4,708 11/18/80 T.S.

REG

2

IEA
SOLAR R&D

INTERNATIONAL ENERGY AGENCY
program
to develop and test
solar heating
and cooling systems

MASTER

TASK IV: DEVELOPMENT OF AN INSOLATION HANDBOOK AND INSTRUMENTATION PACKAGE

SUBTASK REPORT

VALIDATION OF THE GUIDELINES FOR PORTABLE METEOROLOGICAL INSTRUMENT PACKAGES
(AN INTERIM REPORT)

DOE/ER-0083
U.S. Department of Energy
Office of Energy Research
Office of Basic Sciences

OCTOBER 1980

DISCLAIMER

NOTICE

Available from:

National Technical Information Service (NTIS)
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22161

Price:	Printed Copy:	$10.00
	Microfiche:	$4.00

DOE/ER-0083
Dist. Category UC 59, 59a, 59b, 59c, 62, 62b, 62c, 62d, 62e, 63, 63a, 63b, 63c, 63d, 63e

INTERNATIONAL ENERGY AGENCY
program
to develop and test
solar heating
and cooling systems

TASK IV: DEVELOPMENT OF AN INSOLATION HANDBOOK
AND INSTRUMENTATION PACKAGE

SUBTASK REPORT

VALIDATION OF THE GUIDELINES FOR PORTABLE METEOROLOGICAL INSTRUMENT PACKAGES
(AN INTERIM REPORT)

U.S. Department of Energy
Office of Energy Research
Office of Basic Sciences
Washington, D.C. 20585

ABSTRACT

The purpose of this report is to show how the objective of developing guidelines for a solar energy related portable meteorological instrument package, under the auspices of the International Energy Agency (IEA), was carried out and preliminarily demonstrated and validated. A project to develop guidelines for such packages was initiated at IEA's Solar Heating and Cooling of Buildings Program Expert's Meeting held in Norrkoping, Sweden, in February 1976. An international comparison of resultant devices was conducted on behalf of the IEA at a conference held in Hamburg, Federal Republic of Germany, in 1978. Results of the 1978 Hamburg comparison of two devices and the Swiss Mobile Solar Radiation System, using German meteorological standards, are discussed. The consensus of the IEA Task Group is that the objective of the subtask has been accomplished.

ACKNOWLEDGMENTS

This subtask was accomplished through the efforts of many participants, both inside and outside the International Energy Agency community, too numerous to list individually.

Special recognition is given to Mr. Klaus Dehne of the Meteorologisches Observatorium Hamburg (MOH) and to his staff for hosting the conference at MOH in 1978. We placed an additional burden on their already heavy workload, and we appreciate their meeting the challenge.

Mr. J. W. Gruter, Mr. John "Jack" R. Penuelas, and the Swiss Group have our admiration for their package designs and our gratitude for their participation in the preliminary demonstration of the IEA guidelines through the comparison.

On behalf of Task IV,

Michael R. Riches

CONTRIBUTING ORGANIZATIONS AND EXPERTS

Government Organizations

Government of Belgium

National Research Council of Canada

Commission of the European Communities

Kernforschungsanlage Julich, Germany

Consiglio Nazionale delle Ricerche, Italy

Stichting Energieonderzoek Centrum Nederland

Ministerio de Industria (Centro de Estudios de la Energia), Spain

Office Federal de L'Economie Energetique, Switzerland

United Kingdom Atomic Energy Authority

United States Department of Energy

National Contact Persons

BELGIUM	D. Crommelynck Institut Royal Meteorologique de Belique Avenue Circulaire 3 1180 Bruxelles
CANADA	T. K. Won Climatological Applications Branch Atmospheric and Environmental Service, DOE 4905 Dufferin Street Toronto, Ontario M3H 5T4
EUROPEAN COMMISSION	E. Aranovitch European Commission Joint Research Center Euratom Ispra, Italy
GERMANY	F. A. Peuser Projektleitung Energieforschung Kernforschungsanlage Julich GmbH Postfach 1913 D-5170 Julich

National Contact Persons (continued)

ITALY	R. Visentine Consiglio Nazionale Ricerche Progetto Energetica Via Nizza 128 00198 - Roma, Italy
NETHERLANDS	M. H. deWit University of Technology Post Box 513 Eindhoven
SPAIN	L. R. Nadal Instituto Nacional de Tecnica Aerospacial Torrejon de Ardoz Madrid
SWITZERLAND	P. Valko Schweiz. Meteorologische Anstalt Krahbuhlstrasse 58 CH-8004 Zurich
UNITED KINGDOM	A. G. Hardacre Solar Heating Programme Manager Energy Technology Support Unit Building 156, AERE Harwell Oxfordshire OX11 ORA
U.S.A.	M. R. Riches U. S. Department of Energy - MS-J309 Office of Energy Research - ER-14 Washington, D. C. 20545

Invited Guest Scientists

M. Bruck
Solar Energy Division
Austrian Solar and Space Agency
Garnisongoss 7
A-1090 Wien
Austria

R. Dogniaux
Institut Royal Meteorologique de Belgique
Avenue Circulaire 3
A-1180 Bruxelles
Belgium

J. R. Latimer
Atmospheric Environment Service
4905 Dufferin Street
Downsview, Ontario
Canada

Invited Guest Scientists (continued)

C. Gandino
Meteorological Observatory
CEE - 21020 Ispra
Italy

H. Lund
Technical University
Thermal Insulation Laboratory
DHT Building 118
DK-2800 Lyngby
Denmark

K. Dehne
Meteorologisches Observatorium
Frahmredder 95
D-2000 Hamburg 65
Germany

J. W. Gruter
Institut fur Kernphysik (IKP)
Solar Energy Branch
Kernforschungsanlage
Postfach 1913

H. Karl
Institute for Theorie der Elektroteknik
Breitscheidstrasse 3
D-700 Stuttgart
Germany

F. Vivona
Consiglio Nazionale delle Richerche
Progetto Energetica
via Nizza 128
00198 Roma, Italy

T. Sunami
Solar Energy Division
Sunshine Project Promotion Headquarters MITI
1-3-1 Kasumigaseki
Chiyoda-Ku, Tokyo
Japan

L. Dahlgren
Swedish Meteorological and Hydrological Institute
Fack
S-60101 Norrkoping
Sweden

B. Leckner
Chalmers Technical High School
Institute of Energy Technic
Fack
S-402 20 Goteborg
Sweden

Invited Guest Scientists (continued)

B. R. May
Observational Requirements and Practices Branch
Meteorological Office
Room T-21
Eastern Road
Bracknell RG 12 2UR
United Kingdom

TABLE OF CONTENTS

CHAPTER I

INTERNATIONAL ENERGY AGENCY

PORTABLE METEOROLOGICAL INSTRUMENT PACKAGES:

BACKGROUND, OBJECTIVES, AND THE SPECIFICATION

HAMBURG, SEPTEMBER - OCTOBER 1978

BY

M. R. RICHES
OFFICE OF ENERGY RESEARCH
UNITED STATES DEPARTMENT OF ENERGY
WASHINGTON, D. C. 20545

I.1 Background

Based on a demonstrated need for a coordinated approach to solving energy problems, certain members of the organization for Economic Cooperation and Development (OECD) agreed to develop an energy program. The International Energy Agency (IEA) was established within the OECD to administer, monitor, and execute the program.

In July 1975, Solar Heating and Cooling was selected as one of several technology fields for multilateral cooperation. The program to develop and test solar heating and cooling systems was divided into project areas (or tasks). Two of the tasks were designated meteorological support tasks for solar heating and cooling research and application. The project areas are:

I. Investigation of the performance of solar heating and cooling systems - Denmark

II. Coordination of R&D on solar heating and cooling components - Japan

III. Performance testing of solar collectors - Germany

IV. Development of an insolation handbook and instrument package - United States

V. Use of existing meteorological information for solar energy application - Sweden

VI. Performance of solar heating, cooling and hot water systems using evacuated collectors - United States

VII. Central solar heating plants with seasonal storage - Sweden.

At the February 1976 initial meeting of experts in Norrkoping, Sweden, Task IV was divided into two subtasks:

1. The preparation of an insolation handbook

2. The development and testing of portable meteorological instrument packages

This report discusses the second subtask of Task IV - the development of the guidelines, the resultant portable meteorological instrument packages, and a preliminary comparison of the packages to the guidelines.

I.2 Objectives of Task IV Subtask 2

At the Norrkoping meeting in 1976, experts selected for Subtask 2 of Task IV the following objectives:

1. To develop a specification (set of guidelines) for portable meteorological instrument packages.

2. To validate the guidelines using devices built by participants in an international comparison project.

I.3 The Guidelines

At the Norrkoping meeting the participants were asked to survey users in their country on what meteorological parameters should be required for portable sensor packages. Some 400 responses were summarized as draft guidelines and presented at the September 1976 experts meeting in Zurich, Switzerland. This draft was then submitted to the participants for approval. The final guidelines (as shown in Table I-1) were approved at the October 1977 experts meeting in Ispra, Italy. The guidelines specify the required and optional solar radiation parameters and other meteorological parameters. The optional parameter, output of an inclined solar cell, was included to provide a comparison between thermopile and solar cell pyranometers. Many such solar cell pyranometers are used in solar energy work as an inexpensive resource monitoring device. Additionally, an uncorrected (no cosine correction) solar cell of known characteristics can be used to provide those interested in photovoltaic applications how the given cell will perform in the measured (other sensors) environment. Relative humidity (or equivalent) was also included as an optional parameter for monitoring stations where solar cooling applications were of interest.

The terms accuracy and tolerance used in table I-1 were defined by the task IV participants as:

Accuracy - mean values in absolute units related to a recognized standard (achievable if manufacturer's calibration and maintenance schedules are followed)

Tolerance - reproducibility achievable with an instrument if measured under laboratory conditions.

The time of integration (10 minutes) was selected from requests ranging from 1 minute to 60 minutes. Based on the expert judgment of the committee, 10 minutes was sufficient to satisfy most applications except where highly concentrating devices and large collector fields (square kilometers in area) might be of importance. (Also 10 minute integrals are the shortest obtainable from most standard stripchart recorders.) No other electronic specification (except housekeeping data) were included because of the variety of options and the overall high quality of recorder options available. It is assumed that the meteorological parameters are least familiar to engineers and require guidelines.

The solar radiation (approximately 0.3 to 3 micrometers wavelength) measurements were specified as direct (normal incidence) as measured by a pyrheliometer or calculated from diffuse and global radiation measurements[1], global (180° aperture, horizontal pyranometer), and solar on an inclined surface (180° aperture, no foreground or inclination specified - assume would match collector). The incoming infrared radiation (IR) (longwave; approximate wavelength, greater than 3.0 micrometers) was included for heat loss considerations as well as for assessing nightsky cooling potential. Lesser accuracy was specified based on the experience with IR measurements of the expert participants.

Temperature was specified to the accuracy required by solar energy which is lower than achievable with state-of-the-art sensors. Therefore higher accuracy and precision were specified as optional.

Wind speed and direction measurements were included for model calculations. It is important that the wind measurements approximate the actual wind "seen" by the collector field. Therefore accurate sighting is important.

---

[1] no aperture specified

At the October 1977 meeting, The Federal Republic of Germany (through Kernforschungsanlage, Julich) and the United States Department of Energy agreed to build devices according to the IEA guidelines. The Swiss Meteorological Service agreed to participate with their mobile solar radiation research system.

To validate the guidelines, it was decided at Ispra to compare the two devices built to the IEA guidelines through a set of accepted standards and thus see whether or not the IEA guidelines could be achieved. The Swiss instrumentation system was suggested as a tool to substantiate results through its research quality sensor package. The plan for the comparison was prepared at the Ispra meeting; details are presented by Klaus Dehne in Chapter V of this report.

In October 1977, the Federal Republic of Germany offered to host a conference for a comparison/validation as well as for the Task IV experts meeting at the German Weather Services Meteorological Observatory in Hamburg (MOH) in September 1978. Chapters II, III, and IV describe the events and devices of the Hamburg Comparison.

TABLE I-1

Final Specifications for a Portable Meteorological Instrument Package

Item	Accuracy[1]	Tolerance[2]	Time of Integration
Direct (Normal Incidence)	±5% or ±25 Wm^{-2} [3]	2%	10 min continuous[4]
Global (Direct plus diffuse)	±5% or ±25 Wm^{-2} [3]	2%	
Solar on Inclined	±5% or ±25 Wm^{-2} [3]	2%	
Incoming IR (inclined)	±10% or ±25 Wm^{-2} [3]	2%	
Output of an Inclined Solar Cell (Opt.)	—	—	
Air Temperature	±1.0°C[5]	±0.5°C[5]	
Wind Speed	±1 ms^{-1} or ±5%[3]	±0.5 ms^{-1}	
Wind Direction	±10°	±5°	
Humidity (Opt.)	—	—	

Notes:
- o Recording method optional
- o Record: date, time, station identifier, electronic calibration reference
- o Battery takeover for clock, no other power specifications
- o Final data output in SI units (from computer processing or from unit itself)
- o Must have a "jack" for on-station data readout equipment
- o Recommend radiation sensors be calibrated against a recognized standard at 6-12 month intervals

[1]Mean values when in absolute units related to a standard (achievable if manufacturer's calibration and maintenance procedures are followed)

[2]Reproducibility achievable with instrument if measured under laboratory conditions

[3]Whichever is the largest

[4]Other integration times optional

[5]Higher accuracy or precision optional

CHAPTER II

INTERNATIONAL ENERGY AGENCY

SOLAR ENERGY PROGRAM TO DEVELOP AND TEST

SOLAR HEATING AND COOLING SYSTEMS

HAMBURG, SEPTEMBER - OCTOBER 1978

BY

J. W. GRUTER
INSTITUT FUR KERNPHYSIK
SOLAR ENERGY BRANCH
KERNFORSCHUNGSANLAGE
JULICH, FEDERAL REPUBLIC OF GERMANY

II.1 Introduction

In 1977, the Task IV experts proposed a minimum set of meteorological quantities to be measured for solar energy application studies. The member countries were asked to build a demonstration device to be studied in an international comparison. The main goal of this project was to demonstrate that the requirements, put on the list by the experts, could be fulfilled with instruments "from the shelf."

The solar energy group of the KFA decided to build a package for Germany according to these guidelines. Table II-1 lists the meteorological parameters, the required accuracy, the selected instruments, and the names of the manufacturers.

II.2 Instrumentation

To measure short-wave radiation, a pyranometer of the Moll-Gorczynski type, produced by Kipp & Zonen[1], Netherlands, was chosen because of its low cost. According to the recommendations of the Deutscher Wetterdienst, it fulfilled the required accuracy when well calibrated. For inclined surfaces, an Eppley PSP[2] is preferred because of its better performance.

The direct radiation is calculated as the difference between global and diffuse radiation. The diffuse radiation is measured by a shadow-ring technique. The shadow ring was specially constructed for the CM6 pyranometer of Kipp & Zonen by the Deutscher Wetterdienst[3]. This technique was chosen because there was no high-quality tracker on the market for use with a pyrheliometer and for servicing reasons.

The long-wave downward radiation, often referred to as infrared radiation, is calculated as the difference between total downward radiation in the wavelength interval and the global radiation ($0.3\,\mu m < \lambda < 60\,\mu m$). The total downward radiation is measured by the upper instrument of a Schulze balance meter[4].

A solar cell, manufactured by Dodge Products[5], Texas, USA, was added as an inexpensive device to measure global radiation. An intercomparison of this device with standard pyranometers is still under way.

The sunshine duration is the time calculated from direct radiation (normal incidence) values, via software. All periods with direct radiation > 200 W/m^2[6] are counted as sunny periods.

The atmospheric conditions (wind, temperature, and humidity) are measured with standard instruments commercially available on the German market. Emphasis was placed on simple instruments demanding little service.

No special stand was required because the instruments are intended to be used as integral parts of collector and system test facilities. Figure II-1 shows a typical application in a collector test experiment for the determination of collector stagnation temperatures.

