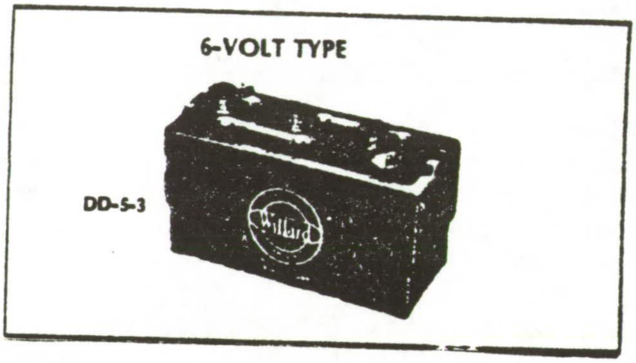
(Similarily, care must be exercised during the operation of Willard CR Batteries to prevent contamination through careless maintenance procedures which could cause serious damage or otherwise affect performance. Precautions to be followed to prevent possible contamination are shown in paragraph 7.1, page 7).

Lead parts in Willard CR Batteries have sufficient current-carrying capacity to allow discharges in amperes up to the minimum voltage limits of the application or to one vpc. The currents will approximate the same figures as one-half the rated ampere-hour capacity of the cell.



Cutaway view of Willard Type DH-5-1 cell shows the construction which is typical of Charge Retaining Batteries. Note that plates are thick (from 5/8" to 15/16"). Grids, straps, posts and terminals are designed to provide optimum performance in applications where discharges extend over long periods.





The Willard Charge Retaining Battery is a source of pure direct current with definite voltage characteristics throughout its life. The operating voltage ranges from 2.12 or 2.13 volts per cell (vpc) to 1.90 or 1.80 vpc, depending on the rate and extent of discharge as measured by the specific gravity of the electrolyte. On momentary intermittent discharges, the finish voltage will very rarely, if ever, fall below 1.90 volts when fully discharged.

During discharge, the voltage characteristics of low discharge type batteries is practically a straight line from 2.12 vpc at the start to 1.95 volts finish. Discharges may, however, be continued to end voltages of 1.80 or 1.75 vpc with the additional capacity provided by the lower end point voltayes. The definite ampere-hour capacity required by the application within its specific voltage range should be the basis for selecting the low discharge type which will best operate for the desired time.

WILLARD CHARGE RETAINING BATTERIES FOR PHOTOVOLTAIC SOLAR ENERGY APPLICATIONS

Battery Type	Part Number	Description	Volts	Cut-off Voltage Per Cell	Amp. Hour Cap.	Cur. Rate Amps	Specific Gravity		Overall Dimensions in Inches			Overall Dimensions in Centimeters			Net Wt. in Lbs.	Net Wt. in Kilograms
							Charged	Disch.	Lgth.	Wdth.	Hgt.	Lgth.	Wdth.	Hgt.		
DA-2-1	6535	Standard	2	1.90 1.75	26 30	0.1	1.300	1.100 1.075	2½	2½	6 11/16	6.4	6.4	16.9	3½	1.6
DD-3-3	4825	Standard — Wing nut terminals						1.120	8½	6¾	9⅝	21.6	17.15	24.4		
	7742	Standard — "L" type terminals	6	1.90 1.75	100 110	0.25	1.300	1.110							40	18.1
	7579	Epoxy sealed														
	8241	With spill proof vents									10⅜			26.4		
DD-5-1	4193	Standard														
	6839	With spill proof vents	2	1.90 1.75	200 220	0.5	1.300	1.120	7 1/16	5½	9½	17.9	13.9	24.1	26	11.8
	5509	Epoxy sealed														
DD-5-3	4118	Standard							16⅛	7 1/16	9½	40.9	17.9	24.1	76	34.5
	5780	With spill proof vents	6	1.90 1.75	200 220	0.5	1.300	1.110	16⅛	7 1/16	9½	40.9	17.9	24.1	76	34.5
	9195	In square steel can							16 15/16	7⅝	10½	43	19.4	26.7	80	36.3
	4500	Epoxy sealed							16⅛	7 1/16	9½	40.9	17.9	24.1	76	34.5
DH-5-1	5476	Standard							7 9/16	8 5/16	14	19.2	21.1	35.6	58	26.3
	7419	In square steel cans	2	1.90 1.75	500 600	1.0	1.300	1.130 1.075	8⅞	8	14⅜	22.5	20.3	36.5	67	30.4
	1388	In steel cans with handles							8⅞	8⅛	18 5/16	22.5	20.6	46.6	68	30.9
	5506	Epoxy sealed							7 9/16	8 5/16	14	19.2	21.1	35.6	58	26.3
DHB-5-1	6578	Standard							7 9/16	8 5/16	16 7/16	19.2	21.1	41.8	62	28.0
	5757	In round steel cans (DHB-5-IC)	2	1.90 1.75	500 600	1.0	1.300	1.130 1.075	9¼ DIA.		19¼	23.5 DIA.		48.9	83	37.6
	5507	In round aluminum cans							9¼ DIA.		19¼	23.5 DIA.		48.9	83	37.6

INSTALLATION & MAINTENANCE INSTRUCTIONS

1. SAFETY PRECAUTIONS:

1.1 In the operation of a battery, hydrogen gas is formed, which may be explosive if ignited. Never bring burning materials such as lighted matches, cigarettes or sparks of any kind near the battery.

1.2 Discharge static electricity from the body before touching cell terminal posts, by first touching a grounded surface such as a water pipe or grounded iron work.

1.3 Make sure that all battery connections are tightened sufficiently. Loose connections could cause excessive heat or sparking which may result in a hydrogen gas explosion.

1.4 Cells connected in series have high voltages that could produce a human shock hazard.

1.5 Only authorized personnel who have been familiarized with battery installation, charging and maintenance procedures should be permitted access to the battery area.

1.6 In handling sulfuric acid electrolyte, wear goggles, plastic or rubber apron, and gloves. Avoid spilling electrolyte. If electrolyte comes in contact with the skin, rinse with clear water immediately. If electrolyte comes in contact with the eyes, flush with water and consult a physician immediately. Bicarbonate of soda solution (one pound to one gallon of water) will neutralize any acid accidentally spilled on clothing or material. Apply the solution until the bubbling stops, then rinse with clear water.

1.7 When mixing electrolyte always add acid to water. Pour slowly and stir constantly, to avoid excessive heat or violent chemical reaction.

1.8 Insulate the handles of all tools used for tightening the connector bolts. This can be easily accomplished by wrapping handles with electrician's tape.

2. INSPECTING BATTERY SHIPMENTS:

2.1 Batteries or cells normally are shipped assembled, charged, and filled with electrolyte to the proper level. When specified for air transport, batteries are dumped free of acid electrolyte and sealed with polyethylene vent plugs to prevent capacity loss.

2.3 Promptly upon delivery from the carrier, inspect and make a note of any damage to the packing material or wet acid stains which would indicate leakage of electrolyte caused by rough handling.

2.4 As soon as practical, unpack the cells and examine the electrolyte level to insure that none has been lost in transit. When the level is less than 1/2" below the tops of the plates, add battery grade sulfuric acid of 1.300 specific gravity. If the electrolyte level is more than 1/2" below the tops of the plates, request an inspection by a representative of the carrier and file a claim for concealed damage.

2.5 Tighten vent plugs.

3. BATTERY STORAGE:

3.1 Batteries should be unpacked and installed as soon as possible after receipt.

3.2 When a battery can not be installed at the time of receipt, it should be stored indoors in a cool, clean and dry location.

3.3 Batteries should not be stored longer than one year intervals without receiving periodic freshening charges. If batteries are stored in a hot, dry climate, freshening charges will be at 6 months intervals. Date of the battery shipment should be used to determine freshening charge requirements.

3.4 Storage periods exceeding those indicated above may result in plate sulphation which may affect electrical performance and expected life.

3.4 When it is anticipated that the storage time will be exceeded, advance preparation should be made to have an adequate charger available and adjacent to an appropriate AC supply voltage. Positioning of the cells to accept the intercell connectors is another consideration of advance planning.

4. BATTERY LOCATION:

4.1 The battery area should be provided with ventilation so as to prevent liberated hydrogen gasses from exceeding 1% concentration.

4.2 The location should be selected to keep out water, oil and dirt. A cool, dry location is preferred. Each cell should be accessible for the addition of water and for taking individual cell voltage and hydrometer readings.

4.3 Locate racks, if required, so that all cells in the battery will have approximately the same operating temperatures. Do not have cells located near a heat source which would then make these cells much warmer than other cells in the string.

4.4 The aisle space provided in front of all racks should be a minimum of 36" where this dimension is not in conflict with any local codes or regulations.

4.5 A minimum of 9" should be made available as clearance above the tops of the cell posts of the top row of cells, to permit access for future maintenance.

5. RACKS: (Where Applicable)

5.1 Battery racks are supplied as one tier, two tier and two step. Rack assembly information is detailed in the Rack Assembly Instructions included with the rack shipment.

5.2 To locate the cells on the racks, mark the center post of each rack. These marks will indicate center points of the center cell whenever the number of cells on the rack is an odd number. Whenever the number of cells is an even number, the marks will indicate the center point between the two center cells.

5.3 Cells should be installed first on the lower tier or step to insure rack stability. The top tier rails should be installed after all the cells located on the lower level have been installed.

6. INSTALLATION:

6.1 DO NOT LIFT any battery or cell by the terminal posts as this will void the warranty.

6.2 Terminal Connections - Each cell is furnished with terminal nuts and bolts made of corrosion-resisting materials. Connections should be clean and drawn up snugly but without applying extreme pressure. After cell connections have been made, an application of petrolatum (Vaseline) will maintain clean, corrosion-proof connections.

IMPORTANT: Intercell and end connectors should be made of lead to prevent corrosion.

6.3 Electrolyte Level - Before putting cells into service, check the electrolyte level with the filling syringe, Part No. H-212 for Type DH cell; Part No. H-201 for Type DHB cell. If low, adjust to the proper level (see table on page #9) adding pure distilled water only. After adding water, charge cells until the water is thoroughly mixed with the solution as indicated by hydrometer readings. In this way, errors in subsequent hydrometer readings taken on discharge, or the possibility of freezing in cold climates, can be avoided.

6.4 Dry-Shipped Batteries - When batteries are shipped dry (see para. 2.1), they are to be activated with 1.300 specific gravity sulfuric acid electrolyte to the filling height above the plates as per appropriate cell as indicated in the Charging Data Table on page 9. The polyethylene shipping vent plugs should be discarded and standard vent plugs should be installed.

