ERDA/NASA/31293/76/3

Distribution Category UC-59C

LISTING OF

SOLAR RADIATION MEASURING EQUIPMENT

AND GLOSSARY

July 1976

by

E. A. Carter
S. A. Greenbaum
A. M. Patel

CENTER FOR ENVIRONMENTAL
AND ENERGY STUDIES
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prepared for:

THE UNITED STATES ENERGY RESEARCH
AND DEVELOPMENT ADMINISTRATION
DIVISION OF SOLAR ENERGY
UNDER CONTRACT NAS8-31293

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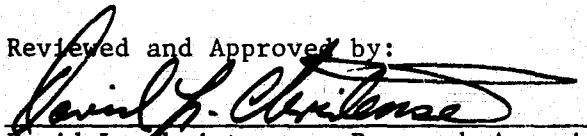

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FOREWORD

This document presents the results of research activities performed by the Center for Environmental and Energy Studies, The University of Alabama in Huntsville, Alabama as Task 3 under Contract NAS8-31293, George C. Marshall Space Flight Center. Mr. O. L. Smith is the NASA/MSFC Technical Coordinator for this task. Mr. William Reid is the UAH Task Team Leader. Mr. David L. Christensen is the Principal Investigator of the contract entitled "Solar Heating and Cooling Technical Data and Systems Analysis".

ACKNOWLEDGEMENT

The help and cooperation from many organizations listed herein is hereby acknowledged. The willing support of the many individuals who provided information for this report is appreciated, particularly the support of Mr. David Reese of the Wyle Laboratories, Huntsville, Alabama; Mr. Fred Koomanoff and Mr. Michael Riches of the ERDA Division of Solar Energy; Mr. Edwin Flowers of the NOAA, Boulder, Colorado; and Mr. Frank Quinlan of the National Climatic Center, Asheville, North Carolina.

TABLE OF CONTENTS

I. INTRODUCTION

The Center for Environmental and Energy Studies at The University of Alabama in Huntsville has performed various research projects to compile information pertaining to solar energy resources, equipment, and environmental data. This project, sponsored by the NASA Marshall Space Flight Center and the Energy Research and Development Administration (ERDA) was designed to locate and describe solar radiation measuring equipment as a three-month task under NASA Contract NAS8-31293.

One immediate need for researchers and other users of solar energy conversion equipment is to select proper instruments for measuring solar radiation. Hence it is the intent of this report to serve as a reference guide so the user can compare performance, accuracy, and cost of equipment presently on the market based on the data provided by the manufacturer. It also provides relevant terms and diagrams for the prospective user of solar radiation instruments. This report updates and expands a preliminary report by R. S. Bell of the UAH Center for Environmental and Energy Studies published in May 1976. Initially, the preliminary list of those companies which currently manufacture radiation measuring equipment was presented to the National Solar Energy Workshop in Huntsville, Alabama (May 19-21). The list was incomplete at that time; however, it was well received and prompted considerable discussion as a "baseline" document.

In June 1976, the manufacturers included in the preliminary listing were contacted through a letter explaining the project and asking for the following specific information: 1) corrections to the listing; 2) additional equipment the manufacturer would like to have listed; 3) additional tests on the response, accuracy, calibration, etc. or other information to which the prospective user might be referred. Enclosed with the letter each manufacturer received a listing of their equipment (as presented in the preliminary report) which had been extracted from their catalog or other source.

Following this inquiry, an attempt was made to locate additional manufacturers of solar radiation measuring equipment not yet identified in the listing. A search for information concerning update quality tests also ensured. Through the use of scientific, industrial, and solar radiation periodicals, other manufacturers were identified and contacted.

The responses received from the thirty-eight manufacturers listed herein indicated their willingness to comply and numerous offers of additional services if needed. With their cooperation, the list and information presented in this document is substantially more complete.

II. ORGANIZATION

This report is organized to list and provide all available information about solar radiation measuring equipment which are being manufactured and are available on the market. The list is in tabular form and includes sensor type, response time, cost data and comments for each model. A cost code (see Table 1) has been included which shows ranges only, due to price fluctuations and because some manufacturers are reluctant to publish their prices. In some instances a price is given for a particular date, but this is subject to change at the manufacturer's or dealer's discretion.

Table 2 is an equipment vs. cost matrix for that equipment for which cost information is available. The numbers in the matrix refer to correspondingly numbered equipment items as shown in the equipment listings. These index numbers are not a part of the manufacturer's model number but are assigned by UAH for cross reference purposes only.

Figures 1 and 2 are diagrams of insolation and basic instruments used in the measurement of solar radiation.

A form has been designed (Attachment 1) to provide a complete profile and intended applications for each model of equipment on the market. This form was developed during the course of the research period to standardize and organize all pertinent data for potential use in a published catalog.

To further extend the information presented in the listing, an address list is provided as Attachment 3. Every manufacturer included in the equipment listing is identified with an appropriate address. Any additional information not included in the listing may be obtained by contacting the manufacturer.

During the course of this work it became apparent that the nomenclature of the equipment and selected words used required some descriptions. Therefore, a Glossary of Solar Radiation Terms frequently used with solar radiation measurement and equipment is included as Attachment 4. This glossary is intended as an aid in the introduction to solar radiation measurements and equipment.

III. CONCLUSIONS AND RECOMMENDATIONS

It is recommended that copies of this report be distributed to each manufacturer and dealer listed herein for any comments or additional information that may be necessary or desirable. Also, it is recommended that the report be distributed to other manufacturers or dealers that may make similar equipment and to researchers for comments.

It is recommended that the form (Attachment 1) be adopted as a standard data sheet to describe solar radiation measuring equipment and this research effort be expanded to further develop, organize, and disseminate all available information concerning solar radiation measuring equipment using this proposed format.

Further efforts are needed in establishing standardized terms and definitions related to solar radiation instruments and measurements, including clarification of some terms which have different meanings and improved diagrams to help in the visualization of the various instrument functions.

GENERAL REFERENCES

1. "Guide to Meteorological Instrument and Observing Practices". Chapter 9. Fourth Edition WMO-No. 8. TP. 3. World Meteorological Organization (1971).

2. "Solar Energy Data Workshop". National Science Foundation NSF-RA-N-74-062 (September 1974).

3. Kinsell L. Coulson, "Solar and Terrestrial Radiation - Methods and Measurements". Academic Press, New York (1975).

4. D. L. Christensen, E. Stuhlinger, "Executive Summary of the National Solar Energy Workshop - ERDA Division of Solar Energy and The State Energy Offices". The University of Alabama in Huntsville (July 1976)

TABLE 1 - COST CODE

This cost code provides a range in dollars for each of the instruments described in Table 2 and and Attachment 2.