TABLE II-1

Meteorological Quantity	Symbol[1]	Accuracy[2]	Instruments and Manufacturers
1. Radiation			
1.1 Irradiance on a horizontal (h) plane			
Direct	G_b	±25 W/m²	determined from $G_h - G_{hd}$
Global	G_h	or	Moll-Gorczynski pyranometer Kipp & Zonen
Diffuse	G_{hd}	±5 %	with shadow ring (type Deutscher Wetterdienst)
1.2 Irradiance on a tilted plane, tilt angle = β[3], azimuth = γ[4]			
Global	$G(\beta,\gamma)$	±25 W/m²	Moll-Gorczynski pyranometer
Global	$G(\beta,\gamma)$	or	photovoltaic pyranometer
Total $0.3 \le \lambda \le 60$ µm	$T(\beta,\gamma)$	±5 %	Schulze balance meter
Long wave (1) $\lambda > 2.5$ µm	$G_l(\beta,\gamma)$	±25 W/m² or ±10 %	Determined from T - G
1.3 Duration of sunshine			
Sunshine Hours = SS		0.1 h	determined by $G_h > 200$ W/m²
2. Atmospheric Conditions			
Air Temperature	t_{air}	±1° C	PT100 (combined with humidity)
Wind Speed	v_w	±1 m/sec	3-cup anemometer } (combined)
Wind Direction	γ_w	±10°	wind vane }
Humidity	h	±5 units[6]	hair hygrometer

1) Symbols References {10}
2) Whichever is largest
3) $\beta = 0$ horizontal
4) $\gamma = 0$ south facing, γ counted clockwise
5) $\gamma_w = 0$ wind blows from south, γ_w clockwise counted
6) 1 unit ≡ 1% relative humidity

Table II-1: IEA guidelines for meteorological measurements and instruments used for the German instrument package.

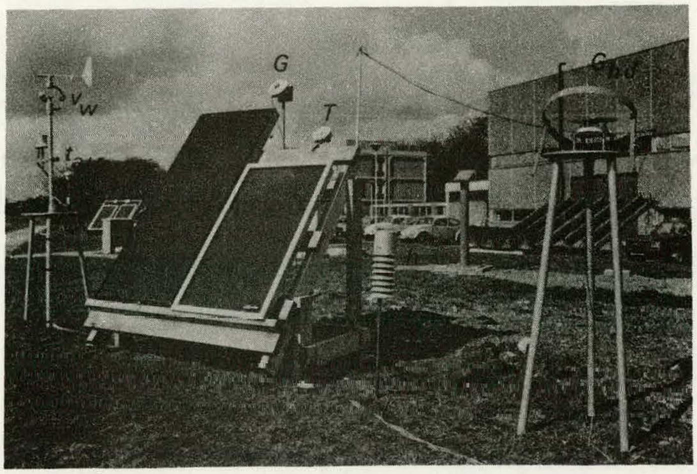


Fig. II-1: Application of the IEA instrument package for determining collector stagnation temperatures.

II.3 Data Acquisition

The measurement signals from various sources are processed by the Microprocessor Aided Data Acquisition System (MADAS) designed and constructed for the requirements associated with meteorological, solar collector, and system studies.

In its present phase of development, the MADAS features:

- **CAMAC base**
- **8080 INTEL Microprocessor**
- **16 K EPROM, 32 K at maximum**
- **8 K BASIC with CAMAC function, interrupt driven**
- **32-channel scanning ADC**
  - **-- sensitivity programmable**
  - **-- inbuilt scanning**
  - **-- pulsed constant current source for passive resistive sensors**
- **scaler input facility**
- **full CAMAC module palette usable.**

The system schematic diagram is shown in Fig. II-2. The system is characterized by the use of two electronic busses. The CAMAC[7] bus provides a standardized communication and power bus; the internal MACAMAC[8] bus is used exclusively for internal communication between CPU, system controller, and the memory. These features allow fast internal conversation and adaptation onto the measurement requirements by selection of the appropriate module from the CAMAC module market.

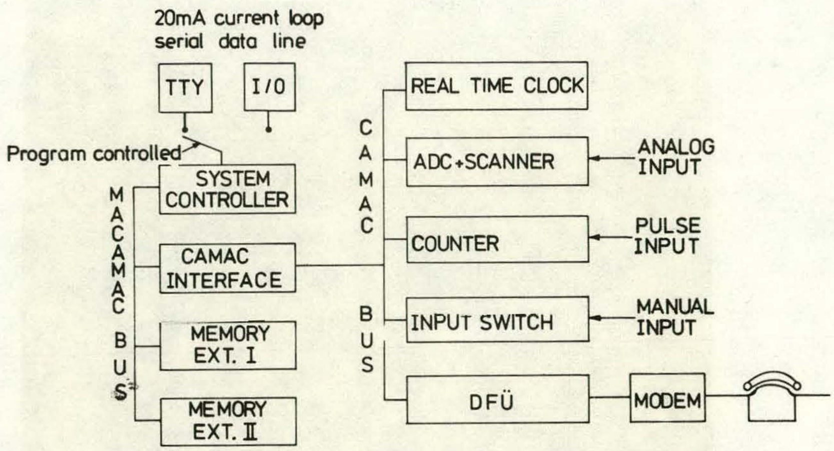


Fig. II-2: System architecture MADAS 70

II.4 The Hamburg Intercomparison Set Up

For the Hamburg intercomparison in autumn 1978, the 32-channel programmable amplifier scanning ADC was not operational. A 16-channel ADC from Joerger, USA[9], with lower precision was used. In order to include the standard instruments of the Deutscher Wetterdienst, a second Joerger ADC was added. A few modifications in the software program made both the KFA and Deutscher Wetterdienst instruments more manageable The main modification dealt with the time optimization of the program. A scanning period of 17 seconds, including computation of averages and variances, was achieved for all 32 channels. A teletype had to be used as an input/output listing device since no other devices were accessible. A good agreement between the two sets of instruments resulted. For preliminary conclusions, consult chapter V. Final data analysis is underway.

The production cost for this system would be below $25,000. However, similar data aquisition devices are now available on the open market with total systems cost at or below $12,000.

II.5 References List

1 Manufacturer: Kipp & Zonen, P. O. Box 507, Delft, Holland.

2 Manufacturer: Eppley Laboratory, Inc., 12 Sheffield Avenue, Newport, Rhode Island 02840.

3 Manufacturer: G.K. Walter Eigenbrodt, Baurat-Wiesestrasse 68, D-2111 Konigsmoor, Federal Republic of Germany.

4 Manufacturer: Dr. Bruno Lange GmbH, Konig weg 10, D-1000 Berlin 37, Federal Republic of Germany.

5 Manufacturer: Dodge Products, Houston, Texas.

6 According to recommendations of the Commission for Instruments and Methods of Observation (CIMO) of the WMO.

7 ESONE Committee, EUR 4100e, 1972, distributed by ESONE Secretariat CBNM-CRC, Steenweg naar Retie, B-2440 Geel, Belgium.

8 MACAMAC, Interner Bericht KFA-ZEL-NE406/76, Kernforschungsanlage Julich, P.B. 1913, D-5170 Julich, Federal Republic of Germany.

9 Manufacturer: Joerger Enterprises, Inc., 166 Laurel Road, East Northport, New York 11731.

10 Reference for Table I-1, Solar Energy, Vol. 21, pp. 65-68 (1978).

CHAPTER III

INTERNATIONAL ENERGY AGENCY

UNITED STATES DEPARTMENT OF ENERGY

PORTABLE SOLAR MONITORING SYSTEM

BY
J.R. PENUELAS
DESERT RESEARCH INSTITUTE
BOULDER CITY, NEVADA

III.1 Introduction

The Solar Monitoring System described in this paper is a versatile electronic measurement package designed to gather scientific data pertinent to solar energy programs. The primary purpose is to compile an accurate data base for a site-specific resource assessment. Data of interest include the various components of solar radiation and other meteorological functions monitored on a continuous basis.

Although the initial design parameters were established at the National Science Foundation sponsored Solar Energy Workshop in 1973, the system was also designed to be consistent with the functional guidelines, specifications, and objectives of the International Energy Agency, Solar Heating and Cooling Program. The major objectives of Task IV were the following:

1. To determine if the IEA specifications were feasible for a portable system.
2. To demonstrate that an acceptable system could be designed and built using premium quality but commercially available components.
3. To demonstrate that the system could be reproduced at reasonable cost.

Major design considerations were that the system be compact, transportable, easy to operate and maintain and that it operate on a low-power budget over wide environmental limits. Particular emphasis was placed on keeping the sophisticated nature of the electronics transparent to the user since it was anticipated that operating personnel would have diverse talents and skill levels. As a result, no special skills are required of the operator.

The system consists of a variety of sensors and transducers, a 5-meter weather tower, a solar platform with provisions for global measurements on inclined and horizontal surfaces, a solar tracker, and the necessary cables to interface to the Data Acquisition Unit. This unit serves as the operational and functional control point for acquiring and recording the information of interest. It contains all the electronic assemblies packaged in a weathertight enclosure and includes a microcomputer, signal processing circuitry, power supplies, and a tape transport mechanism. All components are readily accessible if maintenance is required.

The system, in its basic configuration, was designed to satisfy the majority of current user requirements for remote networks; however, it is recognized that individual users may have additional specific but unique requirements in support of their programs. Provisions have been included to satisfy these needs even beyond the measurement of meteorological parameters.

The development effort was sponsored by Sandia Laboratories on behalf of the United States Department of Energy. The actual design, fabrication, and documentation of the system was performed by the Energy Measurements Group of EC&G, Inc., in Las Vegas, Nevada.

III.2 General Description

The Solar Monitoring System (shown in Figures III-1 through III-4) in its basic configuration records up to sixteen channels of information, but only the first eight have been assigned.

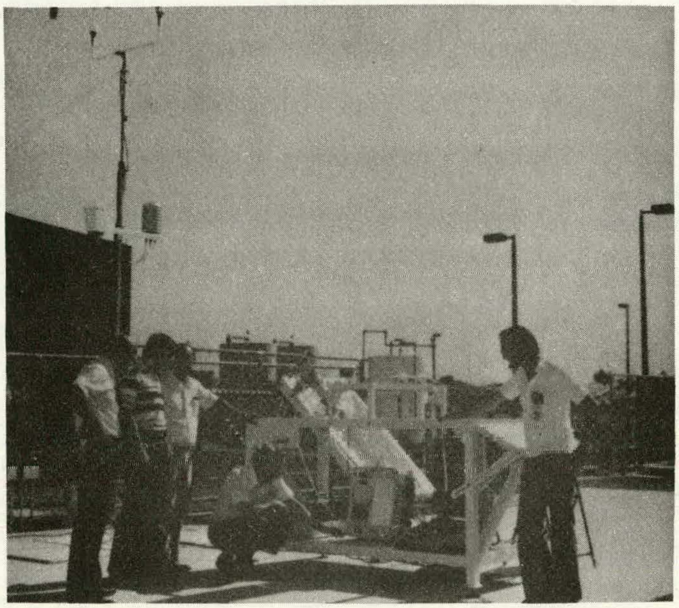


Fig. III-1: Preliminary system installation at the Desert Research Institute in Boulder City, Nevada. The majority of system components are mounted on the solar platform - the open frame table in the center of the picture, some of the details of the weather tower can be seen in the left background.

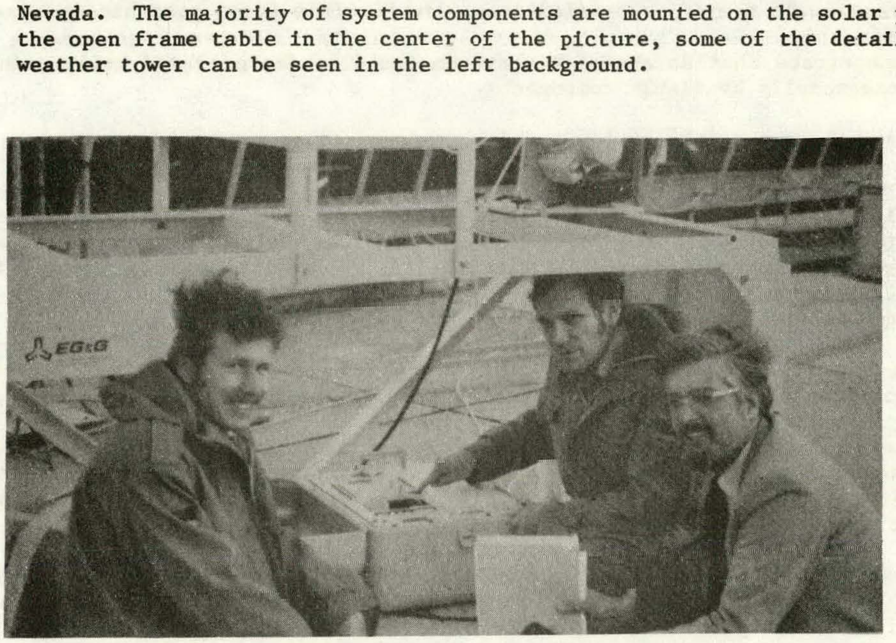


Fig. III-2: Rooftop installation at the Deutscher Wetterdienst in Hamburg, Germany - Mr. Dehne, Mr. Rosenhagen, and Mr. Hielscher.

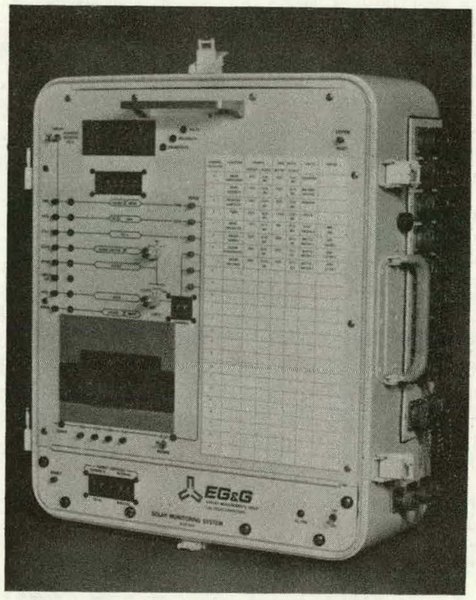


Fig. III-3: Data Acquisition Unit with cover removed.

Fig. III-4: Texas Instruments Silent 700 - Normally this unit is indoors in a controlled environment.

The first five channels are committed to weather sensors that measure ambient temperature, relative humidity, barometric station pressure, wind speed, and wind direction. The temperature and humidity sensors are housed in a motor-driven aspirator assembly; the pressure sensor is in a solar radiation shield. Three channels are dedicated to measuring solar radiation using Eppley precision thermopile radiometric sensors. The first of these is a pyranometer (PSP) that measures global radiation (direct plus diffuse components) on a horizontal surface, the second is a pyranometer (also a PSP) mounted on an adjustable inclined surface, and the third is a pyrheliometer (NIP) for measuring normal incident radiation. The pyrheliometer is attached to a motor driven equatorial mount which accurately tracks the sun when properly aligned and maintained. Typical applications for the other channels include the measurement of diffuse and spectral components, turbidity, IR and UV radiation. Expansion beyond sixteen channels is possible.

All items within the dotted line on the Block Diagram in figure III-5 are internal to the Data Acquisition Unit. To simplify troubleshooting procedures and to replace defective components, a modular packaging concept was used. The various circuits were designed as a family of printed circuit cards organized by function. A typical system would include the following cards mounted in a "card cage": two eight-channel differential amplifiers; special interface circuits for the weather sensors; multiplexer, sample and hold and analog to digital converter; tape transport controller; two input/output ports; transistor drivers; three 2K byte CMOS programmable read-only-memories; one 2K byte CMOS random-access-memory; microprocessor and serial interface and power supplies. Several card slots are available for future expansion.

As shown in the block diagram, precise excitation voltages are developed and provided to the sensors as required. Sensor-output analog-voltage levels are amplified and scaled to a common level in quality instrumentation amplifiers. There are provisions for individual gain, zero and offset bias adjustments, as well as a significant over-range capability. Transient protection is provided on all inputs.