6.5 Installing New Cells - When practical, it is desirable to install cells of approximately similar age in the same or parallel strings. To include 1 or 2 year old cells in the same circuit with a group of new cells might result in an early failure of the entire installation because of the normal failure of the older cell. For this reason, it is necessary to have complete records of each cell.

7. MAINTENANCE:

7.1 Avoid Contamination - Willard Charge Retaining Cells show relatively little self-discharge on open circuit. This is due to the extreme purity of the component parts of the cells. To maintain this purity, it is necessary to scrupulously avoid any contamination from metals, iron rust or any foreign substance.

IMPORTANT: To avoid the danger of contamination when adding to or testing electrolyte solution, it is absolutely imperative that a special hydrometer, filling syringe and thermometer be provided for use on Charge Retaining Cells Only. Under no circumstances should these instruments be used on other conventional type cells or batteries since there is a possibility of transferring impurities to the Charge Retaining Cells, causing considerable damage as a result.

7.2 Protection Against Freezing - There is no danger of freezing if a cell of sufficient capacity is used to carry the discharge through the cold weather periods. When sufficient capacity is available, the danger of freezing will be avoided entirely. The freezing point of sulfuric acid at various specific gravities is shown in the graph on page 8.

7.3 Avoid Leaving In Discharged Condition - When the discharge has been completed, the cells or battery should not be permitted to remain discharged for any greater time than is necessary. Complete discharge of cells should be avoided.

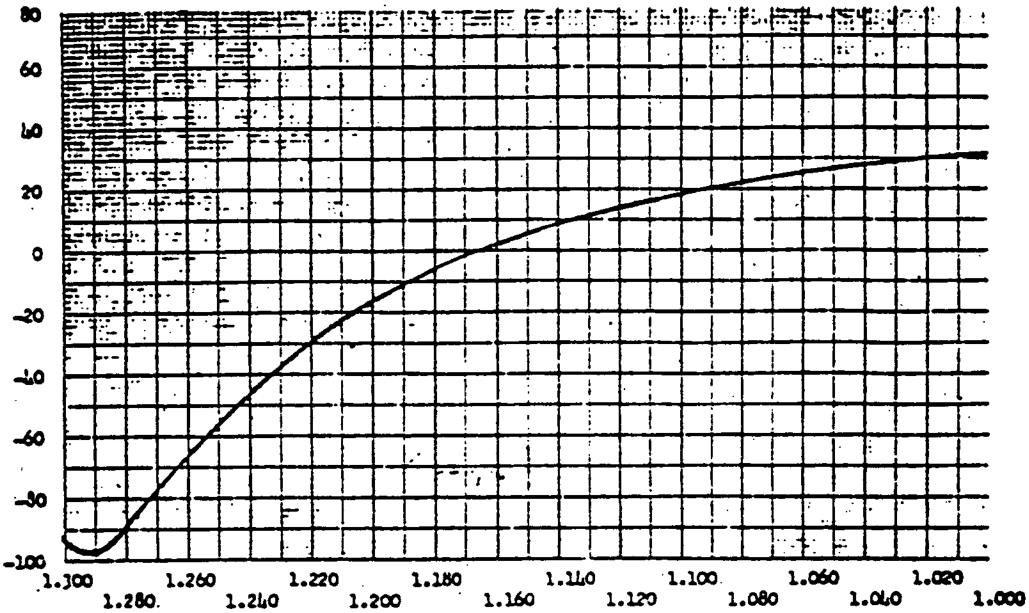
8. RECHARGING - STATIONARY CHARGERS OR PHOTOVOLTAICS:

8.1 Test Cells Before Placing On Charge - Before charging, the specific gravity should be tested to determine the state of charge and the electrolyte level should be checked (refer to electrolyte level data pg. 9). If the electrolyte level is too low, bring it up to the proper level with pure distilled water before placing on charge.

8.2 Connecting Cells On Charging Line - The cells should be connected in series for charging, i.e., the positive terminal of the first cell is connected to the negative terminal of the next cell and so on. To connect the series line of batteries to the charging source, connect the POSITIVE terminal of the batteries to the POSITIVE terminal of the charging source, and the NEGATIVE to the NEGATIVE in a like manner.

DEGREES
FAHRENHEIT

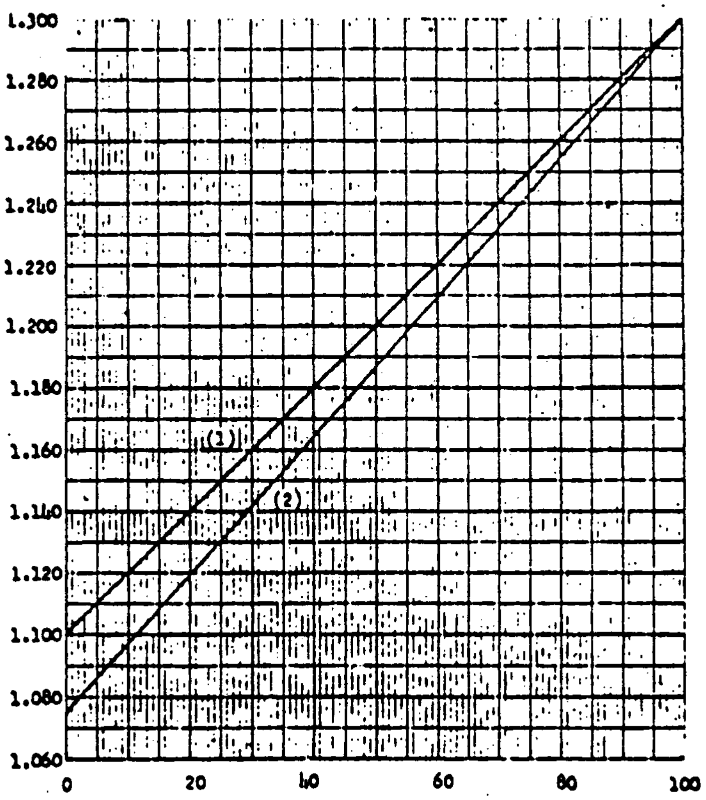
FREEZING POINT OF SULPHURIC ACID ELECTROLYTES AT VARIOUS SPECIFIC GRAVITIES



SPECIFIC GRAVITY - ELECTROLYTE

ELECTROLYTE
SPECIFIC GRAVITY (80°F)

(1) For "DD" TYPES
(2) For "DA" "DH" and "DHB" TYPES



PERCENT CAPACITY REMAINING

RELATION BETWEEN SPECIFIC GRAVITY AND CAPACITY AT VARYING
STAGES OF DISCHARGE WITH FULLY CHARGED SPECIFIC GRAVITY
OF 1.300 at 80°F.

8.3 Proper Charging Rate (For Stationary Chargers) - Charge Retaining Cells may be charged on any direct current, series line either with other storage battery types or separately, but in either case the charging rate should not exceed the normal rate given for the smallest cell in the circuit. Lower rates may be used but the charge must be carried through to completion.

8.4 Charging By Photovoltaics - Charging of cells by photovoltaics should be done at a voltage of 2.40 vpc at a differential of plus or minus 3 millivolts per degree Fahrenheit, i.e., plus 3 millivolts per degree when ambient temperature is less than 80°F and minus 3 millivolts per degree when greater than 80°F. The charging rate for the various cells shall not exceed the recommended rate shown in the table below. It is recommended that only voltage regulated power sources be used in order to conserve water and extend battery life.

CHARGING DATA

Type	Approx. Discharged Gravity (Cut-off Voltage)	Charging Rates (Amperes)	Approx. Charging Time	Finish Gravity	Filling Hgt. Above Plates
	(1.95V)				
DA-2-1	1.120	1	48 Hrs.	1.300	3/8"
DD-3-3	1.140	2.5	55 Hrs.	1.300	7/8"
DD-5-1	1.140	5	55 Hrs.	1.300	7/8"
DD-5-3	1.140	5	55 Hrs.	1.300	7/8"
DH-5-1	1.120	10	75 Hrs.	1.300	1-3/4"
DHB-5-1	1.120	10	75 Hrs.	1.300	1-3/4"

8.5 Hydrometer Readings - Should be taken at regular intervals during the service and recorded on Storage Battery Report (page 12).

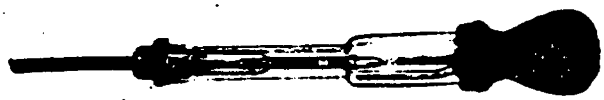
8.6 Temperature Corrections To Hydrometer Readings - Since the specific gravity as shown by the hydrometer varies with the temperature, a correction must be made if the temperature of the electrolyte varies from the normal 80°F. This correction is made as follows: If the temperature of the electrolyte is above 80°F, add two points (.002) to the hydrometer readings for each 5°F above 80°F. If the temperature of the electrolyte is below 80°F, subtract two points (.002) from the hydrometer reading for each 5°F below 80°F.

8.7 Avoid Excessive Overcharge - In charging these cells, it is necessary that the charging rate be held as nearly constant as possible. Excessive overcharging should be avoided.

8.8 Adjustment of Specific Gravity - Should the specific gravity rise above normal and the liquid level is correct, reduction to the normal gravity may be accomplished by drawing off electrolyte and replacing with distilled water, returning the electrolyte to the proper level. Continue the charge after adding water until the gravity does not change. If too much electrolyte has been withdrawn, repeat the process, but, in this case, add electrolyte. Adjustments should be continued until the proper finish specific gravity has been obtained at the proper level. Acid should never be added unless there is an absolute certainty that the cell is completely charged, or to replace electrolyte lost by accident. Temperature corrections in specific gravity readings should always be made when hydrometer readings are being taken.

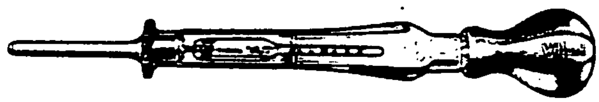
8.9 Hydrometers - The hydrometer used should have a float calibrated to read lower than the standard automotive type hydrometer. For small cells or individual work in testing cells in service Willard Hydrometer H-161 is recommended.

Hydrometer Part No. H-161



THIS HYDROMETER IS MADE FOR CHARGE RETAINING BATTERIES. IT IS A CONVENIENT SIZE FOR TYPE DA-2-1 AND EQUALLY SERVICEABLE FOR ALL CR BATTERIES.