SYMBOL	COST RANGE
F	Less Than $ 100
G	$ 101 - $ 200
H	$ 201 - $ 300
I	$ 301 - $ 400
J	$ 401 - $ 500
K	$ 501 - $ 750
L	$ 751 - $1000
M	$1001 - $2000
N	$2001 - $3000
O	More Than $3000

TABLE 2

SOLAR RADIATION INSTRUMENTS COST MATRIX*

TYPE OF EQUIPMENT \ COST CODE $ →	F <100	G 101-200	H 201-300	I 301-400	J 401-500	K 501-750	L 751-1000	M 1001-2000	N 2001-3000	O >3000
Pyranometer (thermopile)		27-1		13-1,19-6 24-2,28-1	7-19,18-2 19-2,19-5 27-2	5-1,5-2,12-2, 12-3,12-16, 18-1,27-11, 31-2,36-1	5-3,18-4, 27-12,31-1, 31-7,31-8	9-1,30-1		
Pyranometer (cavity)									34-1,34-3	
Pyranometer (others)	14-1,26-1,	17-3,27-8, 37-1, 17-6,	14-3,	1-1,	33-2,	17-1,27-10,		17-2,		
Pyrheliometer			17-4,17-5, 27-9,		7-16,7-20, 18-3,31-3,	7-17,12-4 31-4,31-5,	5-4,7-18, 27-14,	5-7,9-1, 13-3,27-19,		
Radiometer		28-4,		19-4,	12-5,12-7, 33-1,38-1,	6-2,13-2, 19-3,28-3, 36-3,	6-1,27-5 35-3,35-4,	5-6,5-8,6-3, 20-1,27-13, 27-18,		
Net Radiometer	27-4,	3-1,		3-3,27-3, 36-2,	3-2,	27-5,33-3,	27-7,			
Pyrgeometer			14-2,				31-6,35-1, 35-2	5-5, 27-17,		
Other		26-2,		27-16,	12-10,	27-15,	12-8,34-4,	36-4,		12-9

*Equipment for which cost is available (in U.S. dollars)

ATTACHMENT 1

PROPOSED TECHNICAL DATA FORM

Letterhead/Logo

Contact for further information:

Product Data

Model/Part No.

Instrument Classification

Desiccant

Sensor Type

Sensor Surface Coating

Development Status

	Yes	No
Prototype built & tested		
In production		

Production Capacity (monthly)

Performance Data

Sensitivity (mV/Joule-cm^{-2}-min.$^{-1}$)

Stability (%/year)

Impedance (ohm)

Spectral Range (μm)

Time Response (sec)

Temperature Dependence (%/°C)

Linearity (%)

Cosine Response (%)

Calibration Accuracy (%)

Recalibration Schedule (months)

Application Data

	Global Solar	Diffuse Solar	Spectral Solar	Direct Solar	Solar & Infrared	Infrared	Net
Horizontal							
Tilted							

Economic Data

As of Date _____ Cost ($/unit)

Recalibration Cost ($/unit)

Warranty (months)

Delivery time (days)

Comments

QUESTIONNAIRE INSTRUCTIONS

1. **CODE:** In the upper right hand corner of the form in the box provided, do not type anything.

2. **LETTERHEAD/LOGO:** In the space provided, attach a camera-ready mechanical of company or institution letterhead or logo. This letterhead logo must include the name, division, and mailing address. The left-hand edge of the mechanical should align with the left-hand guide line.

3. **CONTACT FOR FURTHER INFORMATION:** In the space provided type the name of the person or office, telephone number, and mailing address to be contacted for further information.

4. **PRODUCTION DATA:** In the space provided, type answers to questions listed:

   a. **Model/Part No.:** Model or part number of the product on list of company or institution.

   b. **Classification of the instrument:**

      1. **Pyrheliometer:** An instrument for measuring the intensity of direct solar radiation at normal incidence.
      2. **Pyranometer:** An instrument for the measurement of the solar radiation received from the whole hemisphere.
      3. **Pyrgeometer:** An instrument for the measurement of net atmospheric radiation on a horizontal upward facing black surface at the ambient air temperature.
      4. **Pyrradiometer:** An instrument for the measurement of both solar and terrestrial radiation (total radiation).
      5. **Net Pyrradiometer:** An instrument for the measurement of the net flux of downward and upward total (solar, terrestrial surface and atmospheric) radiation through a horizontal surface.

   c. **Desiccant:** Material used in the built-in desiccator of the product.

   d. **Sensor Type:**

      1. **Calorimeter**
      2. **Thermocouples or thermopiles**
      3. **Bimetallic**
      4. **Photovoltaic, photoconductive or photo-emissive cells**
      5. **Black body**
      6. **Pyroelectric cell**
      7. **Others (specify)**

   e. **Sensor surface coating:** coating applied on the surface of the sensing element.

5. **DEVELOPMENT STATUS:** In the column provided, check-mark "yes" or "no" to the following (a) and (b) questions, and in the space provided type answer to question (c):

   a. **Prototype built and tested:** A full-scale working prototype has been built, tested in use and test results are available.

   b. **In production:** Company is currently manufacturing product described.

   c. **Production capacity:** Maximum number of product described that can currently be produced per month with existing plant capacity.

6. **PERFORMANCE DATA:** In the space provided, type answers to the questions listed:

   a. **Sensitivity (mV/Joule cm^{-2}-min^{-1}):** Absolute change in the output (millivolts), per unit change in the input (Joule - cm^{-2} -min^{-1}) of the product described.

   b. **Stability (%/year):** The stability of the calibration, i.e., the maximum permissible change in this factor per cent per year.

   c. **Impedance (ohm):** Impedance (ohm) of the product described.

   d. **Spectral Range (μ m):** The upper and lower radiation wavelengths (micro-meter) that product can detect.

   e. **Time Response (seconds):** Maximum time (seconds) taken by the product described to respond.

   f. **Temperature Dependence (%/°C):** The maximum error (%/ °C) due to variation in ambient temperature.

   g. **Linearity (%):** The maximum error (%) due to the non-linearity of the response of the product described when this is assumed linear.

   h. **Cosine Response (%):** The deviation (%) of the directional response of the product described from that assumed cosine response.

   i. **Calibration Accuracy (%):** Amount (%) of response of the product described varies from the calibration standard.

   j. **Recalibration Schedule (months):** Time period (month) after which the product described needs to recalibrate.

7. **APPLICATION DATA:** In the matrix provided, check mark the space for which product described is applicable in horizontal position and state the angular limit in degrees for which product described is applicable in tilted position.

   Radiation

   a. **Global Solar:** Global solar radiation received on a horizontal surface direct from the solid angle of the sun's disk and also radiation that has been scattered or diffusely reflected in traversing the atmosphere.

   b. **Diffuse Solar:** Downward scattered and reflected solar radiation, coming from the whole hemisphere with the exception of the solid angle subtended by the sun's disk.

   c. **Spectral Solar:** Radiation of selected wavelengths of the solar radiation.

   d. **Direct Solar:** Solar radiation coming from the solid angle of the sun's disk on a surface perpendicular to the axis of this cone, comprising mainly unscattered and unaffected solar radiation.

   e. **Solar Infrared:** Global solar and infrared.

   f. **Infrared:** Radiation with wavelength greater than 0.8 micron and less than 1 millimeter.

   g. **Net:** Net radiation is the difference between downward and upward (total and terrestrial) radiation, net-flux of all directions.

8. **ECONOMIC DATA:** In the space provided, type answers to questions listed:

   a. **Cost ($/unit):** The updated cost ($/unit) of the product described.

   b. **Recalibration Cost ($/unit):** The updated cost ($/unit) to recalibrate the product described.

   c. **Warranty (months):** The time period (months) during which the product described is under warranty after the date of purchase.

   d. **Delivery time (days):** The time period (days) required to deliver the product described after receiving the order.

9. **COMMENT:** In the space provided, type comments for the product described.