The multiplexer, sample and hold circuit, and 13-bit analog to digital converter (A/D) process the analog voltage levels into digital form. Each channel is sampled every two seconds. Instantaneous data values are averaged over a use selectable interval of 1 to 60 minutes. The equivalent value in "Engineering Units" representing the arithmetic mean is recorded at the end of each interval for each channel with the exception of wind direction which is represented by the statistically predominant 10^{o} sector that occurred during the interval.

An ASCII[1] representation of the averaged data is recorded on a magnetic tape cassette. A unique feature of the recording mechanism is that a servo-drive is used to control tape motion, rather than a capstan. This eliminates the many potential problems associated with capstan driven cassettes. The tape storage capacity is a function of the number of channels sampled; the averaging interval follows:

---

[1]ASCII - American Standard Character Information Interchange.

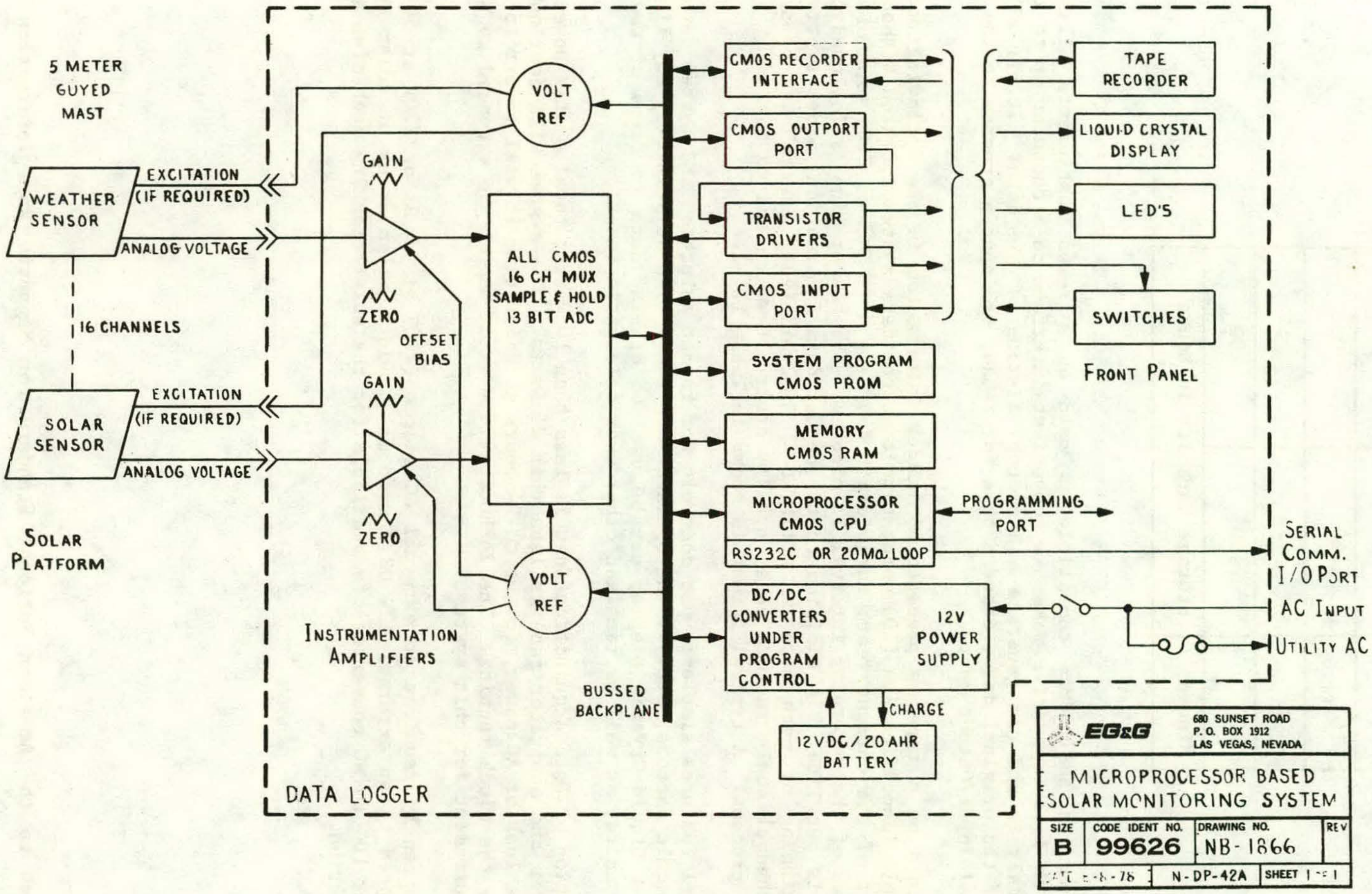


Fig. III-5 DATA ACQUISITION UNIT BLOCK DIAGRAM

Interval	1-8 Channels	9-16 Channels
5	200	100
10	400	200
⋮	⋮	⋮
60	2400	1200
Minutes	Storage Capacity in Hours	

The tape format is ANSI/ECMA[2] compatible as used on a Texas Instruments Silent 700 ASR.[3] The TI Silent 700 with dual tape drive makes a convenient interface to a computer up to 1200 baud for later editing and analysis and can generate a hard copy listing of the data. It can also provide a duplicate cassette of the original data, erase a tape for reuse, or input a program to the Data Acquisition Unit via a serial Input/Output port.

Each data record on a tape is preceded by header information in the following order: a four digit user programmable identification (ID) word; time that the data system operated without primary AC power; the last digit of the current year; three digit day from 1 to 365 or 366; time of day in hours and minutes; the value of the recording interval in minutes. The header line is followed by one or two data lines, 8 channels per line. In addition to the header/data information, a descriptive message is recorded at the beginning of each tape at midnight. The "midnight message" has been expanded to include individual channel scale factors as a quality control measure and to implement a fully automated data reduction process. A typical format is shown in Table III-1.

The front panel features simple-to-use controls for format selection and system setup procedures (entry of time, ID, scale factors, etc.). The operator has the option of selecting any linear scale of engineering units. A Liquid-Crystal Display can be used to display data in terms of raw A/D counts, volts or engineering units, as well as time and other user selectable functions.

Power consumption of Data Acquisition Unit is less than 10 Watts; total system power consumption (including the tracker and aspirator fan) is less than 20 Watts. The system will continue to acquire data, in spite of the loss of AC power, for up to 24 hours at which time it will revert to an ultra-low power mode with only the clock running. The 24-hour period could easily be extended to several days, but it was not a requirement for this system.

The system currently requires an external AC source (110V at 60 Hz or 220V at 50 Hz), but it could easily be adapted to an external 12V DC source as provided by an array of solar cells or wind charger. An inverter (DC to AC converter) is available for the solar tracking mechanism and aspirator fan in this configuration.

---

[2]ANSI/ECMA - Conforms to the American National Standard for Magnetic Tape Information Interchange.

[3]Silent 700 ASR is a Texas Instruments registered trademark.

Table. III-1: Sample Format IEA Demonstration System.

SOLAR MONITORING SYSTEM
EG&G LAS VEGAS, NEVADA
HAMBURG, FRG INTERCOMPARISON

WIND-D	WIND-V	HUMID	TEMP	BARO-P	NIP	PSP-H	PSP-I
0000 00 8:249:15:00 10							
+110.0	+1.339	+64.79	+16.14	+100.4	+1.114	+150.9	+148.8
0000 00 8:249:15:10 10							
+80.00	+1.586	+65.87	+16.13	+100.4	+1.870	+180.1	+177.9
0000 00 8:249:15:20 10							
+80.00	+1.038	+66.09	+16.20	+100.4	+1.971	+163.0	+160.8
0000 00 8:249:15:30 10							
+110.0	+1.465	+65.65	+16.25	+100.4	+1.301	+152.8	+150.6
0000 00 8:249:15:40 10							
+59.99	+1.514	+65.44	+16.11	+100.4	+.9429	+140.2	+137.7
0000 00 8:249:15:50 10							
+80.00	+1.466	+65.14	+16.16	+100.4	+1.301	+141.2	+138.7
0000 00 8:249:16:00 10							
+80.00	+.9702	+66.37	+16.23	+100.4	+1.317	+131.7	+129.2
0000 00 8:249:16:10 10							
+90.00	+.6968	+65.63	+16.29	+100.4	+1.589	+116.1	+113.7
0000 00 8:249:16:20 10							
+90.00	+.7168	+63.56	+16.23	+100.4	+1.137	+107.0	+104.6
0000 00 8:249:16:30 10							
+130.0	+.7256	+65.10	+16.29	+100.4	+1.457	+116.3	+113.5
0000 00 8:249:16:40 10							
+140.0	+.9660	+65.64	+16.17	+100.4	+1.301	+106.5	+104.0

III.3 Options

All internal operations and data manipulations are controlled by a microcomputer. The software includes a utility program, floating point math package, and operating system implemented in Read-Only Memory (ROM). The operating system utilizes a modular concept which allows tailoring the system to unique user requirements by simply changing a plug-in ROM. This powerful yet simple technique can be exploited to dramatically alter system characteristics and performance. For instance:

1. A binary format (as opposed to ASCII characters) could be recorded on tape to optimize tape storage capacity.

2. Raw data rather than Engineering Units could be recorded on tape to minimize system complexity (to reduce operator intervention).

3. Scale factors could be entered in ROM rather than Random-Access-Memory (RAM) to achieve totally unattended operation (excluding routine maintenance, such as cleaning sensors, adjusting of the tracking mechanism, etc.).

4. Data could be stored in RAM rather than tape if extreme environmental conditions are anticipated.

5. Data could be retrieved by remote interrogation via telephone lines, land based radio links, or satellite.

6. The serial interface could be configured to interface with an external computer in a real-time situation.

7. Alternate processing techniques could be utilized; for instance, statistical summaries, integrated totals, etc.

8. The system could be expanded beyond sixteen channels, but each additional function would need to be analyzed on an individual basis.

9. The system could easily be adapted to operate from an array of solar cells or wind charger.

III.4 Items for Continued Development

III.4.1 Tape Playback

In a typical domestic installation, the Solar Monitoring System would be located at a remote site with limited support hardware under rather primitive conditions. The Texas Instruments Silent 700 (or equivalent tape reader) would be permanently located at the university or other agency that performs the tape playback and analysis. This may create a logistics problem if the field operator needs to analyze the contents of the tape cassette.

The problem has been solved in the Department of Energy demonstration system by upgrading the design to allow tape playback on the Data Acquisition Unit. This also opens up the possibility of a remote interrogation technique when tape is the recording medium; however, under these conditions with the tape periodically being recycled, data verification should be implemented during the recording process in order to minimize the error rate.

NOTE: This list of options is being submitted for user guidance only, to indicate the type of flexibility inherent to the system and to provoke some thought on the user's part in planning a remote network. Some of these items have already been implemented; others would require some additional development and would obviously have some cost impact.

III.4.2 Tracking Mechanism

It has been virtually impossible to make direct beam measurements in a remote environment using commercial pyrheliometer mounts with synchronous drives. It is difficult even in well attended locations if the AC power source is unreliable or if weather conditions prevent frequent mechanical adjustments. In spite of these limitations, a standard Eppley equatorial mount was used in the US DOE instrument package during the "Intercomparison" because of the importance of the parameter and the high probability for error if calculated from the total horizontal and diffuse components and, finally, because a better mount was not available.

The lack of a device consistent with the performance of the rest of the system, coupled with our desire to demonstrate a model resource assessment package, has stimulated our own efforts to produce an autonomous microprocessor controlled unit. Although there are currently no plans to interface the device to the US DOE demonstration system, the following is included for information purposes.

> SUN FOLLOWER III: A MICROPROCESSOR CONTROLLED PYRHELIOMETER MOUNT. SUN FOLLOWER III is a microprocessor controlled pyerheliometer (Fig. III-6) mount optimized for use in a remote environment. A typical payload would consist of one to four Normal Incidence Pyrheliometers and a Sun Sensor (a four-quadrant diode assembly for automatic fine correction). For simplicity's sake, a polar (equatorial) mount was used rather than elevation-over-azimuth. As with all polar mounts, it must be leveled with the North-South alignment and site latitude set prior to the first day's initialization; the device is then pointed at the sun using manual controls. All subsequent operations are under software control. Each axis is driven by a precision stepper motor: the hour-angle axis steps at the mean sun rate of 15 degrees per hour in 0.01 degree increments during the daytime "tracking" mode; the next day's hour-angle and declination corrections are made during a rewind cycle at night based on data derived from the solar ephemeris programmed in ROM. Since it is not an "active" tracker, there is no danger of losing "track" at low solar intensities.

Some of the other salient features are:

1. Low power consumption - 15 Watt average
2. Long term unattended operation
3. Closed loop correction at noon provided the solar intensity is above a preset threshold
4. Automatic recovery from an "iced-up" condition
5. Automatic recovery from the loss of external power (typically a photovoltaic array and rechargeable battery)
6. Day of year and time of day derived from a stable internal clock
7. No need to periodically unwind sensor cables
8. Diagnostic port for status reporting and remote interrogation

Although the need for such a device seems obvious, especially in remote networks, it appears that the ultimate demand may be more a function of cost than need. Efforts are therefore continuing to substantially reduce the cost of production units.

III.4.3 Solid State Storage

The tape transport limits the environmental specifications of the system to approximately (-) 20° C to (+) 50° C. If the environmental specifications need to be extended, there appear to be two reasonable alternatives: a tape transport with better environmental specifications (currently in the prototype stage) or additional CMOS memory. An extension of the existing array using conventional memory chips would create a severe packaging problem; however, large scale hybrid packages are currently being assembled in Las Vegas. It appears that two printed circuit cards with hybrid chips could duplicate the present tape storage capacity.

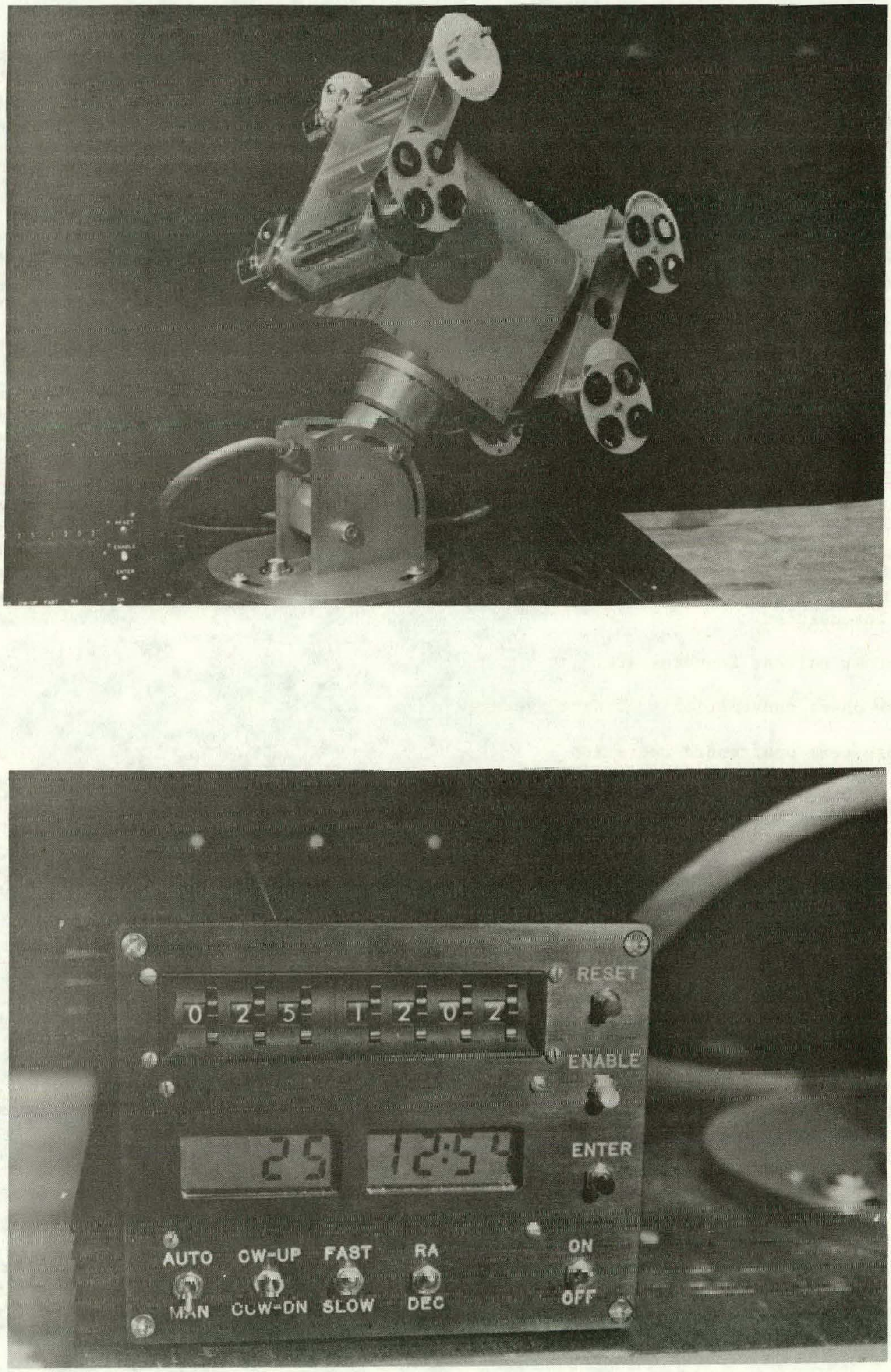


Fig. III-6 Sun Following Pyrheliometer mount and control unit.