Stationary Type - Part No. H-169



A QUICK ACTING WILLARD HYDROMETER FOR SHOP AND SERVICE USE. FLOAT SCALE READING 1.050 TO 1.250

In testing cells larger than the DA-2-1 type, the use of two separate hydrometers is recommended - one with a high reading scale (1.150 to 1.300) and the other with a low reading scale (1.050 to 1.250). The instrument with the high scale is to be used in taking readings during the early part of the discharge and toward the end of the charge. The low scale instrument is to be used in taking readings toward the end of the discharge and during the beginning of the charge. Willard hydrometers Part No. H-169 (scale 1.050 to 1.250) and Part No. H-168 (scale 1.150 to 1.300) should be part of all shop and service equipment.

In all cases, the hydrometers used should be clean and the same hydrometer always used for testing Willard Charge Retaining Cells. To avoid contamination, hydrometers used in testing other types of storage batteries should not be used.

9. AVAILABLE ACCESSORIES:

The following equipment, used in servicing Willard Charge Retaining Cells and Batteries, is available from ESB Wisco Incorporated:

Part	Description	Part No.
Hydrometer	For Small Cells (DA-2-1)	H-161
Hydrometer	For all other Charge Retaining Types	
	High Reading (1.150-1.300)	H-168
	Low Reading (1.050-1.250)	H-169
Thermometer	Floating type with specific gravity correction	Z-30
Syringe Filler	For DH-5-1 use	H-212
Syringe Filler	For DHB-5-1 use	H-201
Post Seal Nut Wrench	For DH and DHB	Z-534
Vent Plug Wrench	For DHB-5-1	Z-530
Carrying Handle	For DH and DHB	V-68

10. SERVICE ROUTINE & PROCEDURE:

10.1 Establish a System of Records - A record system should be set up which will provide the operator or user with a definite record of the service received from each cell. As opinions differ, the form in which this record is to be kept is left entirely to the user. (A suggested format appears on the last page of this publication.) In any case, whether the system is simple or complex, it is required that the following fundamental items be recorded and kept throughout the life of the cell or battery:

- Date of receipt of the cell or battery.
- Manufacturer's date identification ("2-76" for example).
- Description, number or name of system in which installed.
- Date of installation.
- Specific gravity at time of installation.
- Voltage at time of installation.
- Quarterly voltage and corrected specific gravity readings.
- Date of removal from system.
- Specific gravity at time of removal.
- Voltage on discharge at time of removal.

10.2 Quarterly Routine - During the service or discharge portion of the cycle, the following routine is suggested for checking cells:

- Check specific gravity and record readings of each cell.
- Adjust electrolyte level with distilled water if required.
- Check and record voltage of each cell.
- Check all battery connections for contact.
- Clean terminals of any corrosion which might have formed and apply coating of petrolatum (Vaseline) to the terminal where necessary.

If a definite routine is established, there should be no occasion for failure of a system because of the batteries.

QUARTERLY BATTERY REPORT - BATTERY IN PHOTOVOLTAIC SERVICE

COMPANY .... BATTERY TYPE .... DATE INSTALLED ....

LOCATION .... CELL NO. ....

BATTERY NO. .... FULL CHARGE GRAVITY (RANGE)............

DATE & INITIALS OF READER	BATTERY TERMINAL VOLTS	CELL HYDROMETER READINGS	CELL TEMPERATURES

DATE				
CELL	VOLTS	VOLTS	VOLTS	HYD. RDG.
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				
28				
29				
30				
31				
32				
33				
34				
35				
36				
37				
38				
39				
40				
41				
42				
43				
44				
45				
46				
47				
48				
49				
50				
51				
52				
53				
54				
55				

ADDING WATER

ADD WATER AFTER COMPLETING HYDROMETER READINGS.

DATE	QUANTITY
....	.......QTS.
....	.......QTS.
....	.......QTS.
....	.......QTS.
....	.......QTS.
....	.......QTS.
....	.......QTS.

CONNECTOR BOLTS TIGHTENED

DATE	DATE
....	....
....	....
....	....
....	....
....	....
....	....
....	....

READINGS REVIEWED

BY ....

DATE ....

BY ....

DATE ....

BY ....

DATE ....

IN COMMENTS ARE DESIRED SEND TO NEAREST ESB WISCO REPRESENTATIVE:

ESB WISCO INCORPORATED
2510 NORTH BOULEVARD
RALEIGH, NC 27604
(919) 834-8465

REMARKS: ....

....

....

ESB

WORLD LEADER IN
PACKAGED POWER

Solar Power Corporation

AFFILIATE OF EXXON ENTERPRISES INC.

Installation And Maintenance Manual

SERIES "M" ARRAYS
SOLAR ELECTRIC GENERATOR

TABLE OF CONTENTS

INSTALLATION DATA

Site Location: ______

Tilt Angle: ______ Regulator: BVR ______ Design Load: ______ AH/day

Battery: Model ______ connected ______ cells in series by ______ banks in parallel

THE FOLLOWING QA TEST DATA PERTAINS TO YOUR SOLAR ELECTRIC GENERATOR:

Array Performance

Array Model: ______ Serial #: ______

Rated Output*: ______ Amps at ______ Volts

Rated Short Circuit Current*: ______ Amps

No. of Series-Connected Solar Cells: ______

No. of Parallel-Connected Solar Cells: ______

Frame Performance

No. of Separate Frames in Array: ______

______ Model M ______ modules on ______ frame(s).

Rated Short Circuit Current* of frame(s): ______ amps ea

______ Model M ______ modules on ______ frame(s).

Rated Short Circuit Current* of frame (s): ______ amps ea.

Module Performance

MODEL M ______ module

Rated Short Circuit Current*: ______ Amps

No. of Series-Connected Solar Cells: ______

No. of Parallel-Connected Solar Cells: ______

MODEL M ______ module

Rated Short Circuit Current*: ______ Amps

No. of Series-Connected Solar Cells: ______

No. of Parallel-Connected Solar Cells: ______

*At 100mW/ cm^2 sunlight intensity and 28°C cell temperature.

1.0 GENERAL

1.1 This manual includes the unpacking, assembly, and maintenance instructions for the Solar Power Corporation Solar Electric Generator Series M Arrays. For information relating to the installation and maintenance of the storage battery system, refer to Manufacturer's Instructions.

1.2 Properly installed solar electric generator systems should only require regular maintenance visits once a year. Maintenance recommendations are given in Section 4.1.

1.3 If any trouble does develop, Sections 3.0 and 4.0 give complete test, troubleshooting, and repair procedures. If additional help is required, contact the Technical Service Department at Solar Power Corporation.

2.0 UNPACKING AND ASSEMBLY INSTRUCTIONS

2.0.1 Because the arrays may be anchored to different types of mounting surfaces, the customer is expected to supply mounting hardware.

2.0.2 If the total array consists of more than one frame, repeat all instructions for each frame.

2.1 UNPACKING AND ASSEMBLY - ARRAYS WITH TELESCOPING LEGS

2.1.1 Open the crate. Remove the layer of packing material and any other hardware or items that are on top of the array.

2.1.2 Lift the array out of the crate and hold it nearly vertical or place it on the ground, front module surface facing up. DO NOT PUT THE ARRAY ON THE GROUND FACING DOWN.

2.1.3 Unbolt the mounting feet from the leg sections. Retain this hardware and all other hardware removed in the following steps; it will be needed to assemble the legs and mounting feet to the array frame (reference Figure 1b).

2.1.4 Unbolt the two large leg sections (larger cross sectional area) from the bottom mounting brackets. Attach one mounting foot to one end of each of these leg sections as shown in Figure 1, Point C. It may be necessary to loosen the bolt holding the small leg to the top mounting bracket, thus allowing the leg to swing.

2.1.5 Attach the remaining two mounting feet to the bottom mounting brackets (the ones that do not have leg sections attached to them) as shown in Figure 1, Point D.

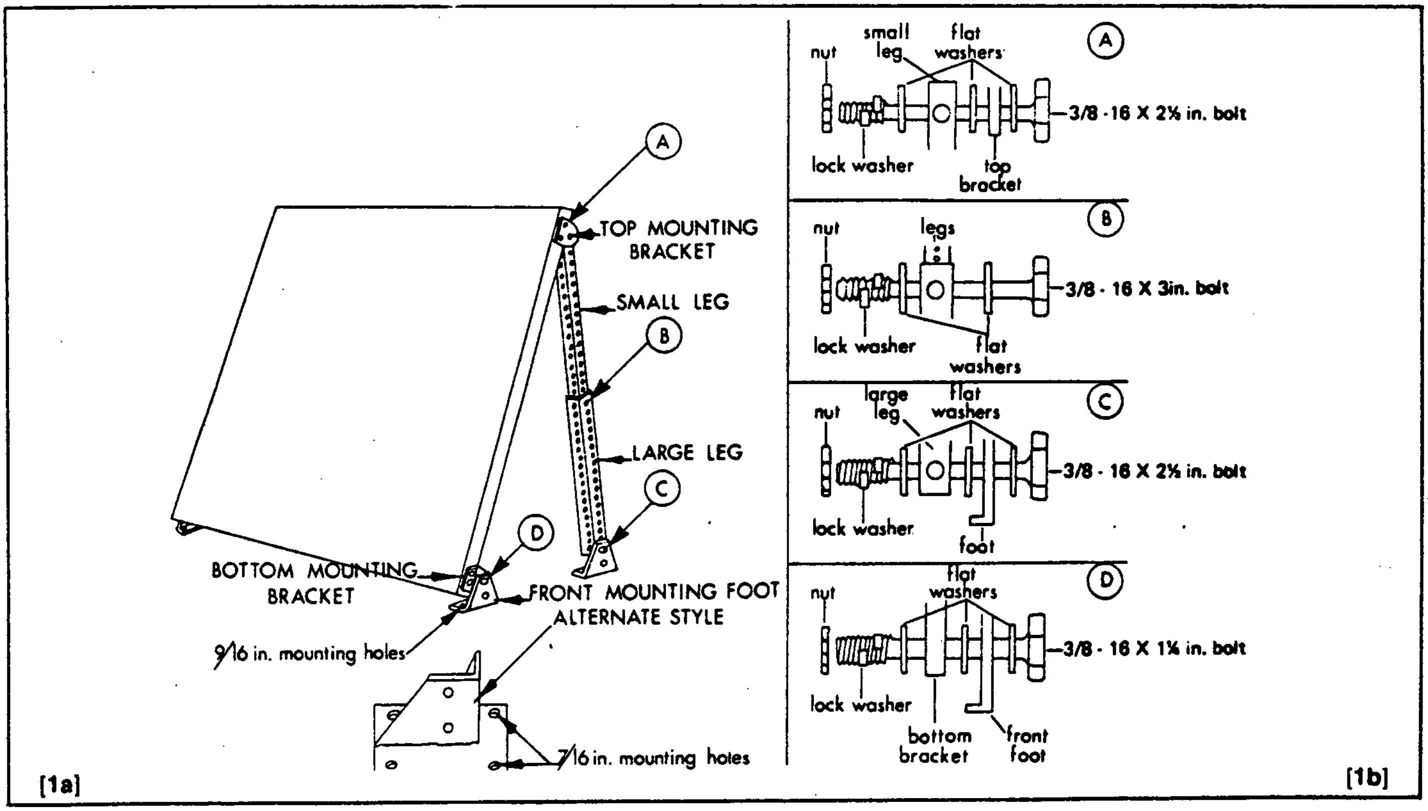
2.1.6 The array is now fully assembled and ready to be moved to its installation location and oriented. If the array must be disassembled or recrated, reverse the above procedure.