ATTACHMENT 2

EQUIPMENT LISTING

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
1-0.	**Belfort Instrument Company**					
1-1.	5-3850A	Pyranograph	Two Rhodium-plated Bimetallic Strips	Time Constant 5 minutes	I ($375; 7/76)	Independent of external power source; Chart sets available. Dome made of borosilicate glass, Sensitivity: 0.1gm-cal/sqcm-min, for 3/32" of chart width, Accuracy: within ± 5% of value recorded or ± 0.05 gm-cal/sqcm-min, whichever is greater, Total range is 3 gram calories per cm^2/min.
2-0.	C. F. Casella Company, Ltd.					
2-1.	W6300 (Bimetallic Actinograph)	Pyranograph	Bimetallic Strip			Designed by the British Meteorological Office; Bimetallic strip is supported at one end only, The movements of the free end are magnified by mechanical linkage and recorded by means of a moving arm and pen on a drum which rotates once a day.
3-0.	C. W. ThornThwaite Associates					
3-1.	601	Miniature Net Radiometer	Thermopile (Spherical covering, 5cm in diameter)		J ($495; 7/76)	Typical output: * 25mV per g-cal per sq. cm. per minute; resistance: * 4 ohms

*Note: Figures given are nominal; individual calibration constants are provided with each instrument

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
3-2.	603	Net Radiometer	Thermopile (Spherical covering, 5cm in diameter)	Time constant, 3.3 seconds	J ($495; 7/76)	Range: -1.0 Ly/min. to +2 Ly/min. (one Ly = one g-cal per sq. cm). Readout Resolution: 0.02 Ly/min. per division (can be read to 0.005 Ly/min.)
3-3.	605	Miniature Net Radiometer	Thermopile		I ($335 7/76)	Typical output: * 3.5 mV per g-cal per sq. cm. per min. Resistance: 70 ohms
4-0.	EKO Inst. Trading Company, Ltd.					
4-1.		Pyranometer	Thermopile (Moll)	99% in 7-8 seconds		
4-2.		Pyranometer	Thermopile	99% in 45 seconds		Bulb type, black and white rings. Single dome.
4-3.		Pyranometer	Thermopile	99% in 20 seconds		Star type. Single dome.
5-0.	Eppley Laboratory Inc.					
5-1.	8-48	Pyranometer	Thermopile	99% in 3-4 seconds	K	Star type; alternate black & white wedge-shaped segments. Single dome.
5-2.	8-48A	Pyranometer	Thermopile	99% in 3-4 seconds	K	Lower sensitivity (3.5 microvolts per watt meter^{-2})

*Figures given are nominal; individual calibration constants are provided with each instrument

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
5-3.	PSP	Precision Spectral Pyranometer	Thermopile	99% in 1 second	L	Parson's black receiver, double dome with Schott optical glass available; measures total sun and sky radiation in wavelength band
5-4.	NIP	Normal incidence Pyrheliometer	Thermopile	99% in 1 second	L	Thermoelectric version of Smithsonian Silver Disk Pyrheliometer.
5-5.	PIR	Precision infrared Radiometer (Pyrgeometer)	Thermopile	99% in 2 seconds	M	Single dome, Spectral range: 4-50 micrometers
5-6.	KAR	Kendall Absolute Radiometer	Thermopile		M	Measures spectral range of .2-50 micrometers at intensities of 10-200 mw cm^{-2}
5-7	ANG	Angstrom	Electrical Compensating		M	Primary working standard for calibration of pyrheliometers and pyranometers (electric compensation)
5-8.	TUVR	Ultra-violet Radiometer (Photometer)	Photoelectric cell	Milliseconds	M	Measures UV under low light levels and conditions of minimum electrical current drain
6-0.	Gamma Scientific, Inc.					
6-1.	820	Radiometer/ Photometer	Receptor Detector Heads (with silicon cell)		L ($840 3/76)	Measures up to 1.1 microns; analog output provided in all receptor detector heads

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
6-2.	900	Radiometer/ Photometer	Receptor Detector Heads (with silicon cell)		K ($585; 3/76)	Operates from self-contained batteries. Analog output is provided in all receptor detector heads
6-3.	CR-1	Computing Radiometer	Photomultiplier Assembly		M	Contains integral microprocessor which simultaneously controls the radiometer and processes its output
7-0.	Hy-Cal Engineering					
7-1.	P-8400-B	Pyrheliometer	Thermopile			Considered by the manufacturer as a prime standard. Quartz window, water-cooled; Range: 0-10 Solar Constant (S.C.); Output: 5mV/S.C.
7-2.	P-8400-D	Pyrheliometer	Thermopile			Quartz window. Identical to P-4800-B, except no provision for water cooling; mounting adaptor provided so that instrument may be bolted to water cooled structure or pipe; Range: 0-10 S.C. Output: 5mV/S.C.
7-3	P-8400-E	Pyrheliometer	Thermopile			Similar to P-8400 B except for special corrective window. Range: 0-10 S.C. Output: 5mV/S.C.
7-4.	P-8400-F	Pyrheliometer	Thermopile			Similar to P-8400-B only Type "T" (copper/constantan) thermocouple used; Range: 0-10 S.C. Output: 5mV/S.C.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
7-5.	P-8400-H	Pyrheliometer	Thermopile			Identical to P-8400-E except it can be used for higher solar fluxes above 10 S.C. Range: 0-10 S.C. Output: 5mV/S.C.
7-6.	P-8400-J	Pyrheliometer	Thermopile			Identical to "P" model except it can be used for higher solar flux above 10 S.C. Range: 100 S.C. maximum Output: 5mV/S.C.
7-7.	P-8400-P	Pyrheliometer	Thermopile			Incorporates all features of P-8400-B; Long term stability for suggested use as prime standard; Range: 0-10 S.C. Output: 5mV/S.C.
7-8.	P-8403-A	Pyrheliometer	Thermopile			Quartz window. Normal incident; removable transducer for use as wide angle pyrheliometer. No water-cooling. Range: 0-10 S.C. Output: 5mV/S.C. Identical in all respects excepting company logo to Item 12-4.
7-9	P-8405-A	Pyranometer	Thermopile			2" diameter Pyranometer overall height 1.75"; single glass hemispherical dome permanently sealed to withstand temperature range from 150°F to 300°F. Range: 0-10 S.C. Output: 5mV/S.C. Identical in all respects excepting company logo to Item 12-3.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
7-10.	P-8405-B	Pyranometer	Thermopile			Like P-8405-A only 20mV/ solar constant sensitivity; Range: 0-10 S.C.
7-11.	P-8405-D	Pyranometer	Thermopile			Like P-8405-A only 10mV/ solar constant Sensitivity; Range: 0-10 S.C.
7-12.	P-8406-A	Pyrheliometer	Thermopile			Model P-8410-A sensor with set of three water-cooled restricted viewing cones; Range: 0-10 S.C. Output: 10mV/S.C.
7-13.	P-8410-A	Pyrheliometer	Thermopile			10mV/solar constant sensitivity; quartz window. Identical in construction to P-8400-B; water-cooled; Range: 0-10 S.C.
7-14.	P-8410-B	Pyrheliometer	Thermopile			Like P-8410-A; 40mV/solar constant sensitivity, quartz window. Water-cooled Range: 0-10 S. C.
7-15.	P-8410-E	Pyrheliometer	Thermopile			Like model P-8410-B except with integral Type "T" (copper/constantan) thermocouple; Range: 0-10 S.C. Output: 40mV/S.C.
*7-16	P-3400-B-SS-120	Pyrheliometer	Thermopile		J ($425; 5/76)	Water cooled. Quartz window. Output: 5mV/S.C. Identical to Item 7-1.
*7-17	P-8403-B-SS-120	Pyrheliometer	Thermopile		K ($650; 5/76)	Normal incidence, water cooled. Quartz window.