III.5 Cost Analysis

Projected costs in 1978 United States dollars for the basic sixteen channel system (but supplied with only eight sensors) are listed below. These figures are based on some reasonable production quantities. It should be noted that although the emphasis was placed on quality and reliability rather than cost, the total package is still within the original budget of $25,000 per system.

1.	Horizontal Pyranometer	$ 1,000.00
2.	Inclined Pyranometer	1,000.00
3.	Pyrheliometer	900.00
4.	Equatorial Mount (AC powered)	1,300.00
5.	Wind Sensors	1,000.00
6.	Ambient Temperature	200.00
7.	Relative Humidity	500.00
8.	Barometric Pressure	400.00
9.	Data Acquisition Unit	11,000.00
10.	Cabling and Connectors	500.00
11.	Hardware	1,200.00
	Total	$19,000.00

The costs for items 1 thru 4 are essentially catalog prices for premium quality components. Substitutions could be made, and the cost impact would be obvious and easy to calculate.

Substitutions could also be made for the weather sensors (items 5 thru 8); however, each item requires a unique interface to the Data Acquisition Unit. Changes in this area would probably require a different interface circuit; therefore, any cost impact would need to be analyzed on an individual basis.

The cost of the Data Acquisition Unit includes the interface for each of the additional uncommitted eight channels. Each of these channels includes its own differential amplifier to accommodate thermopile type sensors comparable to items 1 thru 3. Interfacing for different types of sensors would need to be analyzed on an individual basis. The cost of the Data Acquisition Unit is also based on local shop rates and includes a minimum level of documentation.

The hardware cost (item 11) includes the weather tower and other miscellaneous items but does not include the solar platform described in the text. This platform was designed to satisfy the particular needs of the Department of Energy demonstration package which may not be appropriate to other users or locations. Furthermore, it was felt that many potential users have the capability to fabricate their own; indeed, they may even already have a satisfactory platform.

The 1978 cost of the Texas Instruments Silent 700 is approximately $3,500. The cost was not included in the estimate since the majority of potential domestic users already have comparable units interfaced to their computer facilities.

It should be noted that this cost information is purely an estimate based on our own experience. It was not inspired by any profit motive and in no way obligates any of the parties involved. It was intended to give users and potential users budget information and guidance for planning purposes.

CHAPTER IV

INTERNATIONAL ENERGY AGENCY

SWISS MOBILE SOLAR RADIATION RESEARCH SYSTEM

HAMBURG, SEPTEMBER - OCTOBER 1978

BY

P. VALKO & A. HEIMO
SWISS METEOROLOGICAL INSTITUTE
ZURICH, SWITZERLAND

IV.1 Introduction

The Swiss Meteorological Institute in Zurich has been operating a mobile solar radiation system since 1974. The main function of the system is to provide data on a wide range of solar radiometric phenomena at various sites throughout Switzerland and abroad. The system provides a mobile, state-of-the-art research platform from which detailed data on solar radiation can be acquired and retrieved. The instruments were developed, calibrated, checked, and installed by the Davos Observatory, Switzerland.

At the IEA-sponsored Hamburg Conference in 1978 it was found that the research quality sensors of the Swiss unit exceeded IEA guidelines for instrumentation variety, accuracy, and precision. The Swiss unit is primarily a research tool designed to sample solar radiation climates at various chosen sites and times in order to investigate a wide variety of radiometric phenomena. It is not proposed as a substitute for "IEA-type" devices. Some of the Swiss unit's sensors can operate only in fair weather. The intent of the IEA guidelines pertains to a meteorological sensor package suitable for all-weather design, testing, verification, and monitoring of solar energy systems. The goal of demonstrating to the solar energy community the utility of a "Swiss-type" research device compared to "IEA-type" devices was accomplished.

IV.2 Unit Description

IV.2.1 Vehicle Type

The vehicle is a double axle trailer, 6 m X 2; 3 m X 2.6 m (Figures IV-1 and IV-2). Fully loaded the trailer weighs about four metric tons.

IV.2.2 Power

The trailer carries three 380-volt, 200-meter electrical cables for operating off the normal power grid. A generator (3 X 380 volts, 6 KVA) provides power for remote operation.

IV.2.3 The Computer

The trailer houses the computer which controls the measurement program and initially processes the data (Figure IV-3). The computer is a Digital Equipment Corporation Model PDP 8/E with the following capabilities:

- 24 K Memory
- 2 Magnetic Tape Units TD8E
- 1 Reader-Puncher PT8E
- Disk. Unit RK 8E
- 1 Teletype
- 1 Analog/Digital Converter (32 Input Channels) Interfaces
- 3 Digital Input/Output Interfaces
- 2 Triple Input Interfaces (EP)
- 2 Step-Motor Interfaces (EP)
- 1 Line-Printer VERSATECK 1100 A

Fig. IV - 1

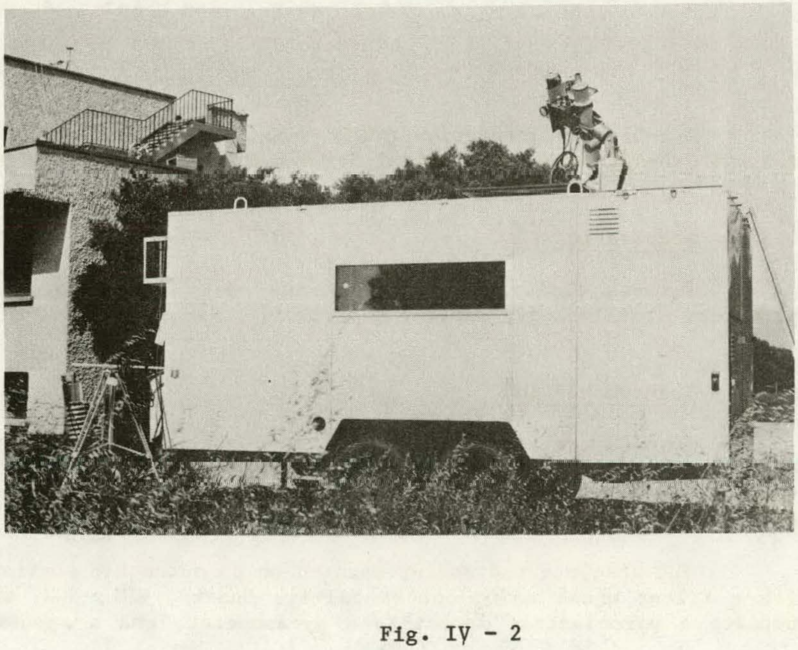


Fig. IV - 1 & 2
The research trailer housing
sensors and computer controls.

Fig. IV - 2

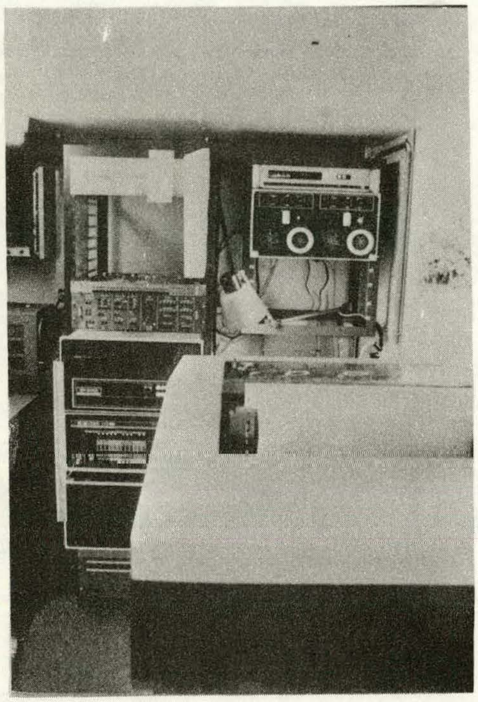


Fig. IV-3. Interior view showing the PDP8/E (for steering the instruments and for primary data processing) and its periphery components: magnetic tape units, line printer and plotter

A telephone connection (MODEM + interface + software) provides computer-to-computer communication with the Swiss Meteorological Service Office computer, a PDP8/A with DECNET8.

IV.2.4 Accessories

Various electronic equipment and spare parts are carried in the trailer. These include a voltmeter, oscilloscope, current generator, pulse generator, telescope, and theodolite.

IV.2.5 Instrumentation

Normally, seven pyranometers are connected to the computer through seven 100-meter cables (17 poles). Four are on a device called the pyranometer flower, as shown in Figures IV-4 and IV-5. Each of these four pyranometers stop through a possible 77 positions. The three remaining pyranometers cau be used in a variety of modes, as will be discussed in Section IV-3 of this paper.

The absolute radiometer mounted on an automatic suntracker (Figures IV-6 and IV-7) is equipped with a filter wheel using Schott filters Quartz, OG1, RG2, and RG8. The automatic sun-tracker also supports a pyroelectric detector, a pyranometer, and a spectroradiometer (measuring 16 wavelengths).

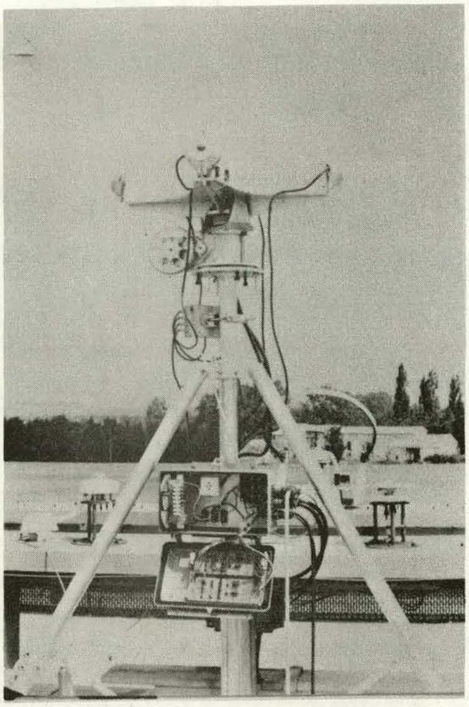


Fig. IV - 4

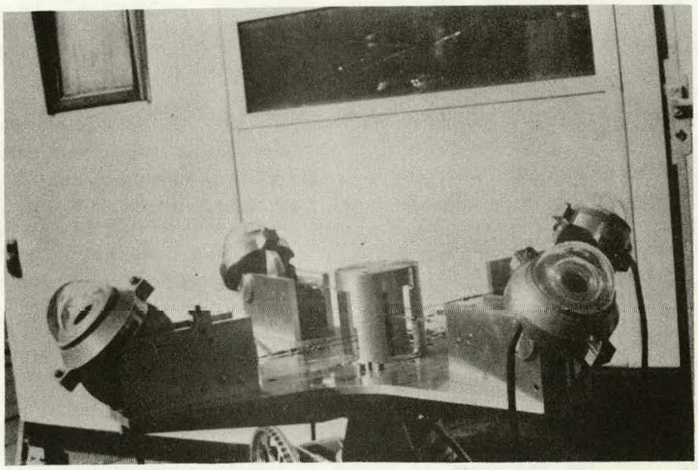


Fig. IV - 5

Fig. IV-4 & 5. Four pyranometers are driven by step motors and measure in 77 different tilts and directions.

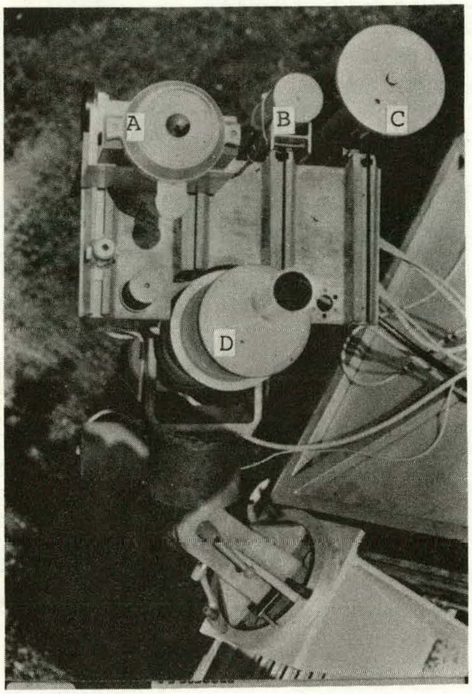


Fig. IV - 6

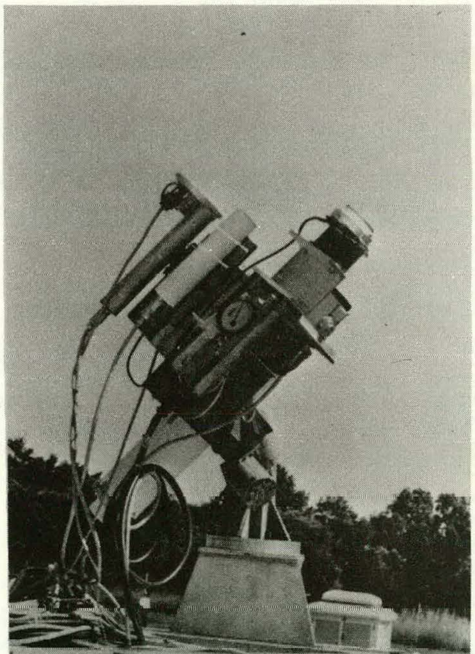


Fig. IV - 7

Fig. IV - 6 & 7. On the trailer's roof four instruments are mounted on an automatic suntracker: pyranometer (A), pyroelectric detector (B), absolute radiometer (C) with broad band Schott-filters OG1, RG2 and RG8 and spectroradiometer (D) measuring at 16 different wavelengths.

Four additional pyroelectric detectors are mounted on a sky scanner, as shown in Figure IV-8.

A 35-mm single-lens reflex camera is used to map the sky. This Nikon F2S with a "fish-eye" lens (aperture 180) is automatically controlled by the computer (Figure IV-9). A Shade disc occludes the direct solar beam from the camera lens.

The pyroelectric detectors have recently been redesigned. Silicon diodes have been used as sensor elements. The new sky photometer will be used for measuring the three Stokes parameters in the sun's vertical and a circumsolar spectrophotometer for measuring the Stokes parameters (I, Q, and U) in the sun's aureole (both are 16-wavelength devices). These devices will be added in 1980.