2.2 ORIENTING THE ARRAY - ARRAYS WITH TELESCOPING LEGS

2.2.1 When selecting a mounting location, make sure that the bottom of the array will be at least 3 feet (or 1 meter) higher than the maximum snow depth level.

2.2.2 IMPORTANT: THE ARRAY MUST BE ALIGNED SUCH THAT THE FRONT (MODULE) SURFACE DIRECTLY FACES DUE SOUTH (DUE NORTH IN THE SOUTHERN HEMISPHERE). WHEN USING A MAGNETIC COMPASS MAKE SURE TO CORRECT FOR THE LOCAL DIFFERENCE BETWEEN MAGNETIC DIRECTION AND TRUE DIRECTION. Anchor the front mounting feet once the array is aligned.

FIGURE 1

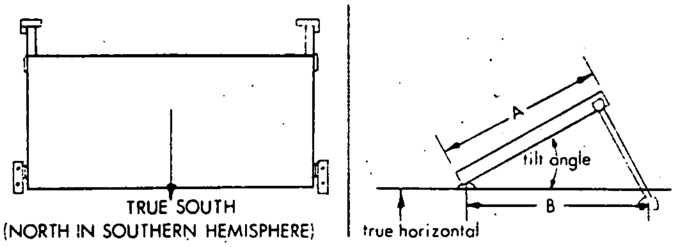


2.2.3 Anchor the legs' mounting feet to the mounting surface. It is best to make support spacing (B) equal to array dimension (A) (reference Figure 2b). Other positions may be used as necessary depending on the angle required and/or terrain considerations.

2.2.4 To set the tilt angle of the array, remove the long bolts anchoring the leg sections together (reference Figure 1, Point B) and adjust the length of the telescoping legs. The tilt angle of the array (the angle the array surface makes with a horizontal surface) should be adjusted to within 2 degrees of the specified angle. An inclinometer (adjustable angle liquid level) is most useful in measuring this angle, although, with care, a protractor and an ordinary bubble level may also be used. Reinsert the bolts and tighten.

2.2.5 Tighten all nuts and bolts.

FIGURE 2



[2 a] [2 b]

2.3 ATTACHMENT OF CABLES

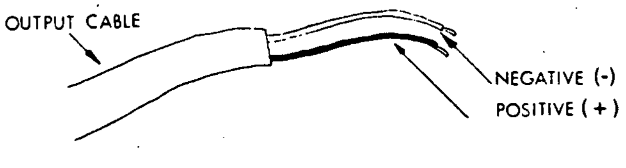
2.3.1 If a battery voltage regulator is included in the system or if one is added to the system, follow the instructions included with the regulator.

2.3.2 **Single Frame Arrays:** The output cable can be attached directly to the battery. Observe the correct polarity; black is positive, white is negative (reference Figure 4). If the polarity is accidentally reversed, no damage will result to either the array or the battery (assuming the battery is of the proper voltage for the array). However, if the polarity is left reversed for more than a few hours, the solar electric generator system will not function and the battery may become discharged.

2.3.3 **Multiframe Arrays:** Each frame is supplied with a separate output cable. Attach the output cable directly to the appropriate battery terminal (observe correct polarity).

2.3.4 After connecting cable(s) to the battery and connecting any required battery intercell connecting wires, protect all battery terminals from corrosion with a layer of grease.

FIGURE 3



3.0 TESTING

There are several tests that can be conducted to check system performance: Test 3-1 (Solar Array Performance), Test 3-2 (Blocking Diode Performance), Test 3-3 (Battery Self-Discharge). These can be performed either independently or in conjunction with the Troubleshooting Guide, Section 4.2.

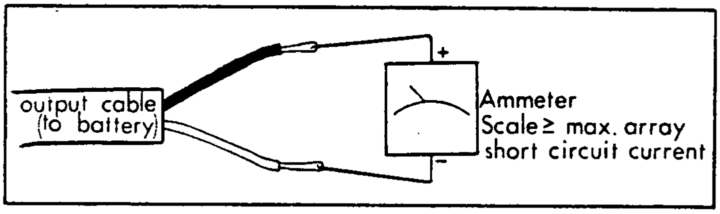
Upon installation, Test 3-1 (Solar Array Performance) should be conducted. Tests 3-2 and 3-3 should be performed if trouble occurs.

The annual maintenance visit can include the following simple check of the solar electric generator system performance. Measure the specific gravity of the battery electrolyte (for lead-acid batteries) with a standard battery hydrometer. Correct the readings to 77°F (25°C) using Table 3-1. Refer to Table 3-2 and relate the percent of battery capacity remaining to the corrected electrolyte specific gravity. If battery electrolyte specific gravity is low, refer to Section 4.2, Conditions 1 and 2.

TEST 3-1: SOLAR ARRAY PERFORMANCE

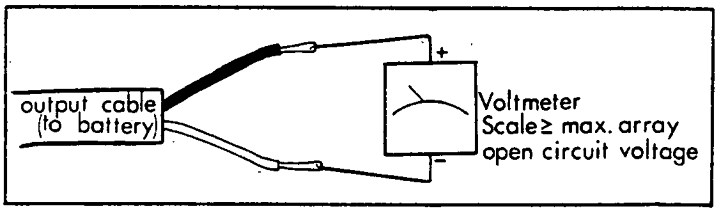
1. This test must be performed during the middle hours of a sunny day. The sun must be clearly visible with no thick haze present.
2. Disconnect array cable(s) or voltage regulator-battery cable from the battery terminals. If the system contains a regulator(s), disconnect regulator(s) following instructions provided with regulator(s) before proceeding to the next step.
3. Connect a suitable ammeter across the two disconnected cable leads (reference Figure 4). The ammeter's resistance should be such that the voltage drop across the ammeter is less than 0.3 volt. Adjust the tilt angle of the array to obtain the maximum current output as indicated by the ammeter.

FIGURE 4



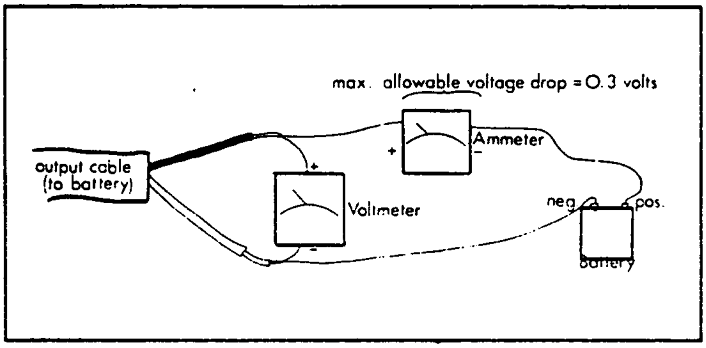
4. The ammeter current reading (short circuit current) should be approximately 70% of the $100 mW/cm^2$ short circuit current (listed under "Array Performance" on the front cover).
5. Disconnect the ammeter. Connect across the same cable leads (reference Figure 5) a voltmeter having an impedance of at least 1,000 ohms per volt. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the total number of solar cells in series (listed under "Array Performance" on the front cover).

FIGURE 5



6. Disconnect the voltmeter. Reconnect the negative lead to the battery. Connect an ammeter between the positive cable lead and the positive battery terminal (positive ammeter lead to the positive cable lead). Connect the voltmeter to the two cable leads (reference Figure 6). If this voltage is less than 2.2 volts times the number of series-connected lead-acid battery cells, the measured current should be at least 80% of the current measured in Step 4 (assuming sunlight conditions unchanged since Step 3).

FIGURE 6



7. For multiframe arrays this test procedure can be repeated for each individual array section by making these tests at each individual array cable termination. For each individual array section, disconnect the cable leads from the terminal block inside the external junction box and repeat Steps 3 through 6. The corresponding information for each frame is listed on the front cover of this manual (reference "Frame Performance").

8. If an array does not pass this test, refer to the Trouble-shooting Guide, Section 4.2.

TABLE 3-1

HYDROMETER READING CORRECTIONS TO 77°F

Electrolyte Temperature [°F]	Correction [add to reading]
140	+0.024
130	+0.020
120	+0.016
110	+0.012
100	+0.008
90	+0.004
80	+0.000
70	-0.004
60	-0.008
50	-0.012
40	-0.016
30	-0.020
20	-0.024
10	-0.028
0	-0.032
-10	-0.036
-20	-0.040
-30	-0.044
-40	-0.048

NOTE: The temperature of the electrolyte solution, not the ambient air temperature, should be measured with an immersion type thermometer. Some hydrometers have a thermometer and temperature correction scale built in.

TABLE 3-2

PERCENT OF 500 HOUR RATE CAPACITY REMAINING
vs.
ELECTROLYTE SPECIFIC GRAVITY (CORRECTED TO 77°F)

	Initial Electrolyte Specific Gravity		
	1.210	1.250	1.300
% Capacity Remaining	Hydrometer Reading [Corrected to 77°F]		
100	1.210	1.250	1.300
90	1.197	1.235	1.283
80	1.185	1.221	1.266
70	1.172	1.206	1.249
60	1.160	1.192	1.232
50	1.147	1.177	1.215
40	1.135	1.163	1.198
30	1.122	1.148	1.181
20	1.110	1.134	1.164
10	1.097	1.119	1.147
0	1.085	1.105	1.130

TEST 3-2: BLOCKING DIODE PERFORMANCE

1. This test must be performed either at night with no artificial light striking the array or with a black opaque cloth covering the entire array (reference Figure 7).