*Identical to 7-1 and 7-8; SS are code numbers to designate S.C. range.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
7-18	P-8403-C-SS-120	Pyrheliometer	Thermopile		L ($850; 5/76)	Normal incidence, water-cooled. 4-position rotatable disc filter holder
7-19	P-8405-A-SS-120	Pyrheliometer	Thermopile		J ($475; 5/76)	5mV/S.C. sensitivity Identical to Item 7-9.
7-20	P-8410-A SS-120	Pyrheliometer	Thermopile		J ($495 5/76)	Water cooled, removable bezel. Identical to Item 7-13.
8-0.	Herbert A. Groise and Company					
8-1.		Pyranometer	Thermopile	5.6 seconds		
9-0.	IBM					
9-1.	Sunfall Monitor	Pyranometer Pyrheliometer	Thermopile		M	Integrated system with digital readout. Sun tracking constructed for remote area operation. Sensors are made by Eppley Laboratory.
10-0.	International Scientific Industries					
10-1.		Pyranometer	Thermopile	1 second		Hermetically sealed with dry air.
11-0.	Ishikawa Trading Company					
11-1.	ICM-4S	Calorimeter	Thermopile			
11-2.		Pyranometer	Thermopile	90% in 30 seconds		Bulb type, black and white rings. Single dome.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
12-0.	Kahl Scientific Instrument Corp. *					*Note: Kahl Scientific manufactures the Solar Radiation Measuring Devices distributed by: GM Manufacturing & Instrument Corp., P.O. Box 947, El Cajon, Calif., 92022.
12-1.	23AM300	Research Photometer	Selenium Photovoltaic cell			Sensitivity: 0.01ft/cdl or 0.1 Lux Range, (dual scale): 0 to 12,000 ft/cdl or 0 to 12,000 Lux; and 0 to 3.6
12-2.	28AM100	Pyranometer	Thermopile	30 seconds	K ($560; 7/76)	Star type. Single dome.
12-3.	28AM500	Pyranometer	Thermopile	63% in 500 Milliseconds	K ($520;	Copper-Constantan thermocouples. 5mV/S.C. Single dome. Identical to Item 7-9
12-4.	28AM520	Pyrheliometer	Thermopile		K ($680; 7/76)	Identical to Item 7-8
12-5.	28AM510	Radiometer	Thermopile	250 milliseconds	J ($450; 7/76)	Usable as a prime standard according to manufacturer. Quartz window.
12-6.	28AM505	Pyranometer	Thermopile		K ($555; 7/76)	Similar to 28AM510 only greater sensitivity, 10 mV/S.C.
12-7.	29AM100	Pyrradiometer	Thermopile		J ($450; 7/76)	Two round copper discs with highly sensitive thermopiles attached to one side.
12-8.	01AM100	Pyranometer	Bimetellic strips	Radiance variation c. 30% in 90 seconds	L ($835; 7/76)	Strip pigments have special coating to inhibit reactions, helps stabilize calibration

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
12-9.	30AM100	Universal Radiation Meter	Moll-gorczynski		O ($3575; 7/76	Two ranges provided
12-10.	35AM100	Universal Sunshine recorder	Spherical glass lens which concentrates solar radiation to burn a trace on paper charts	Instantaneously recorded	J	White chart markings; gray cardboard charts assure constancy in burning rate with minimum physical change due to moisture
12-11.	35AM120	Sunshine recorder	Spherical glass lens which concentrates solar radiation to burn a trace on paper charts	Instantaneously recorded		Pedestal is affixed directly to the platform
12-12.	35AM140	Sunshine recorder	Spherical glass lens which concentrates solar radiation to burn a trace on paper charts	Instantaneously recorded		Similar to 35AM120 but does not have the leveling adjustment and platform; pedestal is permanently secured to mounting plate