IV.3 Measurements Program

IV.3.1 Control

The measurement program is controlled entirely by the computer. A series of measurements is completed in 25 minutes, 40 seconds, with a 4-second interrupt time. During each interrupt, the computer determines what is to be done for each instrument. All analog signals are multiplexed and A/D converted. Instructions to sensors (stepmotors, etc) are fed through three digital output units. Check flags signal the proper execution of the instructions via six digital input units. All registered data are stored in the common memory and saved on magnetic tapes for further evaluation at the end of each series.

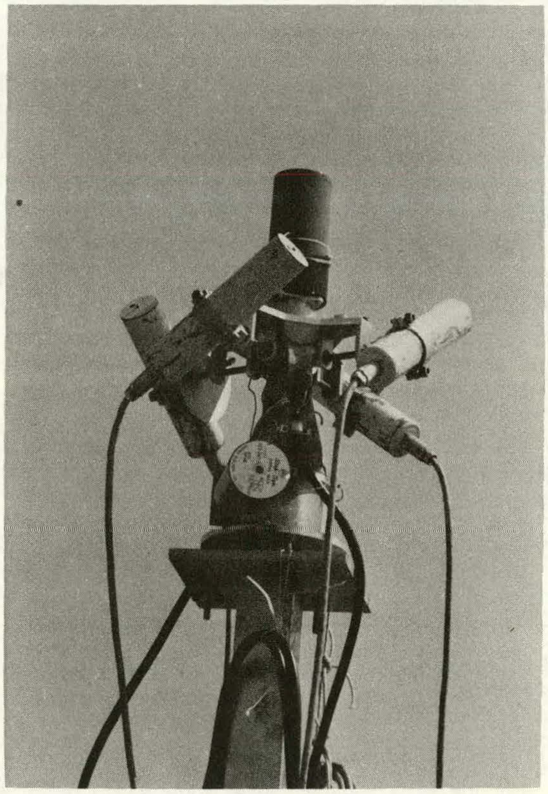


Fig. IV - 8. Four pyroelectric detectors scan the sky (5^{o} aperture)

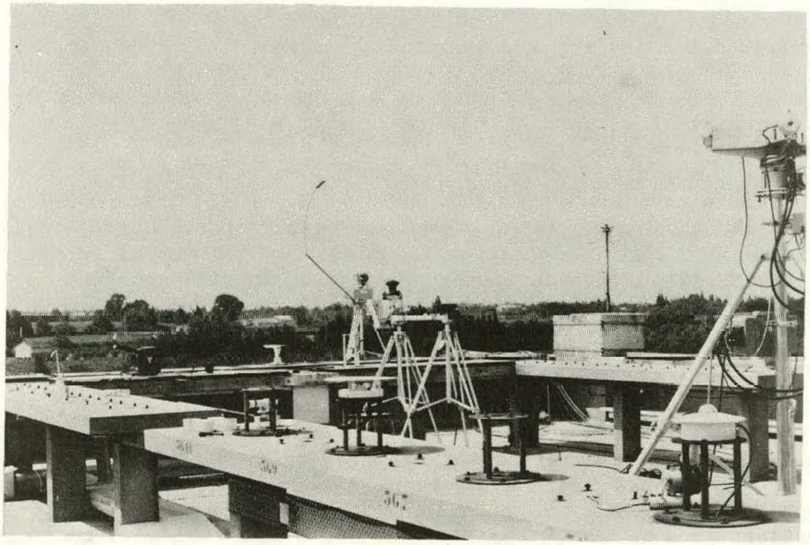


Fig. IV - 9. A shading disc always occults direct solar beam from a fish-eye camera.

IV.3.2 The Pyranometer Measurements

Pyranometers S1 - S4 are mounted on the "pyranometer flower", as shown in Figures IV-4 and IV-5. These four sensors begin a series of measurements with one pyranometer at each cardinal direction (vertical). Each pyranometer steps through 77 tilted positions from vertical to horizontal and return. A mean representative sample takes about 25 minutes, and four representative samples take six minutes each.

Pyranometer S-5 is mounted so that two operating modes are possible. The sensor can be mounted as S1 - S4 and scan the whole sky hemisphere in 77 positions (this pyranometer is three times as sensitive as the other sensors). Usually this is done with the sun's direct rays occluded.

The alternate mounting places S-5 on a 10-meter telescopic mast for angular scanning of the lower hemisphere. Thus, albedo can be scanned.

Pyranometer S-6 is mounted on the sun-tracker, remaining perpendicular to the sun's rays (see Figure IV-6).

The last pyranometer, S-7, is generally mounted horizontally to measure global solar radiation, but it can be rotated and tilted in any position.

IV.3.3 Absolute Radiometer, Spectral Radiometer, and Pyroelectric Scanning Program

The absolute radiometer and the spectral radiometer are placed on the sun-tracker, as seen in Figures IV-6 and IV-7. The absolute radiometer takes twenty-four measurements with or without the Schott filters OG1, RG2, and RG8 (one measurement every 64 seconds). The spectral radiometer measures at sixteen different wavelengths three times in each series of 48 measurements lasting about 25 minutes.

The new pyroelectric detectors are used in a mode similar to that of pyranometers S1 - S4 to scan the whole sky. The four detectors are capable of 121 measurements in about two minutes when arranged as shown in Figure IV-8. The sensors have 5^{o} apertures (0.00598 steradian); thus, they can be used to measure the diffuse sky irradiance from several points in the sky. The fifth sensor will be mounted on the 10 meter mast for angular scanning of surface reflectance.

IV.3.4 Spectrophotometer measurements

A circumsolar and sky spectrophotometer will be added to the sensor complement in 1980. The circumsolar device will record 224 values at angles of $0^{o}, 1^{o}$, 2^{o}, 4^{o} , 7^{o}, 11^{o}, and 16^{o} from the sun's center. Sixteen different wavelengths are measured twice at each angle. The sky spectrophotometer will make 416 measurements of sixteen different wavelengths from 0^{o} to 180^{o} elevation (at 15^{o} steps) in the vertical of the sun.

IV.4 Data Control and Analysis

IV.4.1 Data Control

On-board computers and/or the office computer verify the sensor output and evaluate initial data. All data are printed and/or plotted for each series of measurements. Final evaluations, special analyses, etc., are done on a large computer, the CDC-6500.

IV.4.2 Data Analysis

The data analyzed have a wide variety of possible applications. For instance, pyranometer data show patterns of distribution of global irradiance (depending on the orientation and tilt of the irradiated surfaces), thus facilitating the computation of global irradiance of an arbitrarily-positioned surface.

The absolute radiometer can measure direct radiation without filters so that diffuse radiation for any tilted surface can be calculated. Measurements recorded by the absolute radiometer with filters can be used to determine atmospheric turbidity.

The spectral radiometer can measure the spectral direct radiation at 16 different wavelengths in parts of the sun's spectrum where no water vapor absorption occurs so that precise information on the atmospheric aerosol can be obtained.

Data acquired by the Swiss Mobile Solar Radiation Research System is valuable to solar energy research scientists, meteorologists, and other members of the scientific community in addition to the general public.

CHAPTER V

INTERNATIONAL ENERGY AGENCY

COMPARISON OF PORTABLE METEOROLOGICAL INSTRUMENT PACKAGES

HAMBURG, SEPTEMBER - OCTOBER 1978

BY

K. DEHNE
METEOROLOGISCHES OBSERVATORIUM HAMBURG

The Federal Republic of Germany offered in October 1977 to host a conference for comparison-validation of the IEA guidelines for the Task IV technical experts at the German Weather Service Meteorological Observatory Hamburg (MOH). The invitation was gratefully accepted.

The instrument packages invited to the comparison (see chapters II, III and IV) embody the IEA guidelines (chapter I) describing the kind and accuracy of data needed for solar energy applications.

The testing planned was an international comparison of the packages to recognized standards to demonstrate the achievability of the guidelines-thus verifying the guidelines.

The specific objectives were:

- Presentation of the instrument packages and demonstration of their operation on an an international scale.
- Verification of the accuracy by comparison with data from a recognized set of national radiation standards and thus validation of the guidelines.

This chapter reviews the preparation, execution, and preliminary results of the comparison testing of instrument packages developed through Task IV in an effort to validate the IEA guidelines for meteorological instrument packages.

V.1 Preparation

V.1.1 Site Selection

Consideration was given to a choice between two sites in Hamburg. The roof of the Meteorological Observatory Hamburg (MOH) was chosen, for logistical reasons, over that of the agrometeorological research station 10 kilometers northeast of MOH, although both sites afford good exposure.

V.1.2 Response to Inquiry Regarding Participation in Comparison

In order to estimate the size of turnout at the September 1978 comparison so that facilities (particularly the MOH roof) could be prepared accordingly, an inquiry was sent to organizations previously represented on Task IV and other likely candidates, asking whether or not they intended to participate. Positive responses came from: (1) Kernforschungsanlage [KFA] of Julich, Federal Republic of Germany; (2) Swiss Meteorological Service of Zurich; and (3) United States Department of Energy (DOE).

Originally it had been planned to evaluate data instantaneously, but this was changed because the DOE had not yet defined the data format for its device and because the Swiss research van [MORAS] contains its own computer for data acquisition, processing, and recording.

V.1.3 <u>Installation Plan</u>

The top-view schematic diagram of the installation centers on the observatory roof of the German Weather Service buildings in Hamburg-Sasel (Figure V-1) depicts the following:

- The tiltable drawing desk with grill plate (1).
- Green artifical turf ("astro turf") (2) area of about 50 m^2 in southern foreground.
- The horizontal table (3) for sun-following devices [or pyranometers].
- The special carrier (4) for the shadow-ring devices at the edge of the lawn.
- The central carrier (5) over the lawn for the horizontally positioned pyranometers.
- The carrier (6) for the temperature and humidity sensors in the western corner of the lawn.
- The wind mast (7) [height: 2.8 m] with a cross-formed carrier for four systems of wind sensors.

The wind sensors and tilted pyranometers were arranged compactly to "see" the same conditions, as nearly as possible. The foreground of the tilted pyranometers was homogenized by the use of astro turf.

The Swiss MORAS was sited north-northwest of the observatory, as shown in Figure V-1, where direct solar radiation was measured. The Swiss "pyranometer flower" was placed on the roof of the neighboring building.

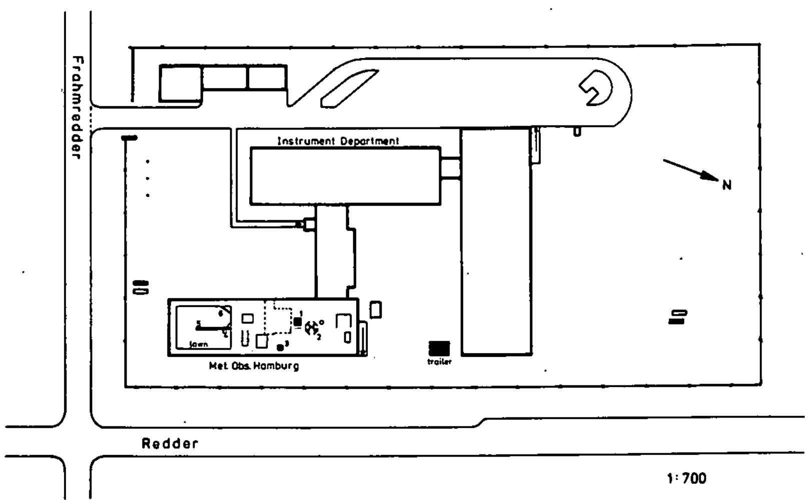
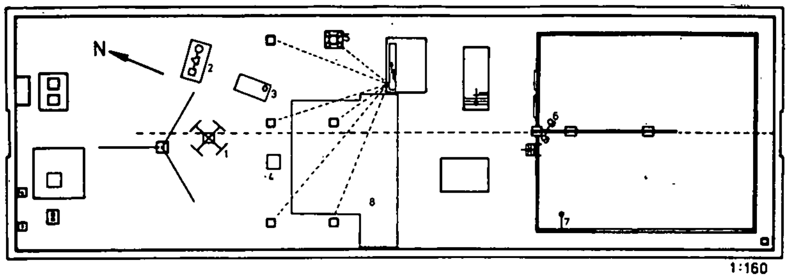


Fig. V-1. Top view of the German Weather Service building in Hamburg-Sasel



1: Wind mast (cross carrier in 2,8 m height) with 3 wind sensors (speed and direction)

2: Little mast (EG&G IP) with sensors for temperature, humidity and pressure (height: 2 m)

3: Solar table (EG&G IP) with Eppley NIP and data logger of EG&G

4: Tiltable desk with 5 pyranometers (2 Eppley PSP; 2 MG-Solarimeter, 1 PD Davos) and 2 balancemeter (type: Schulze)

5: Table with 4 pyranometers for measurements of global radiation (1 Eppley PSP, 2 MG-Solarimeter, 1 PD Davos)

6: Carrier with 2 shadow ring devices (incl. 2 MG Solarimeters)

7: Carrier arm with Frankenberger Sensor (dry and wet temperature)

8: Artificial turf ("astro turf"), about 50 m^2

Fig. V-2. Top view of the observatory roof with installation centers for IEA-IP-Comparison 1978

V.2 Setup Plan

Originally it had been planned for independent engineers to install the three sensor packages, but after discussing the matter with the builders, it was decided that the idea had no advantage. Therefore, each designer installed his own equipment. An engineer travelled with and operated the Swiss MORAS. The KFA and DOE engineers taught MOH staff members to operate their packages.

A few details on the installations of all three meteorological instrument packages follow:

V.2.1 USA Department of Energy (Manufacturer: EG&G, Las Vegas)

- Dates of arrival to completion of installation: 22 to 25 August 1978
- Personnel: 1 engineer + 1 scientist
- Special Parts:
  - 1 Table on which to install all radiation sensors and the data acquisition system
  - 1 mast for sensors of wind, pressure, humidity, and temperature.

V.2.2. Swiss - MORAS (Manufacturer: Davos, Switzerland)

- Dates of arrival to completion of installation: 22 to 26 August 1978
- Personnel: 1 engineer + 1 physicist
- Special Parts:
  - 1 trailer with sun-following device and on-line computer
  - 1 "pyranometer flower" with tripod.
  - 1 fish-eye camera with stand.

V.2.3 Federal Republic of Germany - MADAS (Manufacturer: KFA, Julich)

- Dates of arrival to completion of installation: 17 August to 4 September 1978
- Personnel: 1 scientist (data-logger installation) +

  1 MOH staff member to be co-worker on sensor installation
- No special parts foreseen.

V.2.4 MOH Reference Sensors

The reference sensors of MOH were installed about the same time as the KFA sensors. Measurements, sensors, and equations used were:

- Global Radiation (G): Moll-Gorczynski Pyranometer (Kipp & Zonen, Type: CM6)
- Diffuse Sky Radiation (D): As for G, but with Shadow Ring Device (About 10°)
- Diffuse Solar Radiation (I): Calculated by (G -D)+(sin h_o)
  [h_o = Solar Elevation Angle]
- Global Radiation on Inclined Surface ($G\alpha$): As for G
- Infrared Radiation on Inclined Surface: Calculated by ($T\alpha$- $G\alpha$) $T\alpha$ is total radiation on inclined surface (Measured by the Schulze Balancemeter manufactured by Dr. B. Lange, Berlin.)
- Global Radiation (G_{Si}) with Silicon Cell: Silicon Pyranometer (Lambda Instruments, Type: LI-2005 R)
- Air Temperature (T): Ventilated Dry Thermometer (Frankenberger system)
- Humidity (H): Ventilated Wet Thermometer (Frankenberger System)
- Wind Speed:]
  ] WIMEA (German Weather Service device)
- Wind Direction:]

All MOH data were recorded on the KFA data-logger, except the silicon pyranometer. The data (G and $G\alpha$) for pyranometers were simultaneously recorded on the EG&G device to flag any possible recorder bias. Table V-1 gives an overview of measurements recorded by all three packages.