2. Disconnect the positive lead of the array cable(s) or the voltage regulator-battery cable from the battery terminals. Connect a milliammeter between this disconnected lead and the positive battery terminal (positive milliammeter lead to the positive battery terminal) (reference Figure 7). The current measured should be less than 4mA times the numb of solar cells connected in parallel (listed under "Array Performance" on the front cover).

3. A current exceeding the above value indicates that the diode(s) has developed excessive reverse leakage current. If the array contains a diode mounted in a junction box, it should be replaced (reference Section 4.3). If the system includes a voltage regulator(s), refer to Regulator Manual for testing procedure. Otherwise, the diode(s) is located inside the module(s) and this test should be repeated for each module on the affected frame. Access to each module's leads may be obtained by removing the attached junction box cover. Disconnect the leads at the terminal block before starting the test. Remember that no light can strike the module's surface. Diodes located in the terminal box attached to the back of each module are sealed and cannot be replaced in the field. Any module that shows excessive reverse leakage current should be replaced (reference Section 4.3).

TEST 3-3: BATTERY SELF-DISCHARGE [LEAD-ACID BATTERIES]

NOTE: THIS TEST WILL REQUIRE REMOVAL OF THE BATTERY SYSTEM FROM THE ARRAY SITE.

1. Disconnect all cables from the battery terminals. Charge the battery or battery cell at a current rate not exceeding the battery's capacity in ampere hours divided by 20 hours (e.g., a 100-ampere hour battery would be charged at a current of 5 amperes or less). A standard battery charger should suffice for this purpose. Discontinue charging when the battery's terminal voltage exceeds 2.3 volts per series-connected battery cell.

2. Take a specific gravity reading of the electrolyte in each battery cell and record the corrected values (use Table 3-1 and an immersion thermometer).

3. Allow the battery to stand idle at room temperature for a week. At the end of the week take a second set of specific gravity readings. Compare with readings taken in Step 2. Corrected readings differing by more than 15 points (0.015) indicate a battery cell with excessively high self-discharge.

4.0 MAINTENANCE

4.1 REGULAR MAINTENANCE

(Yearly intervals recommended.)

4.1.1 Check battery electrolyte level. Replenish with distilled water, if necessary. When checking or adding to the battery electrolyte, the battery manufacturer's recommendations should be followed.

4.1.2 Check the module surface(s) for dirt buildup. Normal rainfall will usually be sufficient to provide for self-cleaning, if the array is tilted at 15° or more from the horizontal. However, if dirt buildup becomes excessive, either plain water or a mild detergent solution followed by a water rinse may be used. DO NOT USE SOLVENTS OR STRONG DETERGENTS.

4.2 TROUBLESHOOTING GUIDE

Most problems can be isolated with the aid of the following guide. If it is impossible to locate the problem, please contact the Technical Service Department at Solar Power Corporation for assistance.

CONDITION 1	Other Symptoms
Battery electrolyte specific gravity low [lead-acid batteries]	Specific gravities of all battery cells differ no more than 20 points (0.020)

Checks and Repairs

1. Check all battery electrical connections for corrosion and mechanical soundness. Clean and/or repair.
2. Check to see if there are any obstructions that shadow any portion of the array during any part of the day. If this condition exists, either the obstruction must be removed or the array must be moved to an unobstructed location.
3. Check the orientation of the array. Make sure it is facing directly due south (north in the southern hemisphere) and the tilt angle is correct (reference Section 2.2 or 2.3).
4. Check the load current. Calculate the equivalent number of amp hours per day required by the load. Compare this calculation against the design load listed under "Installation Data" on the front cover. If the measured load exceeds the design load, contact the Technical Service Department at Solar Power Corporation. Each solar electric generator system is designed for a specific load. Deviations from that load may result in unsatisfactory operation.
5. Check the solar array output by following the instructions in Test 3-1. Refer to Conditions 3, 4, 5, or 6 (Section 4.2) as necessary.
6. Check the blocking diode(s) by following the instructions in Test 3-2.
7. Check for high battery self-discharge by following the instructions in Test 3-3. If the battery or part of the total battery system fails this test, replace the defective battery cell(s).

CONDITION 2	Other Symptoms
Same as Condition 1	Specific gravity of only one or a few battery cells low

Checks and Repairs

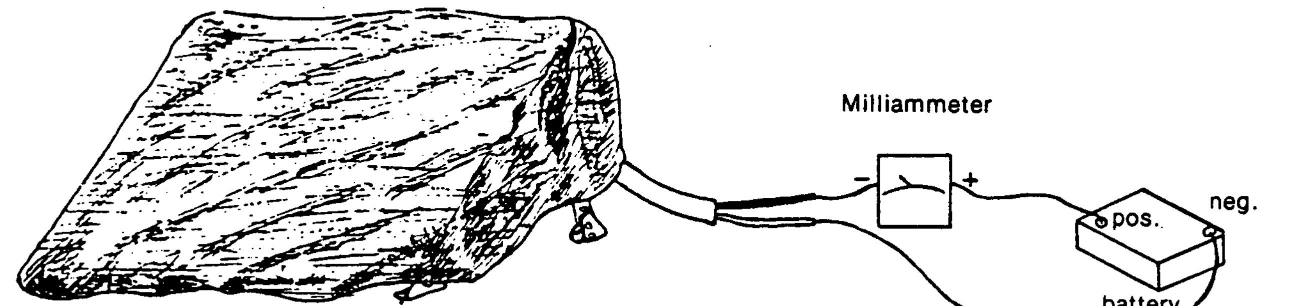
1. Check for excessively high electrolyte level. If so, shelter battery to prevent rain from entering through the vent hole(s).
2. Check the affected cells for high battery self-discharge by following the instructions in Test 3-3. Replace battery cell or battery containing bad cell.

CONDITION 3
Array open circuit voltage equal to zero [from Test 3-1]

Checks and Repairs

1. Single Frame Arrays:
   (a) If the array consists of only one module, that module must be replaced (reference Section 4.3).
   (b) If the array consists of more than one module, remove the cover of the junction box mounted to the back of the array. With the output cable disconnected from the battery terminals, test for voltage at the individual module leads. If voltage is present, there are bad contacts. At the terminal block, or the crimp connectors attached to the output cable are not making contact to the wire, or the output cable's conductors are broken. Clean all connections. Test crimp connectors by pulling on wires. Recrimp or attach wire directly to terminal block if necessary. Test the cable with an ohmmeter or continuity tester. Replace output cable if it is an open circuit.
2. Multiframe Arrays:
   (a) Remove junction box cover. Check for loose connections at the terminal block. Tighten if necessary.

FIGURE 7



Black opaque cloth over <u>entire</u> array or perform at night with no light shining on array.

(b) Test for voltage at the individual array cable terminations. If voltage is present there, proceed to Step 2 (c). If no voltage is present at any of the cable terminations, each array section must be checked individually as described in Step 1(b).

(c) Make sure that at least one lead of the battery cable is disconnected from the battery terminals. Connect a jumper wire between any positive array cable terminal and the positive battery cable terminal. If voltage is now present at the battery cable leads, and there is a blocking diode within an external junction box, either the blocking diode is defective or one of the wires connecting the diode to the terminal block is broken. Detach the plate on which the terminal block is mounted by removing the four corner screws. The blocking diode is located beneath the plate. Inspect for any broken wires and if none are found, replace the diode (reference Section 4.3).

(d) Check the continuity of the battery cable with an ohmmeter or continuity tester. Replace output cable if it is an open circuit.

CONDITION 4

Array open circuit voltage low [from Test 3-1]

Checks and Repairs

1. Check that the voltmeter's resistance is greater than 1,000 ohms per volt, that the sun is clearly visible, that there is no thick haze blocking the sun, and that the array is aimed towards the sun.

2. Single Frame Arrays:

(a) If the array consists of only one module, that module should be replaced (reference Section 4.3).

2. (b) If the array consists of more than one module, remove the cover of the junction box mounted in the back of the array. Disconnect the cable leads from each module. Test each module individually for low open circuit voltage. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the number of solar cells in series (listed under "Module Performance" on the front cover). Any module that does not pass this test should be replaced (reference Section 4.3).

3. Multiframe Arrays: Disconnect the array cables from the terminal block in the external junction box or from the battery terminals. Check the open circuit voltage at each individual cable pair of wires to isolate the affected array section. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the number of solar cells in series (listed under "Array Performance" on the front cover). To locate the defective module in the array section isolated above, follow the instructions in Step 2(b).

CONDITION 5

Array short circuit current low [from Test 3-1]

Checks and Repairs

1. Check for dirt buildup on any module or portion of a module. Clean according to Section 4.1.2.

2. Check for condensation, snow, or ice on module or any portion of a module. Wipe clean.

3. Check for shading of any module or portion of a module. Retest after removing obstruction.

4. Make sure array is aimed directly at the sun. Retest afte correcting tilt.

5. Single frame arrays or when the problem is isolated to a single array frame (reference Step 6): Remove the attach junction box cover. Test each individual module for sho. circuit current as described in Test 3-1, Steps 3 and 4. Compare these values to the short circuit current values listed on the front cover under "Module Performance". Replace any module (reference Section 4.3) which fails Test 3-1. Make sure all connections in the junction box are tight and clean.

6. Multiframe Arrays: Perform Test 3-1 for each array secti (cable) to determine the faulty section. Check for any loose terminals or broken wires within an external junction box. Also check all connectors, if any, for corrosion and tight mating of the male and female contacts. Clean or replace as necessary.

CONDITION 6

Excessive difference between array short circuit and battery charging current [from Test 3-1]

Checks and Repairs

1. Check for corrosion at the battery terminals. Clean terminals and cable leads. Retest.

2. If the array has a junction box(es) (either internal or external), remove the cover(s) and inspect for corrosion on all electrical connections within the box. Clean or replace damaged components. Retest.

3. Test each module individually as described in Steps 3, 4, and 6 of Test 3-1. Compare these values to the short circuit current values as listed on the front cover under "Module Performance". Replace any module(s) that fail Test 3-1 (reference Section 4.3).

4.3 MODULE AND DIODE REPLACEMENT

When it has been determined that a module or a blocking diode needs replacing, proceed as follows:

4.3.1 Replacement of Module

(a) Remove cover of junction box attached to array frame.

(b) Disconnect at the terminal strip the cable leads of the module being replaced.

(c) Loosen the threaded gland of the cable fitting through which the module cable enters the junction box. Pull the end of the cable out of the junction box.