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
12-13.	35AM160	Polar sunshine recorder	Two glass spheres with arc supports and pedestals mounted 180° apart	Instantaneous recorder		Designed for measurement between 60° and 90° Latitude when more than 13 hours of sunshine occur.
13-0.	Kipp-Zonen					
13-1.	Solarimeter	Pyranometer	Thermopile (Moll)	99% in 30 seconds	I	Double dome
13-2.	Albedometer	Pyrradiometer	Thermopile (Moll)	99% in 30 seconds	K	Measures insolation and radiation reflected from surface
13-3.	Actionmeter	Pyrheliometer	Thermopile (Moll)	99% in 21 seconds	M	Quartz window with available filters
14.0	Lambda Instrument Corporation					
14-1.	LI-200S	Pyranometer	Silicon cell	10-90% in 10 microseconds	F	Without glass dome. Spectral response about 400-1200 NM.
14-2.	LI-212S	Pyrgeometer	Silicon Photodiode	10-90% in 10 microseconds	H	Suitable for underwater use. Spectral response adjusted to the CIE standard observer spectral curve; 400-700 NM.
14-3.	LI-220S	Pyranometer	Silicon cell		H	Spectral sensitivity in 70 NM Band centered at 780 NM.
15.0	Lintronic Limited					
15.1	Solarimeter	Pyranometer	Thermopile	66% in 20 seconds	G	Frosted glass dome. Monteith design.
16-0.	Mashpriborintorg					
16-1.		Pyranometer	Thermopile	Less than 40 seconds		Black and white squares. Single dome. Also called Yanishevsky pyranometer.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
17-0.	Matrix, Inc.					Note: All Matrix Solar Radiation Measuring Instruments are calibrated for the entire solar spectrum by comparison with Thermopile type Radiometers
17-1.	MK14E	Pyranometer	Silicon cell	100% in 1 millisecond	K ($695; 2/76)	Integrating, self-contained; special filters available. Uses MK 1-G pyranometer.
17-2.	MK18E	Pyranometer	Silicon Cell	100% in 1 millisecond	M ($1075; 2/76)	Net short wave radiometer version of MK14E
17-3.	MK1-G	Pyranometer	Silicon Cell	100% in 1 millisecond	G ($195; 2/76)	Special filters available. 50 mV/Cal-Cm^{-2}-Min^{-1}
17-4.	MK1-RF	Pyrheliometer	Silicon Cell	100% in 1 millisecond	H ($280; 2/76)	Aperture angles easily varied. Short wave and albedo. Filters available.
17-5.	MK3	Pyrheliometer	Silicon Cell	100% in 1 millisecond	H ($295; 2/76)	Constructed with an internally baffled and blackened 10-inch collimating tube with 5.7^{o} aperture. 25 mV/Cal-Cm^{-2}-Min^{-1}
17-6.	MK6	Pyranometer	Silicon Cell	100% in 1 millisecond	G ($195;	Highly portable instrument for quick measurement from horizontal, vertical, or other surfaces directly.
18-0.	Medtherm Corporation					
18-1.	256-012-"YYY" - 20287	Pyranometer	Schmidt-Boelter Thermopile	(63%) 3-4 seconds	K ($510; 5/74)	Sensor will withstand severe shock and vibration to 22g's.
18-2.	160-012-"YYY" - 20283	Pyranometer	Thermopile	Approximately 1 second	J ($430; 5/74)	Quartz hemispherical dome.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
18-3.	FDTW-024-20020	Pyrheliometer	Thermocouple, cu/c, lead-wire, metallic braid	Approximately 1 second	J ($425; 5/74)	Cooling water requirements recommended for 0.1 GPM at 45°F. to 120°F. Removable sapphire window attachment.
18-4.	256-012-072-20286	Pyranometer	Circular 1cm^2 Thermopile (Schmidt-Boelter type)	(63% Approximately 1 second	L ($910; 5/74)	Calibration supplied referenced to the international pyrheliometric scale.
19-0.	Middleton and Co. Pty., Ltd.					
19-1.		Net Pyrradiometer	Thermopile			Double dome-gas supply Dew compensator
19-2.	Solarimeter CN1	Pyranometer	Thermopile		J ($460; 4/75)	Double dome-pressure changes compensated for stationary unit.
19-3.	SolariAlbedometer CN9	Pyrradiometer	Thermopile		K ($600; 4/75)	
19-4.	Albedometer CN8	Pyrradiometer	Thermopile		I ($360; 4/75)	Measures terrestial radiation only.
19-5.	CN2	Pyranometer	Thermopile		J ($420; 4/75)	Portable unit.
19-6.	CN6	Pyranometer	Thermopile		I ($400; 4/75)	Miniature model.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
20-0	Molectron Corp.					
20-1.	PR-200	Pyroelectric Radiometer	Pyroelectric Element (Sensitivity .2 cm^2)	@ 2 Microwatts Fast response 10 seconds Slow response 100 seconds @ 20 Microwatts Fast response 3 seconds Slow response 100 seconds @ 200 Microwatts Fast response 2 seconds Slow response 100 seconds @ 2, 20, 200 Milliwatts Fast and Slow response 100 seconds	M	Capable of wide range wavelength detection. Standard quartz window; Range without windows: .2 to 40 micrometers Total System calibration to +5 accuracy.
21-0.	NakanoSeisakusho Ltd.					
21-1.		Pyranometer	Thermopile			Single dome.
22-0.	Philipp Schenk					
22-1.	8101	Pyranometer	Thermopile (Dirmhirn)			Star type. Single crystal dome, Sensitivity: about 8mV/cal cm^{-2} min^{-1} Range: 0.3 to 3.0 microns, Time of adjustment: About 20 seconds.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
22-2.	8111	Pyrradiometer	Thermopile (Dirmhirn)			Sensor operates via two thermo batteries Range: 0 to 1.8 g-cal/cm^2min. or inferior values; Output: about 20 to 25 mV/cal cm^{-2} min^{-1} measured loss free; Time of adjustment: 40 seconds.
22-3.	8104	Pyranometer	Thermopile (Dirmhirn)			Sensor utilizes thermo batteries under a glass dome: gives possibility to measure solar radiation under water, Range: 0 to 1mV.
22-4.	8110	Pyrradiometer	Thermopile			Radiation balance meter; two star pyranometers used; can be applied in short and long wave measuring range of 0.3 to 60 microns; Output: about 8mV/cal cm^{-2} min^{-1}.
23-0.	Rauchfuss Instruments and Staff Pty. Ltd.					
23-1.	Integrating Pyranometer	Pyranometer	Silicon Cell			Primarily for agricultural application. Integrating.
24-0.	RdF Corp.					
24-1.	Power Cell	Pyranometer	Conical Cavity Black Body Receiver		L ($900; 7/76)	Receiver has built-in heat source; conical-cavity reduces loss of sensitivity.
24-2.	Field Grade	Pyranometer	Thermopile		I ($400; 7/76)	Spherical dome admits direct and diffues energy over a 170° view-angle.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
25-0.	Feuss					
25-1.	Bimetallic Actinograph No. 58dc	Pyranogrpah	Bimetallic strips	Slow		
26-0.	Rho Sigma					
26-1.	1008	Photovoltaic Pyranometer	Silicon Cell		F ($98.50; 7/76)	Instantaneous response Output: approximately 500 mV at 1 kw/sq meter solar input; Accuracy: 3% during period when 90% solar energy is available.
26-2.	1002	Integrating Insolation Meter	Solar Cell		G ($125; 7/76)	Instantaneous insolation scale: 400 BTU/ft^2-hr. max. Integrator scales: 24 hr. range-3000 BTU/ft^2-hr. max. 120 hr. range-15000 BTU/ft^2-hr. max. Intergrator reading Accuracy: ± 5% of full scale.
27-0.	Science Associates, Inc.					
27-1.	615	Pyranometer	Thermopile	99% in 3 minutes	G	Will also be available with temperature compensation. Identical to Item 15-1.
27-2.	633	Pyranometer	Thermopile		J	Double dome, Moll-Gorczynski design. Manufactured by Kipp & Zonen. Identical to Item 13-1.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
27-3.	621	Net Pyrradiometer	Thermopile	12 seconds	I	Also available with heavy-duty self-supporting poly-ethylene domes. Fritschen type.
27-4.	622	Net Pyradiometer	Thermopile	98% in 30 seconds	F	Swissteco Types S-1 adapater available for unidirectional measure-ments.
27-5.	622-1	Net Pyrradiometer	Thermopile		K	Swissteco Type S-1 adapted for net short wave measurement. Glass domes.
27-6.	630TH-1	Pyrradiometer	Thermopile		L	Gier-Dunkle design.
27-7.	630NE-1	Net Pyrradiometer	Thermopile		L	Gier-Dunkle design.
27-8.	636-2	Pyranometer	Silicon Cell	2 milli-seconds	G	Single glass dome- short wave radiation. Manu-factured by Matrix, Inc. Identical to Item 17-3.
27-9.	636-5	Pyrheliometer	Silicon Cell		H	Apperture 5.7°. Manu-factured by Matrix, Inc. Identical to Item 17-5.
27-10.	636-7	Pyranometer	Silicon Cell		K	Same as 636 only has inte-grator. Manufactured by Matrix, Inc. Identical to Item 17-1.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
27-11.	645-48	Pyranometer	Thermopile	3-4 seconds	K	Manufactured by Eppley Lab., Inc. Identical to 5-1.
27-12.	646	Spectral Pyranometer	Thermopile	1 second	L	Available with a range at filters. Manufactured by Eppley Lab., Inc. Identical to Item 5-3.
27-13.	647 (1)	Ultraviolet Radiometer	Selenium Cell	Milliseconds	M	Spectral response 295-358 mm; other filters available. Manufactured by Eppley Lab, Inc. Identical to Item 5-8.
27-14.	650	Normal incidence Pyrheliometer	Thermopile	1 second	L	Designed for total or spectral measumements. Manufactured by Eppley Lab., Inc. Identical to Item 5-4.
27-15.	651	Sunshine Duration	Glass sphere		K	"Interim reference sunshine recorder" - WMO. Manufactured by C. F. Casella.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
27-16.	653	Actinometer	Bi-metallic elements		I	Same as device manufactured in England by C. F. Casella and Co., Ltd.
27-17.	658	Pyrgeometer	Thermopile	2 seconds	M	Manufactured by Eppley Lab, Inc. Identical to Item 5-5.
27-18.	660	Research Radiometer	Photodiode	Milliseconds	M	Portable, spectral range 240 - 1100 NM.
27-19.	648	Pyrheliometer	Angstrom		M	"Primary working standard" WMO. Manufactured by Eppley Lab., Inc. Identical to Item 5-7.
28-0.	Solar Radiation Instruments					
28-1.	SRI 3	Pyranometer	Thermopile		I	Bird protection rings available. Glass dome.
28-2.	SRI 11	Pyrgeometer	Thermopile			Long, short and total radiation measured.
28-3.	SRI 5	Pyrradiometer	Thermopile		K	
28-4.	SRI 4	Pyrradiometer	Thermopile	99% in 1 minute	G	Double glass domes can easily be converted to pyrheliometer or pyranometer.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
28-5.	SRI 4U	Pyrradiometer	Thermopile		L	Designed for extended underwater use.
29-0.	Solar Research					
29-1.	SR 107	Pyrheliometer	Silicon Photo-voltaic Detector			Portable; Specially manufactured by E.G. & G., Inc.; three screw-on attachments provided with the single basic detector probe.
30-0.	Spectrolab					
30-1.	SR-75	Pyranometer	Multijunction Thermopile	Attains 1/e of value of a step change in less than two seconds	M ($1010; 7/76)	Double glass dome; Output: no less than 5.25 mV Ly^{-1} minute nor greater than 9.8 mV Ly^{-1} minute. Electrical impedance: Less than 500 Ohms D.C. resistance
31-0.	Spectran Instruments					
31-1.	4046	Pyranometer	Self-generating Thermopile	1 second	L	Double glass dome.
31-2.	4048	Pyranometer	Self-generating Thermopile	1 second	K	Single glass dome.
31-3.	4056	Pyrheliometer	Self-generaing Thermopile	1 second	J	Single flat window.
31-4.	4058	Pyrheliometer	Self-generating Thermopile	1 second	K	Single flat window.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
31-5.	4060	Pyrheliometer	Self-generating Thermopile	1 second	K	Single flat window.
31-6.	4064	Pyrgeometer	Self-generating Thermopile	1 second	L	Dual flat windows.
31-7.	4072	Pyranometer	Self-generating Thermopile	1 second	L	Ultraviolet limiting optional dome. 200-400 NM
31-8.	4074	Pyranometer	Self-gener-ting Thermopile	1 second	L	Infrared limiting optical dome, 1-4 μM
32-0.	Suntek Research Associates, Inc.					
32-1.	EX-110	Pyrheliometer	Unknown			Infrared reflectometer similar to one designed by Gier-Dunkle
33-0.	Swissteco Pty., Ltd. *					*Note: All Swissteco Pty Ltd., sensors protected against corrosion and oxidation, artifically aged by heat and deep freeze treatment ensuring stability of established calibration of all sensors independent of temperature to within ± 0.01%/°C. Sensors easily interchangeable facilitating servicing.