V.2.5 Final Positioning of Instruments

Final locations on the observatory roof for the instruments are shown in the top-view schematic diagram in Figure V-2. Principal deviations from the planned arrangements (see Figure V-1) occurred in the lengths of cables and the addition of the EG&G solar table. Figure V-3 displays the distribution of instruments on the tiltable desk. The EG&G data-logger was placed on the lower platform of the solar table. The MOH laboratory housed the KFA data acquisition system, and the Swiss MORAS contained its own data acquisition and processing unit.

Quantities	Symbol	EG&G	KFA	MOH	MORAS	Remarks
Direct Solar Radiation	I	X	X	X	X	
Global Radiation	G	X	X	X	X	
Global Radiation on Inclined Surface	G_α	X	X	X	XX	
Incoming Infrared on Inclined Surface	$(IR)_\alpha$		X	X		
Air Temperature	T	X	X	X		
Wind Speed	W_s	X	X	X		
Wind Direction	W_d	X	X	X		
Humidity	H	X	X	X		Optional
Diffuse Sky Radiation	D		X	X		
Global Radiation with Si-Cell	G_{Si}		X	X		
Sunshine Duration	SS			X		Additional
Atmospheric Pressure	p	X				

TABLE V-1: PARTICIPATION IN THE DIFFERENT I.P.COMPONENTS

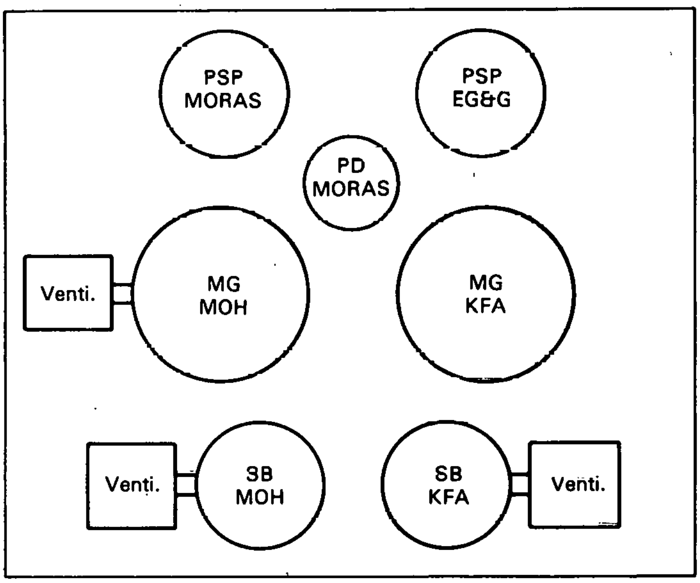


Fig. V-3: Distribution of Radiation Sensors Over the Tiltable Desk (Area: 1.2m x 1.0m) (Pyranometers: PD, PSP, MG Balancemeters: SB)

V.3 Comparison

V.3.1 Introduction

At the end of August, a comparison plan was devised to correlate sensor positioning with albedo conditions (see Table V-2). Adverse weather conditions during the comparison (see Table V-3) forced a revision of the plan. The tilt schedule was the only variable remaining from the original plan. Plans for some tests were cancelled.

Most data were recorded in resolutions of ten-minute means in true solar time and stored to facilitate retrieval if detailed analyses were called. The MORAS delivered data at a higher resolution than the other devices during the first half of September.

V.3.2 Comparison Activities

A brief history of events is presented in Table V-4. The comparison began September 12, 1978, with the KFA data-logger recording MOH data and the MORAS recording ten-minute means. During the first week, it was discovered that the sampling rate was insufficient; therefore, the KFA software was modified to accelerate the sampling rate from one scan every 40 seconds to one every 17 seconds.

As previously mentioned, weather conditions for the tests were less than optimum. With no improvement forecast, the Swiss MORAS was returned to Zurich on September 18. Several Swiss-owned pyranometers, however, remained in Hamburg for the duration of the comparison. The Swiss type horizontal and inclined pyranometers were hosted by the KFA data logger; a second inclined pyranometer (Eppley PSP) was connected to the EG&G data-logger.

Tilt Angle (t)	Foreground	Wind Sensor	Temperature Sensor
t=0°; Over 2+2+1 Day x+2 y−2 1 Clear t=45°; Over 7 Days at Least 1 Clear Day t=60°; Over 7 Days at Least 1 Clear Day On a Very Clear Day at Noon Exchange Tilt Angles Every 10 Minutes Tilt Angle will Vary Daily to get All Weather Conditions at Each Tilt	Normal Case: Artificial Turf Special Case: Concrete; Black Paper (for Clear Days: Morning vs. Afternoon)	Exchange Positions by Turning Mast, Especially if Large Differences are Found	U.S. Device-Sensor Fixed Over Concrete Observatory Sensor- Movable from Position Over Lawn (Natural) to Position Over Concrete in Case of Overcast and Clear Days (Especially Afternoons) KFA (German) Device- Same as Observatory Sensor to Determine Any Concrete vs. Grass Differences

First Day = x
Last Day = y

78-11373M/5-5

TABLE V-2: Comparison Test Plan for Instrumentation Packages

TABLE V-3: Hamburg Weather of September 1978 and October 1978

Quantity	September 1978	Statistical Mean	Deviation 1978-Mean	Deviation 1978-Mean
Rain	180mm	67mm	269%	
Days with Rain	27	15	180%	
Air Temperature	12.8°C	14.0°C		−1.2°C
Sunshine Duration	71h	169h	42%	
Global Radiation (Monthly Mean of Daily Sum)	733J cm^{-2}	981J cm^{-2}	75%	

Quantity	October 1978	Statistical Mean	Deviation 1978-Mean	Deviation 1978-Mean
Rain	53mm	60mm	88%	
Days with Rain	16	17	94%	
Air Temperature	10.5°C	9.6°C		+0.9°C
Sunshine Duration	87.3h	98h	89%	
Global Radiation (Monthly Mean of Daily Sum)	499J cm^{-2}	549J cm^{-2}	91%	

Table V-4: Milestones of the Comparison Course

27 Aug. 1978: End of Installation of EG&G I.P. and of MORAS.

4 Sep. 1978: End of Installation of MOH reference sensors and of KFA I. P.

7 Sep. 1978: First measurements of comparison (10 min. means).

9 Sep. 1978: MORAS routine converted to HAMESS program (i.e. 10 min. means).

12 Sep. 1978: Acquiquisition of MOH data by KFA data logger (MADAS) (Data sampling rate: 1 per 40.s).

18 Sep. 1978: Departure of MORAS trailer. MORAS pyranometers connected to KFA logger.

20 Sep. 1978: Improved sampling rate of 1 per 15s for KFA data logger.

23-25 Sep. 1978: Breakdown of KFA data logger.

3 Oct. 1978: Exchange of tilt angle to 45°

9 Oct. 1978: Exchange of tilt angle to 60°

13 Oct. 1978: Tests at noon time

20 Oct. 1978: End of comparison.

Because of poor weather, it was decided to extend the comparison period to October 20. (Task IV and V IEA experts met in Hamburg from October 17 to 20 1978.)

The angle of inclination of the tiltable desk was changed from 0° to 45° on October 3 and maintained until October 9, when it was increased to 60°. Special sensor and tiltable desk tests were conducted October 13, one of the few sunny days during the comparison (see Tables V-3).

V.3.3. Maintenance

Routine maintenance (i.e. changing cassette tapes, cleaning, and making minor repairs on the instrument packages) was performed by the MOH staff.

V.4 Preliminary Results

V.4.1 Data

The data set consisted of recordings of ten-minute means taken during a six-week period. Exceptions to the ten-minute rule were measurements of direct solar radiation taken exclusively during stable weather conditions by the MORAS during the first half of September.

Table V-5 typifies a data print-out of ten-minute means from each of the devices: the MADAS (KFA), USA/DOE (EG&G), and the MORAS (EMC).

Initial analysis showed the quality of the data sufficient. Ten-minute means resulting from more rapid sampling rate of the MADAS (KFA) was instrumental in raising the quality of the data set. Any potential errors attributable to low sampling rates and deviations of the print-out from true solar time can be discounted by evaluating the hourly means built from ten-minute means.

Because of the poor weather, there are few test results of high-level solar radiation days (> 500 w/m^2) in the data set. There were more days below 100 W/m^2 with correspondingly high relative errors in the radiation data set.

Because of the cloudiness, periods of direct solar radiation (I) are short, and the data set for (I) is small. There are three reasons why only clear sky conditions can be used in the comparison of (I). First, apertures of the sensors differ. The aperture for the Eppley pyrheliometer (EG&G) is 5° compared to 10° for that of the shadow-ring devices (KFA and MOH). Second, the accuracy of calculating ($I = [G - D] \div \sin h_o$) is reduced for the shadow-ring devices because the differences between global radiation (G) and diffuse radiation (D) are small. For this calculation, solar elevation angle (h_o) was the angle at mid-point of the solar hour studied. Accuracy in the calculation for (I) would have been heightened if (h_o) had been calculated for each ten-minute mean. It was agreed, however, that this exercise would not have affected the comparison results significantly. Third, inability to point the pyrheliometer to the sun on cloudy days caused tracking errors and thus data errors. It was impossible to check the alignment on low-level radiation days with a high degree of accuracy. Without at least one, and preferably two, daily alignment checks, pyrheliometer data are more or less "suspect." A "smart" tracker can eliminate this problem.

Dew and rain rendered some pyranometer data inaccurate. Only the MOH standards were equipped with a ventilator to avoid or at least reduce humidity and condensation on the glass domes.

V.4.2 Results of Initial Evaluation

The objective of the initial evaluation of the data sets, using IEA guidelines as standards, was to deliver a preliminary overview of the achievabilities of the accuracies specified in the guidelines.

In the inital evaluation, ratios of hourly means to corresponding hourly values of the reference sensors were calculated from data recorded during 186 hours beginning September 19. For 140 hours, only radiation data were analyzed. In the other 46 hours, all parameters were analyzed. Hours with global radiation mean values > 100 W/m^2 were preferred.

Radiation data were classified according to IEA guidelines at ± 25 W/m^2 and $\pm 5\%$ ($\pm 10\%$ for IR) deviation. At 25 W/m^2, the number of hours not meeting the criteria follow:

Parameter	Number of Hours not Meeting ± 25 W/m^2 Guideline	Number of Hours in Sample
I	71	360
G	8	540
G_α	8	540
IR_α	21	180
D	1	180

The problems associated with direct solar radiation (I) were discussed in Section V.4.1. The probability of a sensor failure in the EG&G Eppley NIP was excluded by comparing its operation under clear sky conditions with that of the MOH Linke Feussner Aktinometer. The data obtained by these two sensors showed a high correlation ($\pm 1\%$ deviation), thus aperture dependent errors and tracker errors are suspect in the 71 failures.

The majority of the 21 deviations for infrared radiation ($IR\alpha$) occured at $\alpha = 60°$ during clear weather from October 10 through 13. However, when the $\pm 10\%$ accuracy requirement is applied, only one hourly mean is judged deficient.

Testing the global radiation (G) and global radiation at the tilt angle (G_α) against the $\pm 5\%$ accuracy requirement was done only when the irradiation was > 100 W/M^2. Some 300 hourly means met this selection criterion in October. Of the 300 hourly means, G deviated ($\pm 5\%$) 20 times, and G_α deviated 18 times.

Using a data set of 100 hourly means, the silicon pyranometer (G_{Si}) of the KFA instrument package deviated more than $\pm 10\%$ from the MOH (G) only four times. In general, the data (manufacturer's calibration factors are used) from the KFA pyranometers are beneath MOH standards. This can be seen in the sample analysis data in Figure V-4. The EG&G and Swiss MORAS pyranometers, on the other hand, tended to record higher values than those of MOH standards.

V.4.3 General Remarks on the Instrument Packages

This Swiss MORAS was developed specifically for solar radiation research programs and was not intended to be a portable meteorological instrument package in the IEA sense. Currently, it requires a resident engineer to operate the computer. It has a weather-sensitive pyrheliometer but no infrared radiometer. Its objectives are much broader than those of the other two instrument packages. The MORAS serves as an excellent example of a mobile meteorological research station with possible applicability to many short-term solar energy related research tasks.

The KFA instrument package used in Hamburg had all mandatory and optional sensors specified by the IEA but had not yet reached its fullest design potential. The internal statistical program which printed out standard deviations from the means allowed the data scatter to be estimated. The MADAS data-logger was programmed to accept data on any combination of 30 channels, but the magnetic storage system (floppy disc) with tape reels had not yet been installed.

The EG&G instrument package fulfilled the portability criteria. The large table used in Hamburg supported the packing box and served as a sensor platform, but it was unnecessary for operating the package. Actual values of each parameter could be displayed to facilitate monitoring and adjusting. Tests proved the device weatherproof.

During the analysis, the MOH pyranometers connected to the EG&G data-logger delivered higher mean values than did the same sensors connected to the KFA data-logger. A mean difference in global radiation in October of two percent was calculated; the reason for the discrepancy is unknown.

Comparisons of wind and temperature data showed some inconsistencies. Reasons for the differences may have resulted partially from disparities in placement of the devices on the rooftop. The temperatures recorded by the EG&G system often rose 1^{o} higher than those recorded by the KFA system.

The wind direction data of the EG&G device deviated 10^{o} from standard values. These deviations probably resulted from differences in methods of calculating the mean wind direction. The EG&G device, the most frequently used, observed wind direction rather than the average wind direction.

A complete evaluation of all data is planned to provide an in-depth comparison of both the radiation and non-radiation meteorological data.

V.5 Final Remarks

The Hamburg Comparison was a success in spite of the small number (3) of instrument packages and the poor weather (low-level radiation).

In the opinion of the participants, the experience gained and the data gathered are valuable, and the task objectives were accomplished.

Based on the results of the Hamburg Comparison, the need for technical modifications is apparent. It is recommended that the IEA Guidelines be modified to include:

- o Precise aperture angles for measuring both direct and diffuse light be specified and compared against like aperture standards
- o minimum system sampling rates (scans/minute) for data-loggers must be at least 1/50 of integration time.