(d) Remove the nuts and bolts holding the module onto tl array frame. Lift off the module; save the hardware removed.

(e) Insertion of Replacement Module:
Reverse the removal procedure; (a) through (d) above.

4.3.2. Replacement of Blocking Diode Located in Junction Box

(a) Disconnect battery cable at battery terminals.

(b) Remove the junction box cover and the metal plate on which the terminal block is mounted. Loosen or remove cable leads from the terminal block, if necessary.

(c) The diode will usually be mounted on a heat sink. Make a sketch showing which lead goes to which terminal and how the hardware is assembled. Unsolder the leads to the diode. Remove the diode.

(d) Insert the new diode (exact same number as the diode being replaced). Take care to replace the hardware in the same order as was on the removed diode.

(e) Solder the leads to the new diode. Take care that the leads go to the same terminals as on the removed diode. (Array positive lead to anode; battery positive lead to cathode.)

(f) Replace the metal plate and the junction box cover.

(g) Reconnect the battery cable to the battery terminals.

4.3.3. Replacement of Blocking Diode Located in Module

A blocking diode within the module cannot be replaced in field. The module should be removed from the array frame (reference Section 4.3.1, a-d) and returned to Solar Power Corporation for repair.

5.0 TOOLS AND EQUIPMENT

5.1 INSTALLATION & MAINTENANCE TOOLS

Ratchet Handle (3/8" or 1/2" drive)
6" Extension
1/2" Socket and Wrench
9/16" Socket and Wrench
7/16" Socket and Wrench
3/4" Socket and Wrench
Screw Drivers (1/8" to 1/2" wide)
Slip Joint Pliers (1½" diameter grip)
Locking Pliers
Crimping Tool (VACO 22-10 or equivalent) and assorted crimp terminals
Wire Strippers
Diagonal Cutters (medium)
Compass (magnetic)
Inclinometer

5.2 TESTING EQUIPMENT

Simpson 260 VOM (or equivalent)
Immersion Thermometer
Battery Hydrometer

Solar Power Corporation
AFFILIATE OF EXXON ENTERPRISES INC.
20 CABOT ROAD, WOBURN, MASSACHUSETTS 01801, TELEPHONE (617) 935-4600 TWX 710-348-0602

March 1979

Solar Power Corporation
AFFILIATE OF EXXON ENTERPRISES INC.

Installation And Maintenance Manual

SERIES "G" (L.F.) ARRAYS
SOLAR ELECTRIC GENERATOR

TABLE OF CONTENTS

INSTALLATION DATA

Site Location:____________________

Tilt Angle:____________ Regulator: BVR________ Design Load:________AH/day

Battery: Model__________connected________cells in series by________banks in parallel

THE FOLLOWING QA TEST DATA PERTAINS TO YOUR SOLAR ELECTRIC GENERATOR:

Array Performance

Array Model:________Serial #:________

Rated Output* ________Amps at________Volts

Rated Short Circuit Current*:________Amps

No. of Series-Connected Solar Cells:________

No. of Parallel-Connected Solar Cells:________

Frame Performance

No. of Separate Frames in Array:________

________ Model G ________modules on________frame(s).

Rated Short Circuit Current* of frame(s):______amps ea

________ Model G ________modules on________frame(s).

Rated Short Circuit Current* of frame (s):______amps ea.

Module Performance

MODEL G ________module

Rated Short Circuit Current*:________Amps

No. of Series-Connected Solar Cells:________

No. of Parallel-Connected Solar Cells:________

MODEL G ________module

Rated Short Circuit Current*:________Amps

No. of Series-Connected Solar Cells:________

No. of Parallel-Connected Solar Cells:________

*At 100mW/ cm^2 sunlight intensity and 28°C cell temperature.

1.0 GENERAL

1.1 This manual includes the unpacking, assembly, and maintenance instructions for the Solar Power Corporation Solar Electric Generator Series G Arrays. For information relating to the installation and maintenance of the storage battery system, refer to Manufacturer's Instructions.

1.2 Properly installed solar electric generator systems should only require regular maintenance visits once a year. Maintenance recommendations are given in Section 4.1.

1.3 If any trouble does develop, Sections 3.0 and 4.0 give complete test, troubleshooting, and repair procedures. If additional help is required, contact the Technical Service Department at Solar Power Corporation.

2.0 UNPACKING AND ASSEMBLY INSTRUCTIONS

2.0.1 Because the arrays may be anchored to different types of mounting surfaces, the customer is expected to supply mounting hardware.

2.0.2 If the total array consists of more than one frame, repeat all instructions for each frame.

2.1 UNPACKING AND ASSEMBLY - ARRAYS WITH TELESCOPING LEGS

2.1.1 Open the crate. Remove the layer of packing material and any other hardware or items that are on top of the array.

2.1.2 Lift the array out of the crate and hold it nearly vertical or place it on the ground, front module surface facing up. DO NOT PUT THE ARRAY ON THE GROUND FACING DOWN.

2.1.3 Unbolt the mounting feet from the leg sections. Retain this hardware and all other hardware removed in the following steps; it will be needed to assemble the legs and mounting feet to the array frame (reference Figure 1b).

2.1.4 Unbolt the two large leg sections (larger cross sectional area) from the bottom mounting brackets. Attach one mounting foot to one end of each of these leg sections as shown in Figure 1, Point C. It may be necessary to loosen the bolt holding the small leg to the top mounting bracket, thus allowing the leg to swing.

2.1.5 Attach the remaining two mounting feet to the bottom mounting brackets (the ones that do not have leg sections attached to them) as shown in Figure 1, Point D.

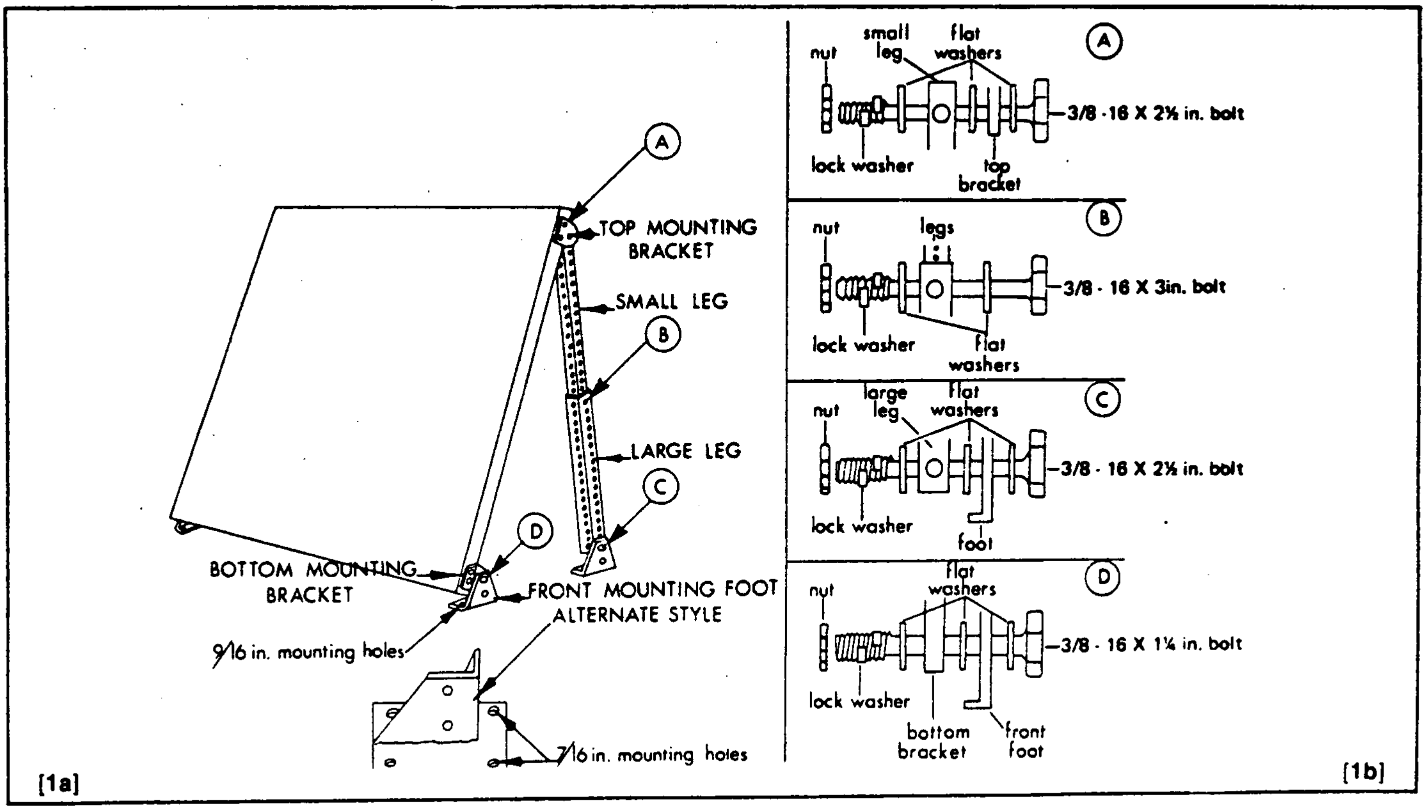
2.1.6 The array is now fully assembled and ready to be moved to its installation location and oriented. If the array must be disassembled or recrated, reverse the above procedure.

2.2 ORIENTING THE ARRAY - ARRAYS WITH TELESCOPING LEGS

2.2.1 When selecting a mounting location, make sure that the bottom of the array will be at least 3 feet (or 1 meter) higher than the maximum snow depth level.

2.2.2 IMPORTANT: THE ARRAY MUST BE ALIGNED SUCH THAT THE FRONT (MODULE) SURFACE DIRECTLY FACES DUE SOUTH (DUE NORTH IN THE SOUTHERN HEMISPHERE). WHEN USING A MAGNETIC COMPASS MAKE SURE TO CORRECT FOR THE LOCAL DIFFERENCE BETWEEN MAGNETIC DIRECTION AND TRUE DIRECTION. Anchor the front mounting feet once the array is aligned.

FIGURE 1

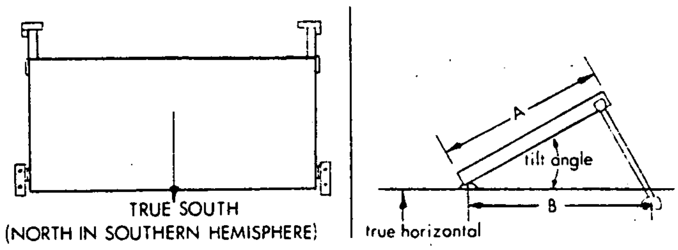


2.2.3 Anchor the legs' mounting feet to the mounting surface. It is best to make support spacing (B) equal to array dimension (A) (reference Figure 2b). Other positions may be used as necessary depending on the angle required and/or terrain considerations.