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
33-1.	ST-25	Pyrradiometer	Copper Constantan Sensitivity - 0.25mV/mW cm^{-2}	98% in 30 seconds	J	Polythene hemispheres; inside dry gas circulation; outside ventilation (air curtain).
33-2.	SS-25	Pyranometer	Copper-constantan sensitivity - 0.25mV/mW cm^{-2}	98% in 30 seconds	J	Double glass domes; inside dry gas circullation; outside ventilation (air curtain).
33-3.	S-1	Net Pyradiometer (Balance Meter)	Copper-constantan sensitivity - 0.45mV/mW cm-2	98% in 25 seconds	K	Polythene hemispheres; inside dry gas circulation; outside ventilation (air curtain).
34-0.	Technical Measurement, Inc.					
34-1.	Kendall MK IV	Radiometer	Black Cavity	6 seconds	N	Measures radiation in range 0.035 to 4.2 watts/cm^2. Sensitivity greater than 10 MV/ watts - cm^{-2}.
34-2.	Kendall MK V	Radiometer			N	
34-3.	Kendall MK VI	Radiometer	Black Cavity	10 seconds	N	Measures radiation in the range 0.02 to 0.2 watts/cm^2. Sensitivity greater than 20 MV/ watts - cm^{-2}.
34-4.	MK II	Solar Tracker			L	

	MANUFACTURER/MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
35-0.	Teledyne Geotech *					*Note: Teledyne Geotech units require power for plate aspiration; temperature compensated.
35-1.	TCH-188-01	Pyrgeometer	Thermopile	68% in 10 seconds	L ($850; 11/74)	
35-2.	TCH-188-19	Pyrgeometer	Thermopile	68% in 10 seconds	L ($850; 11/74)	
35-3.	TCN-188-01	Pyrradiometer	Thermopile	68% in 10 seconds	L ($850; 11/74)	
35-4.	TCN-188-19	Pyrradiometer	Thermopile	68% in 10 seconds	L	
36-0.	Weather Measure					
36-1.	R413	Pyranometer	Thermopile	4 seconds	K	Single glass dome. Star pyranometer.
36-2.	R421	Net-Radiometer	Thermopile	12 seconds	I	Fritschen type. Polyethylene domes.
36-3.	R422	Pyrradiometer	Thermopile	12 seconds	K	Lupolene domes.
36-4.	R423	Radiation Balance	Thermopile	8 seconds	M	Lupolene domes.

	MANUFACTURER MODEL	CLASSIFICATION	SENSOR TYPE	RESPONSE TIME	COST CODE	COMMENTS
37-0.	XKR Research					
37-1.	Heliotrio^{tm}	Pyranometer	Silicon Cell	Not Applicable	G	Measures hours of insolation above a fixed threshold which trips on a .1 hour counter (tenths of hour is smallest increment); Accuracy is ± 10% on the threshold level. Unit is calibrated to buyer's threshold level (calibrated against Eppley pyranometers).
38-0.	Yellow Springs Instruments					
38-1.	65A	Radiometer	Interchangable Thermistors		J ($475; 6/76)	Developed in conjunction with the Kettering Research Laboratories; Range: covers uV to 0.30 micrometers and IR to 2.7 micrometers; Recorder output: Signal of 0 to 106-120 millivolts.

ATTACHMENT 3

ADDRESS LIST OF MANUFACTURERS

Belfort Instrument Co.
1600 South Clinton Street
Baltimore, Maryland 21224

C. F. Casella and Co., Ltd.
Regent House, Britannia Walk
London, N. I.

C. W. Thornthwaite Associates
Route 1
Elmer, New Jersey 08318

EKO Instruments Trading Co., Ltd.
Japan
(Correct address not available)

Eppley Laboratory, Inc.
12 Sheffield Avenue
Newport, R. I. 02840

Gamma Scientific, Inc.
3777 Ruffin Road
San Diego, California 92123

Hy-Cal Engineering
12105 Los Nietos Road
Santa Fe Springs, Californis 90670

Herbert A. Groise and Co.
Rear 1
Gordon Drive
Malvern, Australia

IBM - Federal Systems Division
Research Park
Huntsville, Alabama 35807

International Scientific Industries
P. O. Box 537
Flagstaff, Arizona 86001

Ishikawa Trading Co., Ltd.
6-13, 4 Chome, Shinkawa
Mitaka, C. Yokyo, 181, Japan

Kahl Scientific Instruments Corp.
P. O. Box 1166
El Cajon (San Diego), California 92022

Kipp and Zonen
P. O. Box 507
Delft, Holland

Lambda Instruments Corp.
4421 Superior Street
P. O. Box 4425
Lincoln, Nebraska 68504

Lintronic Limited
54-58 Bartholomew Close
London, EC1

Mashpriborintorg
Smolenskaya - Sennaya Square
32/34
Moscow G-200, USSR

Matrix Inc.
537 South 31st Street
Mesa, Arizona 85204

Medtherm Corporation
P. O. Box 412
Huntsville, Alabama 35804

Middleton and Co., Pty, Ltd.
8 Eastern Road
South Melbourne, Australia

Middleton Instruments
P. O. Box 192
Port Melbourne, Australia

Molectron Corp.
177 N. Wolfe Road
Sunnyvale, California 94086

Nakano - Seisakusho Ltd.
Hiyashimito 1525
Ueno City, Mic Prefecture
Japan

Philipp Schenk
Gse.m.b.H. Wien and Co., KG
1212 Wien

Rauchfuss Instruments and Staff Pty. Ltd.
12 Monomeeth Drive, Mitcham
Victoria, 3132, Australia

Rdf Corporation
23 Elm Avenue
Hudson, New Hampshire 03051

R. Feuss
D-1 Berlin 41
Dunther Str. 8
Postfach 350, Germany

Rho Sigma
15150 Raymer Street
Van Nuys, California 91405

Science Associates, Inc.
230 Nassau Street
P. O. Box 230
Princeton, N. J. 08540

Solar Radiation Instruments
21-21A Rose Street
Altona, Victoria
Australia 3018

Solar Research
17050 Chatsworth
Granada Hills, California 91344

Spectran Instruments
P. O. Box 891
La Habra, California 90631

Spectrolab
12484 Gladstone Avenue
Sylmar, California 91342

Suntek Research Associates, Inc.
33 Edinboro Street
Boston, Massachusetts

Swissteco Pty. Ltd.
Instrument Division
26 Miami Street
East Hawthorne
Vic. 3123, Melbourne, Australia

Technical Measurements, Inc.
P. O. Box 838
La Canada, California 91011

Teledyne Geotech
3401 Shiloh Road
Garland, Texas 75041

Weathermeasure Corp.
P. O. Box 41257
Sacramento, California 95841

SKR Research
403 Santa Fe Avenue
Pt. Richmond, California 94801

Yellow Springs Instrument Co.
Yellow Springs, Ohio 45387

ATTACHMENT 4

GLOSSARY OF SOLAR RADIATION TERMS

With the rapidly growing interest in solar energy and the presumably small amount of exposure most persons have had to solar radiation measuring equipment, a need arises for definitions which will help to clarify the various terms and their meanings.