Undoubtedly, further recommendations will be made after the participants and other experts in the field of meteorology have rewieved the Hamburg Comparison results. A further comparison action may be of value under the following conditions:

- o climate of comparison site guarantees high solar radiation levels
- o additional countries will build devices and will participate
- o all packages have a full complement of sensors to ensure uniformity in data comparability

Table V-5: Examples of Original Data Lists (from 12 Sept. 78)

KFA (MADAS)

Example of Data List

TIME: 11.20 (TST)
DATE: 78/ 9/ 12

1	467.3+- 10.15	2	616.0+- 14.87	3	148.6+- 11.39
4	24.13+- 1.370	5	641.0+- 17.57	6	354.0+- 10.48
7	661.0+- 26.84	8	15.00+- 3.800	9	10.10+- 1.072
10	0.000+- 0.000	11	55.00+- .1000	12	.4340+- .2084

1	493.2+- 9.260	2	644.0+- 15.05	3	150.7+- 12.54
4	23.40+- 1.430	5	653.0+- 13.44	6	383.0+- 2.700
7	10.80+- 4.100	8	15.70+- 3.700	9	7.900+- 8.500
10	340.0+- .7500	11	1.500+- 0.000	12	54.21+- 0.000

Data Key

1 Dir. Solar (hor.)	2 Global (hor.)	3 Diffuse (hor.)
4 Diff./Global %	5 Global (incl.)	6 IR (incl.)
7 Silicon-Cell	8 Temp.	9 Wind (speed)
10 Wind (dir.)	11 Humidity	12
		15

1 Dir. Solar (hor.)	2 Global (hor.)	3 Diffuse (hor.)	
4 Diff./Global %	5 Global (incl.)	6 IR (incl.)	MOH
7 Wet Temp.	8 Temp.	9 Wind (speed)	Data
10 Wind (dir.)	11 Sunshine	12 Humidity	

MORAS

Example of Data List

ANZAHL A/D-ABLESUNGEEN PRO MESSWERT 100
ABSTARD ZWISCHEN 2 MESSWERTEN IN SEC 20
KAMESS BILDET MITTELWERT UEBER 3 MESSWERTEN

GEMITTELTE WERTE VON BIS (CET)	S 1. . . . . S 5		S 6	S 7
11 7 0 11 16 40	−11.07	−6.37	461.08	457.30
11 17 0 11 26 40	−10.54	−5.39	633.89	627.06
11 27 0 11 36 40	−11.12	−5.62	648.05	646.13
11 37 0 11 46 40	−10.00	−5.46	395.26	397.07
11 47 0 11 56 40	−11.02	−6.35	220.90	230.34
11 57 0 12 6 40	−11.20	−9.19	643.51	649.14
12 7 0 12 16 40	−11.13	−8.00	629.20	632.74
12 17 0 12 26 40	−11.19	−8.46	504.20	505.30

S 6 resp. S 7: Global radiation resp. Global radiation on Inclined
S1. . . .S5: Channels of "Pyranometer Flower"

EG&G

Example of Data List

0002 00 8:255:11:37 10
+320.0 +6.685 +63.87 +15.49 +100.6 +750.0 +651.3 +658.8
+649.3 +639.5 +646.4

Data Key

Tape No./Year Index/No. of Day/Time (CET)/Interv. (min.)
Wind-D/Wind-Sp/Humid/Temp./Baro-P/Direct-S/Global/Global-Incl.
Global-Inc. (MORAS)/Global (MOH)/Global-Incl. (MOH)

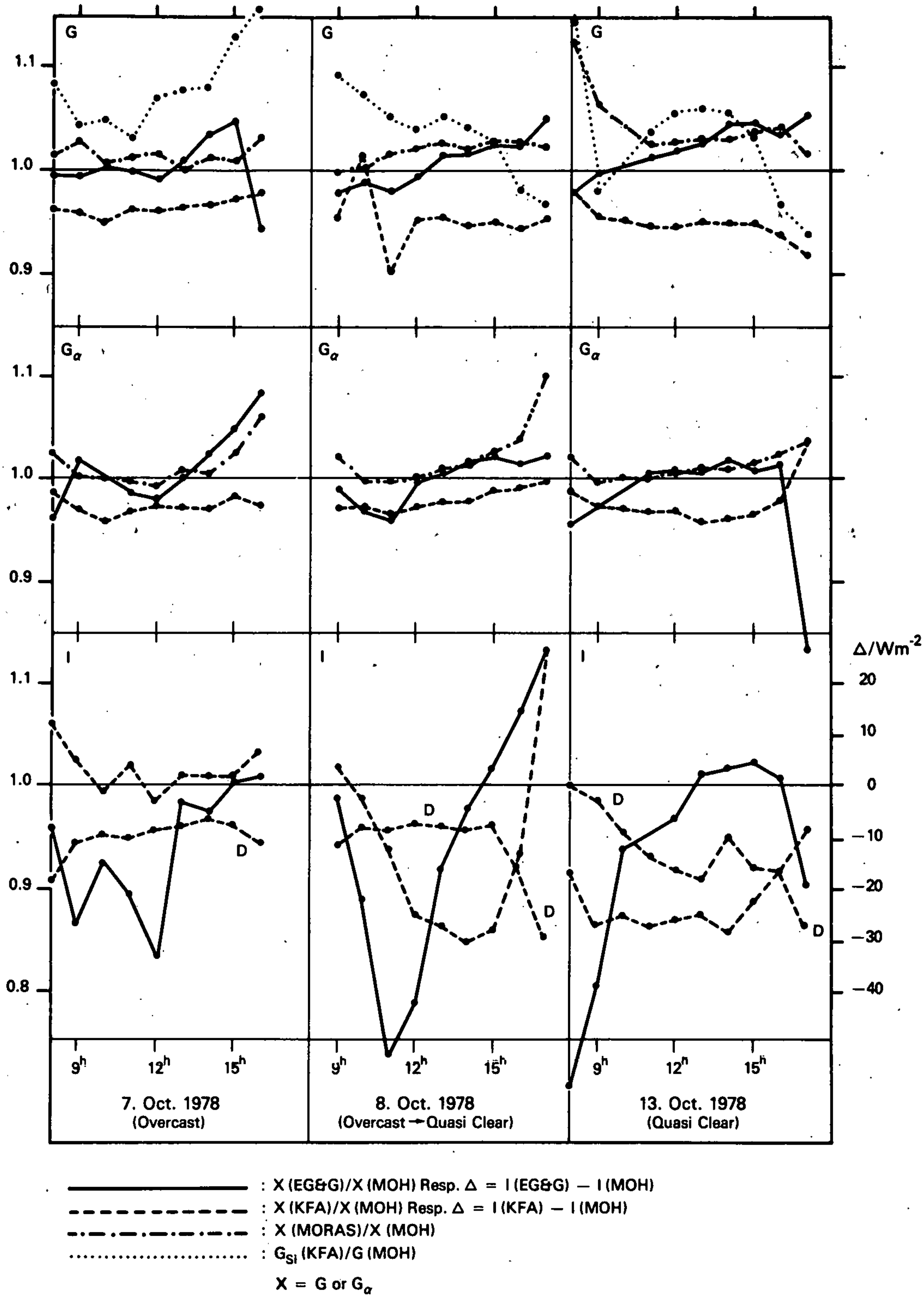


Fig. V-4: Daily Course of Ratios Resp. Differences of Hourly Means Related to the Reference Values, for 3 days with Different Weather Type.

CHAPTER VI

PRELIMINARY CONCLUSIONS

VI. Preliminary Conclusions

The initial results presented in this report were discussed at the October 1978 Hamburg experts meeting. In general, the conclusion was that we had achieved our objectives for the subtask, and the comparison was a success. We had:

1 Written a specification based on user needs to be used as a guideline for building portable meteorological instrument packages.

2. Built devices according to the guidelines, using currently available sensors and electronics, at a reasonable cost ($20,000 and $30,000) for production.

3. Validated the guidelines through the comparison of the devices built to an accepted set of meteorological standards.

Based on these preliminary conclusions, the expert working group foresees no necessity for further IEA meteorological instrument package comparisons. It was concluded that any device built can now be tested against a set of known meteorological standards, that the results can be published, and that these results can be compared to the IEA guidelines.

It is recommended that solar energy scientists use the specifications as a guideline when purchasing meteorological monitoring packages or when designing and building their own meteorological monitoring packages. Further details on available solar radiation sensors is included in Appendices C and D.

APPENDIX A

STANDARAIZED DATA ACQUISITION PACKAGE FOR THE ANALYSIS OF MULTI-COMPONENT SOLAR HEATING SYSTEMS

E. Benes, M. Bruck[1], F. P. Viehbock, P. Blum, L. Wimmer, W. Husinsky, K. C. Harms

Institut fur Allgemeine Physik, University of Technology Vienna
Karlsplatz 13, A-1040 Vienna, Austria

[1]Austrian Solar and Space Agency (Assa),
Garnisongasse 7, A-1090 Vienna, Austria

STANDARDIZED DATA ACQUISITION PACKAGE FOR THE ANALYSIS OF MULTI-COMPONENT SOLAR HEATING SYSTEMS

E.Benes, M.Bruck[1]), F.P.Viehböck, P.Blum, L.Wimmer, W.Husinsky, K.C.Harms

Institut für Allgemeine Physik, University of Technology Vienna
Karlsplatz 13, A-1040 Vienna, Austria

[1])Austrian Solar and Space Agency (ASSA),
Garnisongasse 7, A-1090 Vienna, Austria

ABSTRACT

Evaluation of different solar energy test stations has shown the necessity to standardize long term data acquisition and recording in order to improve the effeciency of multi-component heating systems. Therefore the Austrian Federal Ministry for Science and Research initiated and financially supported the development of a standardized data acquisition package. This package consists of various transducer types and the compact microprocessor-controlled data logger "HELIO-DATA 1".
The primary data are acquisited every minute by reading the transducers in sequence. Every 12 hours a data block (nightly or daily sums, nightly or daily mean values) is recorded at the ECMA 34 standard magnetic tape cassette. These cassettes are exchanged once a month and sent from the various stations under test to the central computer evaluation station.

INTRODUCTION

There is a natural gap between the need for room heating and the simultaneous availability of insolated solar energy, especially in northern countries. To overcome this problem, so called multi-component heating systems are used, which are combinations of solar collectors, heat storage tanks, heat pumps, and conventional stand by heaters. The efficiency and economy of such multi-component systems for the low temperature heat supply can be judged only on the background of accurate long term measurements of all parameters relevant for the system performance.

To avoid frustrating experience, an adequate measuring system should have the following features:

- fully automatic acquisition, modification (summing, averaging) and storage of the measured data.
- high data storage capacity
- direct display of all current measured values (temperatures, heat flow counts, etc.) in proper units
- easy handling
- high reliability
- immediate detection and display of failures in the heating or measuring system (drop out of pumps or heat flow meters)

NEEDS TOWARD A STANDARD

Since multi-component heating systems tends to be rather complex, a great number of data has to be collected for detailed system analysis. The installation of transducers like temperature probes, flow meters, solarimeters, electric energy counters, etc., as well as the corresponding amplifier, display and recording devices significantly contributes to the overall costs of a test station. Therefore all efforts reducing the costs for the measuring system and the data evaluation should be encouraged.

A standard measuring equipment, capable of solving even the most general measuring problem, can be used for the whole rapidly growing number of multi-component heating systems with the advantage of a low cost series production. Besides that, it is very complicated - if not impossible - to compare data regarding different integration times, different rules in the measuring points selection, and different accuracy classes. Furthermore, an economic, computer-aided data evaluation (e.g. specialized plot routines) requires a unique data storage medium and a standardized data format. Already in 1977 the above reasons motivated an ASSA working group [1] to propose a standard of the data acquisition and evaluation on which the development of the HELIO-DATA 1 package reported in this paper is based.

MULTICOMPONENT SYSTEM ANALYSIS

Fig. 1 shows a scheme of the most general type of a multicomponent system for low temperature heat supply. We call this type of representation the energy path graph at the highest abstraction level. The whole system between the measuring points of gross and net energy output is regarded here as a black box containing the so-called heat distribution and storage system. The energy sources at the left side of Fig. 1 consist of transformers which convert the energy in primary energy sources into usable heat (gross heat output). The energy destinations at the right side are users whose heat demand (net heat output) is to be covered.

For a specific system it is possible to use the energy path graph representation form to describe the heat distribution and storage system at the interesting abstraction level, that is in more or less detail, thus defining the points of energy, respectively heat flow measurement.

MICROPROCESSOR-ORIENTED TRANSDUCER SELECTION

In this section the chosen transducer types and measuring techniques are introduced for each measurand. The primary transducer selection criterion was a microprocessor adapted output signal, that is an analog voltage or a pulsed voltage with the pulse frequency representing the measured value. There has been made no compromise with regard to accuracy.

Temperature

Temperatures and temperature differences are measured with Platinum resistance (Pt 100) thermometers. These have the following advantages compared with thermocouples:

- no temperature-stabilized reference point respectively no compensation circuit necessary
- excellent linearity
- ten times more sensitive, that means a much better signal to noise ratio
- standard, non-shielded thin four-wire copper cable instead of an expensive special alloy (two-) wire cable.

Flow

Flow meters are primarily used for the heat flow measurement. The used flow transducers are of the turbo-wheel type with an electronic pulse transmitter initiated by induction. Besides the flow of heat transfer media, liquid fuel flow rates may also be measured.

Heat

Heat transfer is estimated by multiplication of the flow rate with the difference between inlet and outlet temperature, the mass density and the specific heat capacity of the heat transfer medium.

Electrical energy

The measurement of electrical consumers with constant power consumption like heat flow medium pumps, electrical heaters, etc. is performed by accumulation of their switched-on time. This switched-on time is multiplied with the average power consumption value which has to be measured only once for all. This method has the advantage that it needs only one additional relay contact as transducer element. The relay itself is simply the existing relay of the system control used to switch the component on or off at the proper time.

Consumers with varying electrical power demand, like heat pumps, must be acquisited by a conventional power meter with pulse output.

Insolation, humidity, wind speed and direction

Total insolation onto collector plane and sometimes in addition onto ground plane is measured with a conventional thermocouple-based solarimeter or with a photovoltaic solar cell of sufficient broad band response. Humidity is measured with a thin film capacitor. This capacitive probe needs no maintenance and works also under freezing conditions. Wind speed is measured by driving a d.c. generator with a revolving ball socket cross. A potentiometer output voltage proportional to the angle of wind direction may be used for the estimation of this rather meaningless parameter.

Other measurands

Special systems may require acquisition of additional measurand types. This can be performed with any transducer type as long as the transducer features an output voltage or output pulse frequency proportional to the measured value. Signal voltage and frequency range must be only within the input specifications of the data acquisition device HELIO-DATA 1 described in the following section.

COMPACT DATA LOGGER "HELIO-DATA 1"

As there is a great number of universal data loggers on the market, the suitability of these powerful devices for multi-component heating supply analysis was checked at first. Except for free programmable data acquisition systems which are of another price category, universal data loggers show at present two gaps in their specifications:

1. There are no satisfactory heat measuring capabilties. There is no multiplication between flow and temperature difference and therefore no direct heat flow count display possible. Although often practised, a data compression by integrating the flow and calculating the average temperature difference before the separate recording of flow and temperature difference data is not allowed. This is because it is mathematically inadmissable to multiply the factors after integration for yielding the heat flow count.

2. There is no immediate connection between the pulse output of a flow transducer and a standard input of a data logger possible. A frequency/voltage (f/U)-converter or a counter modul must be used to adapt the pulse output to an analog or a digital input, respectively. The f/U-converter reduces the accuracy of flow measurement significantly. This is especially true for short intermitting flows which are characteristic of the warm water demand. On the other hand, the digital counter modul outputs result in a wire and pin number extensive solution.

In order to avoid the above problems, a specialized microprocessor-controlled data logger HELIO-DATA 1 has been developed. Fig. 2 shows the front view of this compact device. The front panel contains all control functions in a clear design. On the left side one can see the magnetic type cassette drive with the ejection button. To the right of the cassette drive the so-called micro-terminal for the interactive communication between device and operator is located. It consists of an eight-digit, 7-segment LED display as well as of number and control keys.

All connectors are located on the rear side (see Fig. 3). Each bayonet socket is labelled with the corresponding measuring point number. The 24 analog inputs are integrated in eight plug-in interface modules containing four bayonet sockets each, the 24 digital inputs are divided in two times eight pulse inputs and eight relay contact inputs. The measuring points e.g. 10, 20, 30 form a transducer triplet for the heat flow counter 30, consisting of inlet and outlet temperature probes, and heat transfer medium flow , respectively. All sockets shown in Fig. 3 form one so-called sensor connecting block. Up to three additional sensor connecting blocks may be connected via the extension bus connector.

The block diagram in Fig. 4 shows, besides the already mentioned cassette drive, microterminal and sensor-connecting block, the microcomputer card cage containing the 8085 CPU, 4k RAM, 8k EPROM, I/O-Ports, analog to digital converter, and the battery-buffered CMOS-Clock. The pulse outputs of the flow transducers are directly coupled to input port lines, the pulse frequency is determined by checking the input line status (high or low) periodically and accumulating the indicated changes by software counters [2]. There are only optically-coupled isolators in between the flow transducer pulse outputs and the microprocessor input ports to avoid ground loop troubles.

CMOS CLOCK OPERATION, TIMING CHARACTERISTICS

A battery-buffered CMOS-Clock provides the system with complete absolute time and date information, even after line power fail. While power fails, the data acquisition is interrupted. That does not matter, because during the power drop out period, the multicomponent heating system does not work either.

The timing of the device is characterized by the following functions:

- Every minute sequential acquisition of all primary measurands and intermediate storage of momentary (e.g. temperatures) and accumulated (e.g. flow count) values in RAM.
- A the end of each measuring cycle, that is once a minute, calculation of secondary measurands (heat and other energy counts) by multiplication.
- At the end of the integration interval (standard case at 6.00 a.m. and 6.00 p.m.) scaling and recording of a complete data block on the magnetic tape cassette.