2.2.4 To set the tilt angle of the array, remove the long bolts anchoring the leg sections together (reference Figure 1, Point B) and adjust the length of the telescoping legs. The tilt angle of the array (the angle the array surface makes with a horizontal surface) should be adjusted to within 2 degrees of the specified angle. An inclinometer (adjustable angle liquid level) is most useful in measuring this angle, although, with care, a protractor and an ordinary bubble level may also be used. Reinsert the bolts and tighten.

2.2.5 Tighten all nuts and bolts.

FIGURE 2



[2 a] [2 b]

2.3 ATTACHMENT OF CABLES

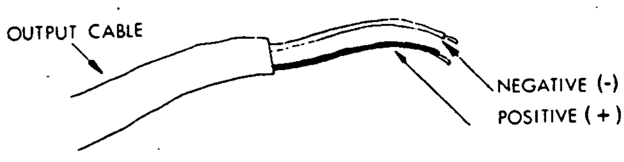
2.3.1 If a battery voltage regulator is included in the system or if one is added to the system, follow the instructions included with the regulator.

2.3.2 **Single Frame Arrays:** The output cable can be attached directly to the battery. Observe the correct polarity; black is positive, white is negative (reference Figure 4). If the polarity is accidentally reversed, no damage will result to either the array or the battery (assuming the battery is of the proper voltage for the array). However, if the polarity is left reversed for more than a few hours, the solar electric generator system will not function and the battery may become discharged.

2.3.3 **Multiframe Arrays:** Each frame is supplied with a separate output cable. Attach the output cable directly to the appropriate battery terminal (observe correct polarity).

2.3.4 After connecting cable(s) to the battery and connecting any required battery intercell connecting wires, protect all battery terminals from corrosion with a layer of grease.

FIGURE 3



3.0 TESTING

There are several tests that can be conducted to check system performance: Test 3-1 (Solar Array Performance), Test 3-2 (Blocking Diode Performance), Test 3-3 (Battery Self-Discharge). These can be performed either independently or in conjunction with the Troubleshooting Guide, Section 4.2.

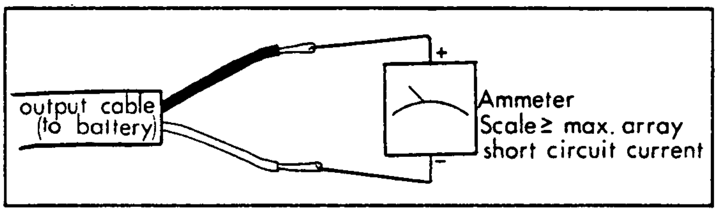
Upon installation, Test 3-1 (Solar Array Performance) should be conducted. Tests 3-2 and 3-3 should be performed if trouble occurs.

The annual maintenance visit can include the following simple check of the solar electric generator system performance. Measure the specific gravity of the battery electrolyte (for lead-acid batteries) with a standard battery hydrometer. Correct the readings to 77°F (25°C) using Table 3-1. Refer to Table 3-2 and relate the percent of battery capacity remaining to the corrected electrolyte specific gravity. If battery electrolyte specific gravity is low, refer to Section 4.2, Conditions 1 and 2.

TEST 3-1: SOLAR ARRAY PERFORMANCE

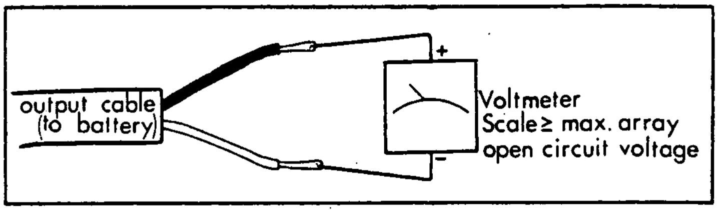
1. This test must be performed during the middle hours of a sunny day. The sun must be clearly visible with no thick haze present.
2. Disconnect array cable(s) or voltage regulator-battery cable from the battery terminals. If the system contains a regulator(s), disconnect regulator(s) following instructions provided with regulator(s) before proceeding to the next step.
3. Connect a suitable ammeter across the two disconnected cable leads (reference Figure 4). The ammeter's resistance should be such that the voltage drop across the ammeter is less than 0.3 volt. Adjust the tilt angle of the array to obtain the maximum current output as indicated by the ammeter.

FIGURE 4



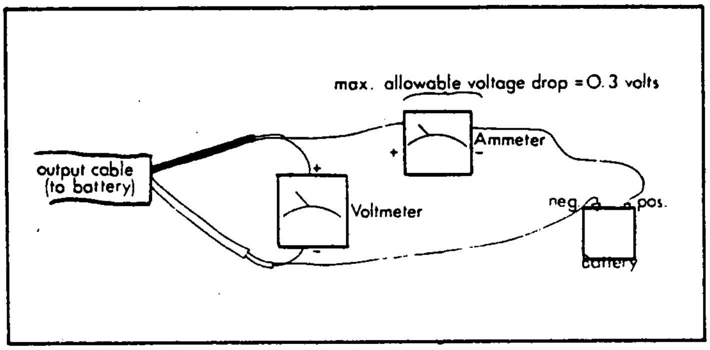
4. The ammeter current reading (short circuit current) should be approximately 70% of the 100mW/cm^2 short circuit current (listed under "Array Performance" on the front cover).
5. Disconnect the ammeter. Connect across the same cable leads (reference Figure 5) a voltmeter having an impedance of at least 1,000 ohms per volt. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the total number of solar cells in series (listed under "Array Performance" on the front cover).

FIGURE 5



6. Disconnect the voltmeter. Reconnect the negative lead to the battery. Connect an ammeter between the positive cable lead and the positive battery terminal (positive ammeter lead to the positive cable lead). Connect the voltmeter to the two cable leads (reference Figure 6). If this voltage is less than 2.2 volts times the number of series-connected lead-acid battery cells, the measured current should be at least 80% of the current measured in Step 4 (assuming sunlight conditions unchanged since Step 3).

FIGURE 6



7. For multiframe arrays this test procedure can be repeated for each individual array section by making these tests at each individual array cable termination. For each individual array section, disconnect the cable leads from the terminal block inside the external junction box and repeat Steps 3 through 6. The corresponding information for each frame is listed on the front cover of this manual (reference "Frame Performance").

8. If an array does not pass this test, refer to the Trouble-shooting Guide, Section 4.2.

TABLE 3-1

HYDROMETER READING CORRECTIONS TO 77°F

Electrolyte Temperature [°F]	Correction [add to reading]
140	+0.024
130	+0.020
120	+0.016
110	+0.012
100	+0.008
90	+0.004
80	+0.000
70	-0.004
60	-0.008
50	-0.012
40	-0.016
30	-0.020
20	-0.024
10	-0.028
0	-0.032
-10	-0.036
-20	-0.040
-30	-0.044
-40	-0.048

NOTE: The temperature of the electrolyte solution, not the ambient air temperature, should be measured with an immersion type thermometer. Some hydrometers have a thermometer and temperature correction scale built in.

TABLE 3-2

PERCENT OF 500 HOUR RATE CAPACITY REMAINING
vs.
ELECTROLYTE SPECIFIC GRAVITY (CORRECTED TO 77°F)

	Initial Electrolyte Specific Gravity		
	1.210	1.250	1.300
% Capacity Remaining	**Hydrometer Reading [Corrected to 77°F]**		
100	1.210	1.250	1.300
90	1.197	1.235	1.283
80	1.185	1.221	1.266
70	1.172	1.206	1.249
60	1.160	1.192	1.232
50	1.147	1.177	1.215
40	1.135	1.163	1.198
30	1.122	1.148	1.181
20	1.110	1.134	1.164
10	1.097	1.119	1.147
0	1.085	1.105	1.130

TEST 3-2: BLOCKING DIODE PERFORMANCE

1. This test must be performed either at night with no artificial light striking the array or with a black opaque cloth covering the entire array (reference Figure 7).

2. Disconnect the positive lead of the array cable(s) or the voltage regulator-battery cable from the battery terminals. Connect a milliammeter between this disconnected lead and the positive battery terminal (positive milliammeter lead to the positive battery terminal) (reference Figure 7). The current measured should be less than 4mA times the numbe of solar cells connected in parallel (listed under "Array Performance" on the front cover).

3. A current exceeding the above value indicates that the diode(s) has developed excessive reverse leakage current. If the array contains a diode mounted in a junction box, it should be replaced (reference Section 4.3). If the system includes a voltage regulator(s), refer to Regulator Manual for testing procedure. Otherwise, the diode(s) is located inside the module(s) and this test should be repeated for each module on the affected frame. Access to each module's leads may be obtained by removing the attached junction box cover. Disconnect the leads at the terminal block before starting the test. Remember that no light can strike the module's surface. Diodes located in the terminal box attached to the back of each module are sealed and cannot be replaced in the field. Any module that shows excessive reverse leakage current should be replaced (reference Section 4.3).

TEST 3-3: BATTERY SELF-DISCHARGE [LEAD-ACID BATTERIES]

NOTE: THIS TEST WILL REQUIRE REMOVAL OF THE BATTERY SYSTEM FROM THE ARRAY SITE.

1. Disconnect all cables from the battery terminals. Charge the battery or battery cell at a current rate not exceeding the battery's capacity in ampere hours divided by 20 hours (e.g., a 100-ampere hour battery would be charged at a current of 5 amperes or less). A standard battery charger should suffice for this purpose. Discontinue charging when the battery's terminal voltage exceeds 2.3 volts per series-connected battery cell.

2. Take a specific gravity reading of the electrolyte in each battery cell and record the corrected values (use Table 3-1 and an immersion thermometer).

3. Allow the battery to stand idle at room temperature for a week. At the end of the week take a second set of specific gravity readings. Compare with readings taken in Step 2. Corrected readings differing by more than 15 points (0.015) indicate a battery cell with excessively high self-discharge.

4.0 MAINTENANCE

4.1 REGULAR MAINTENANCE

(Yearly intervals recommended.)

4.1.1 Check battery electrolyte level. Replenish with distilled water, if necessary. When checking or adding to the battery electrolyte, the battery manufacturer's recommendations should be followed.