This Glossary of Solar Radiation Terms purports to define every important term likely to be found in the literature today. These definitions have been extracted from prominent references concerning meterological instrumentation, and have been selected based on clarity and general usage. However, these definitions may not be the same for the terms as used in other disciplines; for example, the term "air mass" has a different meaning in meteorology. Also, general agreement does not exist on all of these definitions. Comments, suggestions and additional references will be appreciated.

The sources and abbreviations used in this Glossary include the following references:

AMS - '59----------Glossary of Meteorology. American Meteorological Society. Edited by Ralph E. Huschke

FRANKLIN - '75----------Introduction to Meteorology. Wiley, Franklyn and Cole.

IMV - '66----------International Meteorological Vocabulary. WMO/OMM/BMO-No. 182.

WMO - '71----------Guide to Meterological Instrument and Observing Practices. WMO-No. 8. TP. 3.

ATTACHMENT 4

GLOSSARY OF SOLAR RADIATION TERMS

ABSORPTION

The process in which incident radiant energy is retained by a substance. A further process always results from absorption: that is, the irreversible conversion of the absorbed radiation into some other form of energy within and according to the nature of the absorbing medium. The absorbing medium itself may emit radiation, but only after an energy conversion has occurred. (AMS - '59)

ABSORPTION COEFFICIENT

1. A measure of the amount of normally incident radiant energy absorbed through a unit distance or by a unit mass of absorbing medium. (AMS - '59)

2. Quantity k_λ in the equation

$$I_\lambda = I_{\lambda o} e^{-k_\lambda x}$$

for the radiant flux I_λ of radiation of wavelength λ, initially radiant flux of I_{λ_o}, after passing through a thickness x of an absorbing medium is called absorption coefficient. (IMV - '66)

ABSORPTIVITY (called ABSORPTION FACTOR: infrequently called ABSORPTIVE POWER)

A measure of the amount of radiant energy absorbed by a given substance of definite dimensions; defined as the ratio of the amount of radiant energy absorbed to the total amount incident upon the substance.

The absorptivity of any actual substance is a function of temperature as well as wavelength. For a non-opaque substance, it is also a function of the thickness of the substance. (AMS - '59)

ACTINOGRAPH

Instrument for recording the total radiation falling from a small solid angle on a plane surface perpendicular to the axis of the solid angle. It is mainly used to record direct solar radiation.

ACTINOMETER

The general name for any instrument used to measure the intensity of radiant energy, particularly that of the sun (AMS - '59)

ACTINOMETRY

Branch of physics devoted to the study and measurement of radiation; especially in meteorology, solar, atmospheric and terrestrial radiation. (IMV - '66)

AIR

Mixture of gases which composes the earth's atmosphere. (FRANKLYN - '75)

AIR TEMPERATURE

Temperature read on a thermometer which is exposed to the air in a position sheltered from direct solar radiation. (IMV - '66)

ALBEDO

Ratio of the radiation reflected by a surface to that incident on it. (IMV - '66)

ALBEDOMETER

The general name for instrument used to measure the ratio of the radiation reflected by a surface to that incident on it.

ANGLE OF INCIDENCE

The angle at which a ray of energy impinges upon a surface, measured between the direction of propagation of the energy and a perpendicular to the surface at the point of impingement, or incidence. (AMS - '59)

ANGLE OF REFLECTION

The angle at which a reflected ray of energy leaves a reflecting surface, measured between the direction of the outgoing ray and a perpendicular to the surface at the point of reflection. (AMS - '59)

ANGLE OF REFRACTION

The angle at which a refracted ray of energy leaves the interface at which between the direction of the refracted ray and a perpendicular to the interface at the point of refraction. (AMS - '59)

ATMOSPHERIC RADIATION

The part of terrestrial radiation which is emitted by the atmosphere. (IMV - '66)

ATTENUATION OF SOLAR RADIATION

Loss of energy suffered by a beam of radiant energy which traverses the earth's atmosphere. Losses are caused by scattering by air molecules, by selective absorption by certain molecules, and by absorption and scattering by aerosols. (IMV - '66)

AUREOLE

Name given to that exterior ring in a series which is nearest the luminary in a corona, and is usually quite distinct. It is reddish or chestnut in hue and, as a rule, less than 5^{o} radius.

AZIMUTH

The length of the arc of the horizon (in degrees) intercepted between a given point and an adopted reference direction, usually true north, and measured clockwise from the reference direction. (AMS - '59)

BEAM

A ray or collection of focused rays of radiated energy. (AMS - '59)

BLACK BODY

A hypothetical "body" which absorbs completely all incident radiation, independent of wavelength and direction; that is, one which neither reflects nor transmits any of the incident radiation. It is the emitter of electromagnetic radiation which, at a given temperature, presents the maximum spectral density of radiant emittance. (IMV - '66 & AMS - '59)

BLACK BODY RADIATION

Theoretical maximum amount of electromagnetic radiation of all wavelengths which may be emitted per unit area of a body at a given temperature. (IMV - '66)

BOLOMETER

Instrument for measuring the intensity of radiant energy. Its principle is based on the variation of electrical resistance, with the incoming radiation, of one or both the metallic strips which the instrument comprises. (IMV - '66)

CALORIMETER

An instrument designed to measure quantities of heat; sometimes used in meteorology to measure solar radiation. (AMS - '59)

CIRCUMSOLAR RADIATION

Radiation scattered by the atmosphere into the area of the sky immediately adjacent to the sun. It causes the solar aureole, and its areal extent is directly related to the atmospheric turbidity, being greater with higher turbidity.

CLOUD COVER (also called CLOUDINESS, CLOUDAGE)

That portion of the sky cover which is attributed to clouds, usually measured in tenths of sky covered. (AMS - '59)

COMPENSATED PYRHELIOMETER

Pyrheliometer based on the comparison of the heating of two identical metal strips, one exposed to a radiation, the other to a joule effect. (IMV - '66)

CONDUCTION

A heat-transfer process by molecular action but not involving molecular transport. (FRANKLYN - '75)

CONVECTION

Organized internal motions within a layer of air, leading to vertical transport of heat is called convection.

*Convection caused by density differences within the air is called free convection.

*Convection caused by mechanical forces such as those arising from air motion over a rough or sloping surface is called a forced convection.

COOLING DEGREE-DAY

Form of degree-day used to estimate the energy requirements for air conditioning or refrigeration. One cooling degree-day is counted for each degree that the daily mean temperature is higher than a base temperature. (IMV - '66)

CORPUSCULAR RADIATION

Radiation composed of particles. (IMV - '66)

COSMIC RADIATION

Radiation, of very high energy and great penetrative power, which emanates from cosmic regions. (IMV - '66)

DEGREE-DAY

Generally, a measure of the departure of the mean daily temperature from a given standard: one degree day for each degree (^{o}C or ^{o}F) of departure above (or below) the standard during one day. (AMS - '59)

DIFFUSE SOLAR RADIATION-SKY RADIATION

Downward scattered and reflected solar radiation, coming from the whole hemisphere with the exception of the solid angle subtended by the sun's disc. (IMV - '66)

DIRECT SOLAR RADIATION

Solar radiation coming from the solid angle of the sun's disc on a surface perpendicular to the axis of this cone, comprising mainly unscattered and unreflected solar radiation. (IMV - '66)

DOWNWARD (TOTAL) RADIATION

Solar and terrestrial radiations directed downwards (towards the earth's surface). (IMV - '66)

EFFECTIVE NOCTURNAL RADIATION

A. Radiation balance of a horizontal upward-facing black surface at the ambient air temperature, in the absence of solar radiation.