4.1.2 Check the module surface(s) for dirt buildup. Normal rainfall will usually be sufficient to provide for self-cleaning, if the array is tilted at 15° or more from the horizontal. However, if dirt buildup becomes excessive, either plain water or a mild detergent solution followed by a water rinse may be used. **DO NOT USE SOLVENTS OR STRONG DETERGENTS.**

4.2 TROUBLESHOOTING GUIDE

Most problems can be isolated with the aid of the following guide. If it is impossible to locate the problem, please contact the Technical Service Department at Solar Power Corporation for assistance.

CONDITION 1	**Other Symptoms**
Battery electrolyte specific gravity low [lead-acid batteries]	Specific gravities of all battery cells differ no more than 20 points (0.020)

Checks and Repairs

1. Check all battery electrical connections for corrosion and mechanical soundness. Clean and/or repair.
2. Check to see if there are any obstructions that shadow any portion of the array during any part of the day. If this condition exists, either the obstruction must be removed or the array must be moved to an unobstructed location.
3. Check the orientation of the array. Make sure it is facing directly due south (north in the southern hemisphere) and the tilt angle is correct (reference Section 2.2 or 2.3).
4. Check the load current. Calculate the equivalent number of amp hours per day required by the load. Compare this calculation against the design load listed under "Installation Data" on the front cover. If the measured load exceeds the design load, contact the Technical Service Department at Solar Power Corporation. Each solar electric generator system is designed for a specific load. Deviations from that load may result in unsatisfactory operation.
5. Check the solar array output by following the instructions in Test 3-1. Refer to Conditions 3, 4, 5, or 6 (Section 4.2) as necessary.
6. Check the blocking diode(s) by following the instructions in Test 3-2.
7. Check for high battery self-discharge by following the instructions in Test 3-3. If the battery or part of the total battery system fails this test, replace the defective battery cell(s).

CONDITION 2	**Other Symptoms**
Same as Condition 1	Specific gravity of only one or a few battery cells low

Checks and Repairs

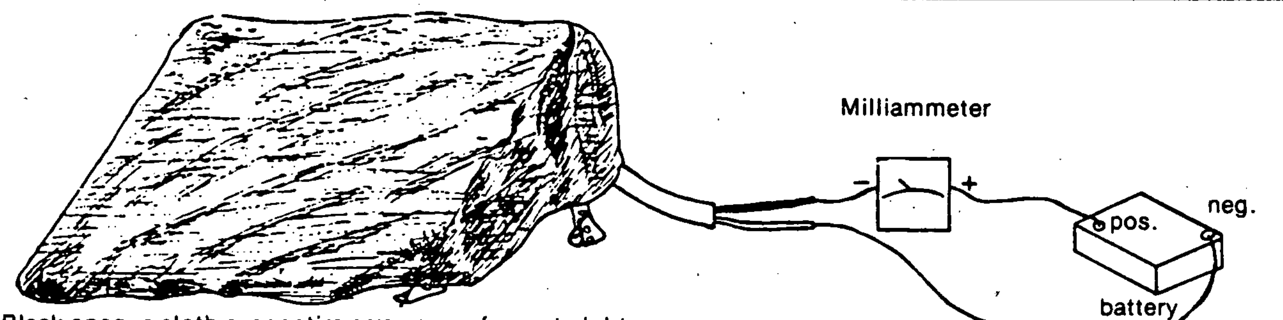
1. Check for excessively high electrolyte level. If so, shelter battery to prevent rain from entering through the vent hole(s).
2. Check the affected cells for high battery self-discharge by following the instructions in Test 3-3. Replace battery cell or battery containing bad cell.

CONDITION 3
Array open circuit voltage equal to zero [from Test 3-1]

Checks and Repairs

1. Single Frame Arrays:
   (a) If the array consists of only one module, that module must be replaced (reference Section 4.3).
   (b) If the array consists of more than one module, remove the cover of the junction box mounted to the back of the array. With the output cable disconnected from the battery terminals, test for voltage at the individual module leads. If voltage is present, there are bad contacts. At the terminal block, or the crimp connectors attached to the output cable are not making contact to the wire, or the output cable's conductors are broken. Clean all connections. Test crimp connectors by pulling on wires. Recrimp or attach wire directly to terminal block if necessary. Test the cable with an ohmmeter or continuity tester. Replace output cable if it is an open circuit.
2. Multiframe Arrays:
   (a) Remove junction box cover. Check for loose connections at the terminal block. Tighten if necessary.

FIGURE 7



Black opaque cloth over entire array or perform at night with no light shining on array.

(b) Test for voltage at the individual array cable terminations. If voltage is present there, proceed to Step 2 (c). If no voltage is present at any of the cable terminations, each array section must be checked individually as described in Step 1(b).

(c) Make sure that at least one lead of the battery cable is disconnected from the battery terminals. Connect a jumper wire between any positive array cable terminal and the positive battery cable terminal. If voltage is now present at the battery cable leads, and there is a blocking diode within an external junction box, either the blocking diode is defective or one of the wires connecting the diode to the terminal block is broken. Detach the plate on which the terminal block is mounted by removing the four corner screws. The blocking diode is located beneath the plate. Inspect for any broken wires and if none are found, replace the diode (reference Section 4.3).

(d) Check the continuity of the battery cable with an ohmmeter or continuity tester. Replace output cable if it is an open circuit.

CONDITION 4

Array open circuit voltage low [from Test 3-1]

Checks and Repairs

1. Check that the voltmeter's resistance is greater than 1,000 ohms per volt, that the sun is clearly visible, that there is no thick haze blocking the sun, and that the array is aimed towards the sun.

2. Single Frame Arrays:
   (a) If the array consists of only one module, that module should be replaced (reference Section 4.3).

2. (b) If the array consists of more than one module, remove the cover of the junction box mounted in the back of the array. Disconnect the cable leads from each module. Test each module individually for low open circuit voltage. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the number of solar cells in series (listed under "Module Performance" on the front cover). Any module that does not pass this test should be replaced (reference Section 4.3).

3. Multiframe Arrays: Disconnect the array cables from the terminal block in the external junction box or from the battery terminals. Check the open circuit voltage at each individual cable pair of wires to isolate the affected array section. The voltmeter reading (open circuit voltage) should be greater than 0.48 volt times the number of solar cells in series (listed under "Array Performance" on the front cover). To locate the defective module in the array section isolated above, follow the instructions in Step 2(b).

CONDITION 5

Array short circuit current low [from Test 3-1]

Checks and Repairs

1. Check for dirt buildup on any module or portion of a module. Clean according to Section 4.1.2.

2. Check for condensation, snow, or ice on module or any portion of a module. Wipe clean.

3. Check for shading of any module or portion of a module. Retest after removing obstruction.

4. Make sure array is aimed directly at the sun. Retest after correcting tilt.

5. Single frame arrays or when the problem is isolated to a single array frame (reference Step 6): Remove the attache junction box cover. Test each individual module for shor circuit current as described in Test 3-1, Steps 3 and 4. Compare these values to the short circuit current values listed on the front cover under "Module Performance". Replace any module (reference Section 4.3) which fails Test 3-1. Make sure all connections in the junction box are tight and clean.

6. Multiframe Arrays: Perform Test 3-1 for each array sectic (cable) to determine the faulty section. Check for any loose terminals or broken wires within an external junction box. Also check all connectors, if any, for corrosion and tight mating of the male and female contacts. Clean or replace as necessary.

CONDITION 6

Excessive difference between array short circuit and battery charging current [from Test 3-1]

Checks and Repairs

1. Check for corrosion at the battery terminals. Clean terminals and cable leads. Retest.

2. If the array has a junction box(es) (either internal or external), remove the cover(s) and inspect for corrosion on all electrical connections within the box. Clean or replace damaged components. Retest.

3. Test each module individually as described in Steps 3, 4, and 6 of Test 3-1. Compare these values to the short circuit current values as listed on the front cover under "Module Performance". Replace any module(s) that fail Test 3-1 (reference Section 4.3).

4.3 MODULE AND DIODE REPLACEMENT

When it has been determined that a module or a blocking diode needs replacing, proceed as follows:

4.3.1 Replacement of Module

(a) Remove cover of junction box attached to array frame.

(b) Disconnect at the terminal strip the cable leads of the module being replaced.

(c) Loosen the threaded gland of the cable fitting through which the module cable enters the junction box. Pull the end of the cable out of the junction box.

(d) Remove the nuts and bolts holding the module onto t! array frame. Lift off the module; save the hardware removed.

(e) Insertion of Replacement Module:
Reverse the removal procedure; (a) through (d) above.

4.3.2. Replacement of Blocking Diode Located in Junction Box

(a) Disconnect battery cable at battery terminals.

(b) Remove the junction box cover and the metal plate on which the terminal block is mounted. Loosen or remove cable leads from the terminal block, if necessary.

(c) The diode will usually be mounted on a heat sink. Make a sketch showing which lead goes to which terminal and how the hardware is assembled. Unsolder the leads to the diode. Remove the diode.

(d) Insert the new diode (exact same number as the diode being replaced). Take care to replace the hardware in the same order as was on the removed diode.

(e) Solder the leads to the new diode. Take care that the leads go to the same terminals as on the removed diode. (Array positive lead to anode; battery positive lead to cathode.)

(f) Replace the metal plate and the junction box cover.

(g) Reconnect the battery cable to the battery terminals.

4.3.3. Replacement of Blocking Diode Located in Module

A blocking diode within the module cannot be replaced in field. The module should be removed from the array frame (reference Section 4.3.1, a-d) and returned to Solar Power Corporation for repair.

5.0 TOOLS AND EQUIPMENT

5.1 INSTALLATION & MAINTENANCE TOOLS

Ratchet Handle (3/8" or 1/2" drive)
6" Extension
1/2" Socket and Wrench
9/16" Socket and Wrench
7/16" Socket and Wrench
3/4" Socket and Wrench
Screw Drivers (1/8" to 1/2" wide)
Slip Joint Pliers (1½" diameter grip)
Locking Pliers
Crimping Tool (VACO 22-10 or equivalent) and assorted crimp terminals
Wire Strippers
Diagonal Cutters (medium)
Compass (magnetic)
Inclinometer

5.2 TESTING EQUIPMENT

Simpson 260 VOM (or equivalent)
Immersion Thermometer
Battery Hydrometer

☆ U.S. GOVERNMENT PRINTING OFFICE: 1980—640-247/130 REGION NO. 4