B. Radiation balance of a horizontal downward-facing black surface at the ambient air temperature.

C. Radiation balance of a horizontal downward-facing black surface at the ambient air temperature in the absence of solar radiation. (IMV - '66)

EFFECTIVE RADIATION

Radiation balance of a horizontal upward-facing black surface at the ambient air temperature. (IMV - '66)

EXTRA-TERRESTRIAL RADIATION

Solar radiation received at the limit of the earth's atmosphere. (IMV - '66)

GLOBAL SOLAR RADIATION

Global solar radiation received on a horizontal surface direct from the solid angle of the sun's disk and also radiation that has been scattered or diffusely reflected in traversing the atmosphere. (WMO - '71)

HEATING DEGREE-DAY

Form of degree-day used as indication of fuel consumption. One heating degree-day is counted for each degree that the daily mean temperature is lower than a base temperature.

INFRARED RADIATION

Radiation with wavelengths higher than about 0.8 micron, and less than 1 millimeter.

INSOLATION

1. Amount of direct solar radiation incident per unit horizontal area at a given level.

2. Downward-directed solar radiation. (IMV - '66)

INSOLATION DURATION

Three kinds are distinguished:

a. Bright sunshine duration: time interval during which solar radiation reaches adequate intensity to cast distinct shadows.

b. Geographically or topographically possible sunshine duration: maximum interval during which solar radiation can reach a given surface.

c. Maximum possible solar duration: interval of time between rising and setting of the upper limb of the sun. (IMV - '66)

INTERNATIONAL PYRHELIOMETRIC SCALE

Pyrheliometric scale decreed as being in operation from July 1, 1957, in order to meet an urgent need for a single international scale. (IMV - '66)

ISOHEL

Curve of equal sunshine duration during a given interval of time. (IMV - '66)

ISOTROPIC RADIATION

Diffuse solar radiation which has the same intensity in all directions. (IMV - '66)

IRRADIANCE (FLUX OF RADIATION PER UNIT AREA)

(at a point on a surface)
Quotient of the flux of radiation incident on an infinitesimal element of a surface containing the point under consideration, by the area of that element. (IMV - '66)

IRRADIATION

(at a point on a surface)
Product of an irradiance and it's duration. (IMV - '66)

LONG-WAVE RADIATION

Radiation with wavelengths greater than four microns. (IMV - '66)

LUCIMETER

Instrument for measuring the mean intensity of solar global radiation (direct and diffuse) near the earth's surface in a specified time interval. (IMV - '66)

NET PYRANOMETER

A net pyranometer is an instrument for measuring the difference of the solar radiation falling on both sides of a horizontal surface from the whole hemisphere.

NET PYRGEOMETER

Instrument for measuring the difference of the atmospheric radiation falling on both sides of a horizontal surface at the ambient air temperature.

NET PYRRADIOMETER

Instrument for the measurement of the net flux of downward and upward total (solar, terrestrial surface and atmospheric) radiation through a horizontal surface. (WMO - '71)

NET RADIATION

Difference between downward and upward (total and terrestrial) radiation; net flux of all radiation. (IMV - '66)

NET SOLAR RADIATION

Difference between the solar radiations directed downwards and upwards; net flux of solar radiation. (IMV - '66)

NET TERRESTRIAL RADIATION

TERRESTRIAL RADIATION BALANCE

Difference between downward and upward terrestrial radiation; net flux of terrestrial radiation. (IMV - '66)

PERCENTAGE OF POSSIBLE SUNSHINE

A. Ratio of the actual duration of bright sunshine to the geographically or topographically possible duration.

B. Ratio of the actual duration of bright sunshine to the astronomically possible duration of sunshine. (IMV - '66)

PYRANOGRAPH

Instrument for recording the solar radiation falling from a solid angle 4π on a spherical surface.

PYRANOMETER-SOLARIMETER

A pyranometer is an instrument for the measurement of the solar radiation received from the whole hemisphere It is suitable for the measurement of the global or sky radiation. (WMO-'71)

PYRGEOMETER

A pyrgeometer is an instrument for the measurement of net atmospheric radiation on a horizontal upward facing black surface at the ambient air temperature. (WMO-'71)

PYRHELIOMETER-ACTINOMETER

A pyrheliometer is an instrument for measuring the intensity of direct solar radiation at normal incidence; it can either be a primary standard instument or a secondary instrument scaled by reference to a primary instrument. (WMO-'71)

PYRHELIOMETRIC SCALE

Scale of measurement of irradiance as determined by an absolute standard type pyrheliometer. (IMV - '66)

PYRRADIOMETER

A pyrradiometer is an instrument for the measurement of both solar and terrestrial radiation. (WMO-'71)

RADIANCE (RADIANT INTENSITY PER UNIT AREA)

(at a point of a surface in a given direction)
Quotient of the radiant intensity, in the given direction, of a infinitesimal element of the surface containing the point under consideration, by the area of the orthogonal projection of this element on a plane perpendicular to the given direction. (IMV - '66)

RADIANT EMITTANCE

(from a point of a surface)
Quotient of the flux of radiation emitted by an infinitesimal element of surface containing the point under question, by the area of that element. (IMV - '66)

RADIANT FLUX (FLUX OF RADIATION, RADIANT POWER)

Power emitted, transferred, or received in the form of radiation. (IMV - '66)

RADIANT INTENSITY

(of a source in a given direction)
Quotient of the radiant power emitted by source, or by an element of source in an infinitesimal cone containing the given direction, by the solid angle of that cone. (IMV - '66)

RADIATION

Emission or transfer of energy in the form of electromagnetic waves or particles. (IMV - '66)

RADIOMETER

Instrument for measuring radiation. (IMV - '66)

REFLECTED SOLAR RADIATION
REFLECTED GLOBAL RADIATION

Upward-directed solar radiation, reflected and scattered by the Earth's surface and the atmosphere. (IMV - '66)

REFLECTOMETER

Downward-facing pyranometer (solarimeter), used for measuring reflected solar radiation. (IMV - '66)

SHORT-WAVE RADIATION

Radiation with wavelengths less than four microns. (IMV - '66)

SOLAR CONSTANT

Amount of solar radiation incident, per unit area and time, on a surface which is normal to the radiation and is situated at the outer limit of the atmosphere, the earth being at its mean distance from the sun. (IMV - '66)

SOLAR RADIATION

Radiation emitted by the sun. (IMV - '66)

SPECTRAL SOLAR RADIATION

Radiation of selective wavelengths of the solar radiation.

SPHERICAL PYRANOMETER

Instrument for measuring the solar radiation falling from a solid angle 4π on a spherical surface. (IMV -'66)

SPHERICAL PYRGEOMETER

Instrument for measuring the long-wave radiation falling from the solid angle 4π on a spherical surface. (IMV - '66)

SPHERICAL PYRRADIOMETER

Instrument for measuring total radiation falling from a solid angle 4π on a spherical surface. (IMV - '66)

TERRESTRIAL RADIATION

Radiation by the earth, including its atmosphere. (IMV - 66)

TOTAL RADIATION

Sum of solar radiation and terrestrial radiation. (IMV - 66)

TRANSMISSION COEFFICIENT

Measure (γ) of the intensity of radiant flux which remains in a beam after traversing unit thickness of a medium. For luminous flux it is related to the extinction coefficient (σ) by the relation:

$$\gamma = e^{-\sigma}$$

IMV - '66)

TURBIDITY

In meteorology, and condition of the atmosphere which reduces its transparency to radiation, especially to visible radiation.

ULTRA-VIOLET RADIATION

Radiation with wavelengths less than 0.4 micron and higher than 0.03 micron. (IMV - '66)

UPWARD (TOTAL) RADIATION

Solar and terrestrial radiations directed upwards (towards space). (IMV - '66)