The recording time and the integration interval may be changed by the micro-terminal for increased time resolution. This is especially advantageous during the test phase of the multi-component heating system.

MICROTERMINAL DIALOGUE

The micro-terminal is used for the immediate display of measurement data, which represent the current state of the system. All values are displayed in international units according to the measuring point listing (see Fig. 5). After typing in the measured value number, this number appears on the left side of the display. After pressing the EXECUTE control key, the selected actual measured value appears on the right side of the display and is automatically updated every minute. It is also possible to key in not automatically acquisited parameters, like the monthly amount of consumed solid fuel, to get all values stored together on the magnetic tape. To notice failures in the system immediately, that is long before the monthly evaluation of the magnetic tape cassette, the microcomputer checks the validity of the analog signal ranges as well as the coincidence between the heat flow medium pump switched on state and the occurrence of heat flow counts. A transducer drop out is indicated by a flushing display of the corresponding measuring point number and an acoustic alarm.

The discrimination between a not-used floating transducer input and a transducer input with e.g. a broken wire in the sensor cable is done by keeping in evidence the used sockets in a so-called personality EPROM. In this easy to change, read only memory chip all station-specific parameters are stored, that is for each transducer the offset and scaling factors. Except for the necessarily different transducer equipments of the test stations,the personality EPROM is the only test-station specific part in the HELIO-DATA 1 system.

MAGNETIC TAPE CASSETTE AND DATA FORMAT

A comparison has been made between the following data media to find the best way of data transfer from the test stations to the central evaluation computer:

- paper tape
- magnetic tape cassette (digital and analog version)
- mini floppy disk
- collecting the data by a person carrying a data-recording device from test station to test station
- automatic transmission of the data via a phone line
- manual recording.

The confrontation of the most important features like portability (readability on devices of different manufactures), price, storage capacity, data error frequency, and reliability has shown clearly that the digital magnetic tape cassette together with the ECMA [3] 34 and 41 ("basic system") recording standard is superior to all competitors. Following the ECMA standard gives a portability of the magnetic tape cassette, which only the teletype paper tape had shown before. In addition to cyclic redundancy check (CRC), every data block is recorded twice for the sake of safety. A comparison is made by the evaluating computer between the block twins and if they do not correspond, the correct one may be identified by means of the CRC.
The cassettes are exchanged once a month, although the maximum running-time without loss of data would be six months. Fig. 6a shows a direct print-out of a data block from the magnetic tape cassette; Fig. 6b shows a data block with some blanks and carriage returns inserted to get a clearer structure strictly corresponding to the measuring point listing in Fig. 5.

COMPUTER-CONTROLLED DATA EVALUATION

By summing up (e.g. energy values), respectively calculating the mean values (e.g. temperatures) of the 12-hour blocks for one month, the so-called "monthly data block" is formed, by summing up respectively calculating the mean values of the data for one year the "yearly data block" if formed. Examples for graphic representations of data like the energy balance diagram or the seasonal curve of collector gross output are shown in this session in the following paper.

CONCLUSION

The introduced data acquisition system HELIO-DATA 1 serves as a national standard for the analysis of multicomponent solar heating supplies. It allows for an accurate quantitative comparison between competitive philosophies of such complex energy distribution systems. The authors hope that HELIO-DATA 1 is a step towards an international standard for data acquisition in the energy management field.

As a consequence of the modular concept and since the microprocessor in the HELIO-DATA 1 device has direct access to all relevant process data, hardware and software can be easily further developed to a control unit for a more sophisticated regulation of multicomponent heating systems. Experience gathered up to now shows clearly that an intelligent control system can considerably reduce heat losses and may further help conserving the energy we have.

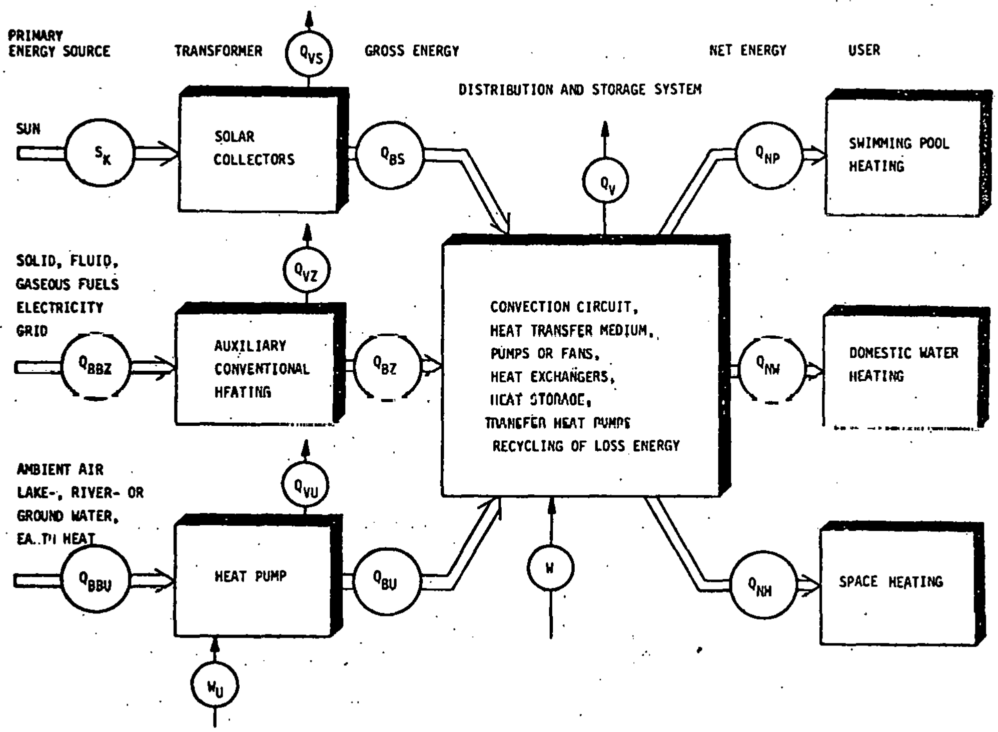
ACKNOWLEDGEMENTS
The authors wish to thank Messrs. A. Hopfmüller, P. Berlinger, N. Böck and R. Blochberger for their help in making and testing the hardware moduls, as well as the Austrian Federal Ministry of Science and Research for the financial support.

LITERATURE

1. E. Benes, M. Bruck, "Standardisierung der Meßwerterfassung und Auswertung bei multivalenten Solar-Heizungssystemen", ASSA-SE-B18/77.

2. E. Benes, "Durchflußmengenmesser, insbesondere für Wärmemengenmessung", Austrian Pat. Nr. 4A3604/79 pending.

3. ECMA: European Computer Manufacturers Association
   Standard 34: Data Interchange on 3.81 mm Magnetic Tape Cassette (32bpmm, phase-encoded), 1973.
   Standard 41: Magnetic Tape Cassette Labelling and File Structure for Information Interchange, 1973.



S_K ... Insolation on the collector surface per unit area

Q_{VS} ... loss energy of solar collectors

Q_{BS} ... gross heat output of the solar system

Q_{BBZ} ... heat equivalent of the fuel used by the auxiliary conventional heating

Q_{VZ} ... loss energy of the auxiliary conventional heating

Q_{BZ} ... gross heat output of the auxiliary conventional heating

Q_{BBU} ... heat removed from the environment by the transformer heat pump

Q_{VU} ... loss energy of the transformer heat pump

W_U ... driving energy of the transformer-heat pump

Q_{BU} ... gross heat output of the transformer-heat pump

Q_V ... loss energy of the distribution and storage system

W ... energy demand of the distribution and storage system

Q_{NP} ... heat transferred to the swimming pool

Q_{NW} ... heat transferred to the service water

Q_{NH} ... heat transferred to domestic space heating

Fig. 1. Heat path graph of the most general multi-component heating system

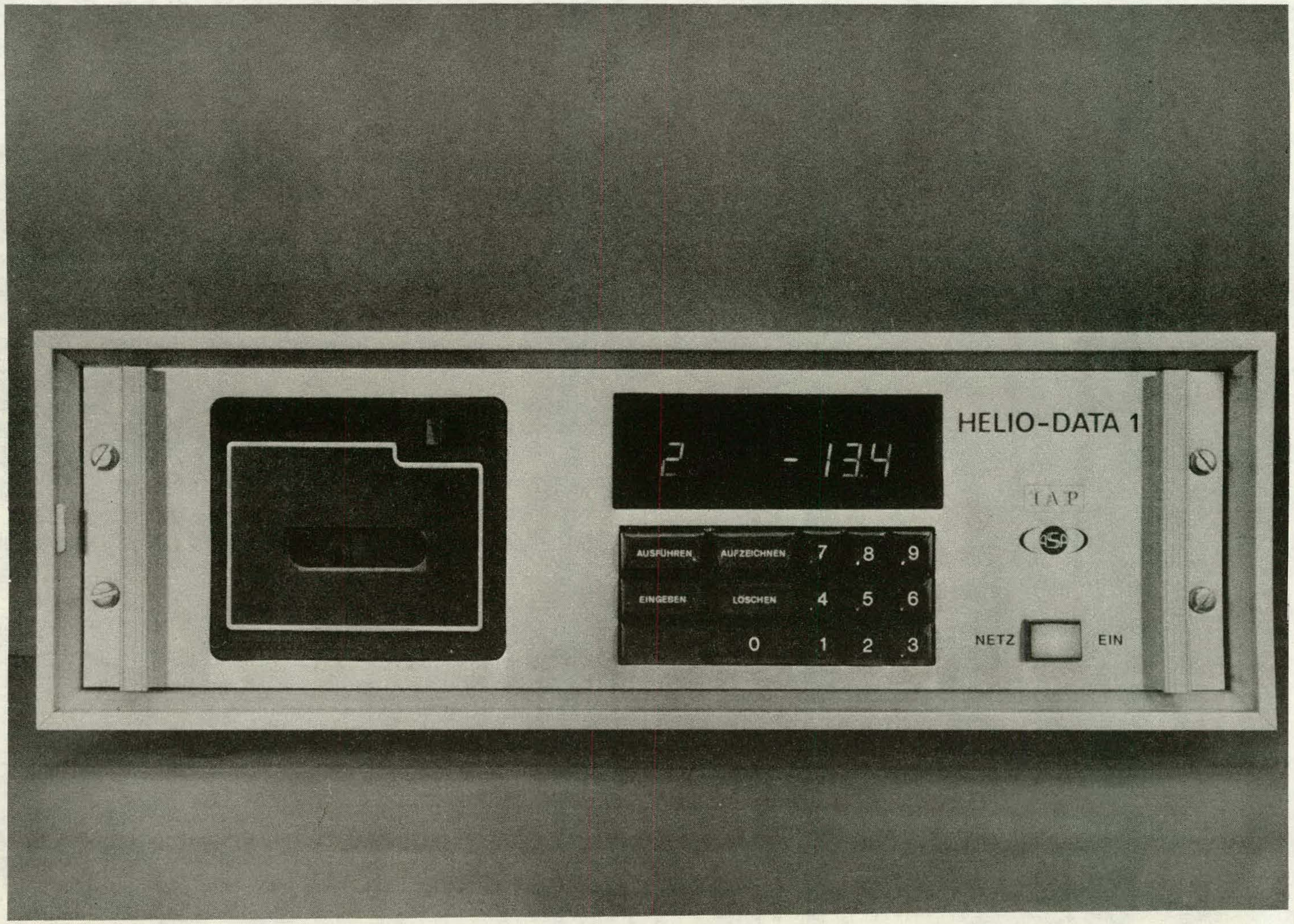


Fig. 2: Front view of the compact data acquisition device HELIO-DATA 1 with digital magnetic tape cassette drive and display and keyboard of the micro-terminal.

Left justified in the display-field one can see the keyed-in measuring point number (e.g. 2; air temperature), right justified the corresponding momentary measured value in the unit according to the measuring point listing (e.g. -13,4 °C).

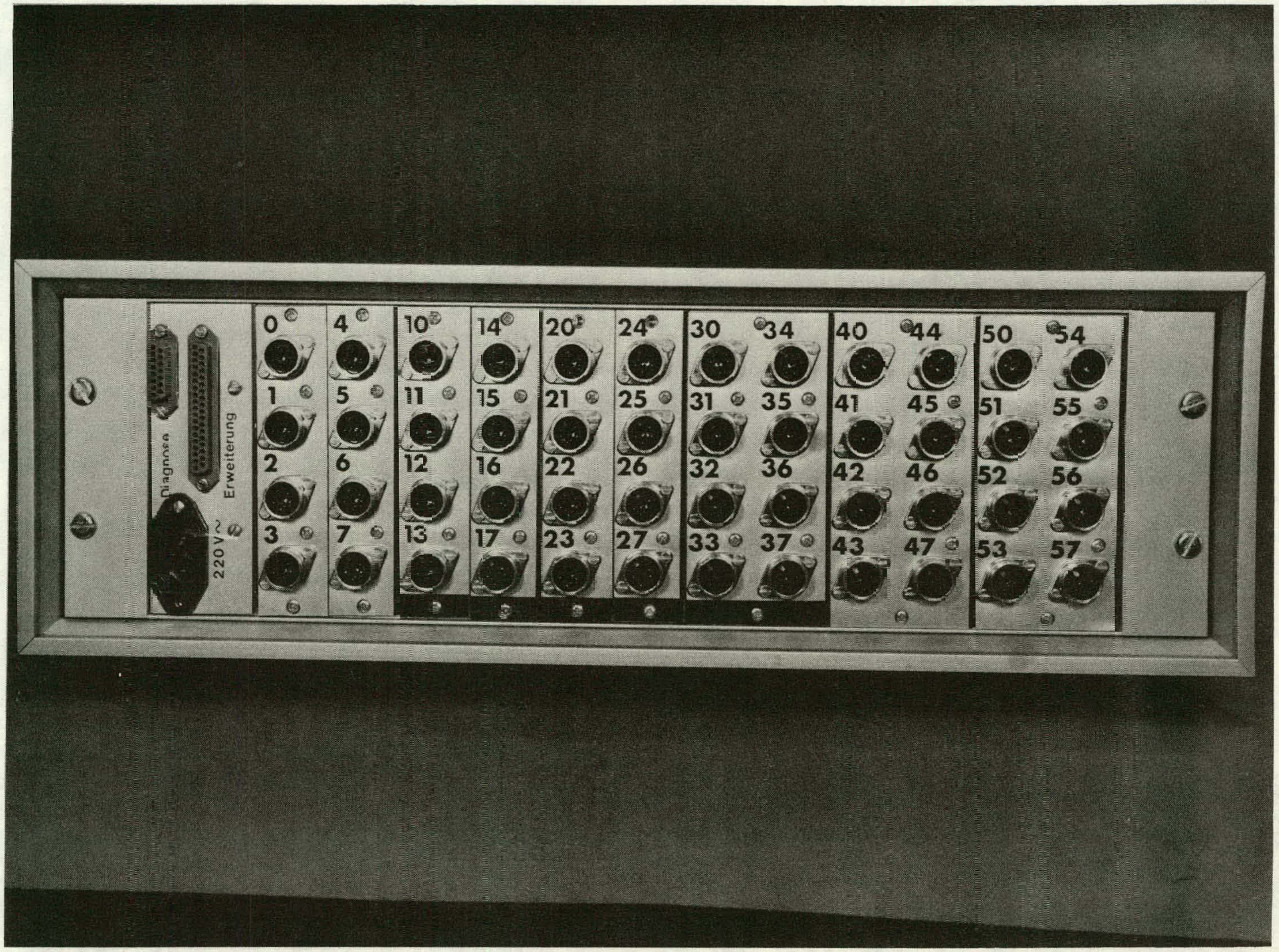


Fig. 3: Rear view of the compact data acquisition device HELIO-DATA 1 shows 24 analog inputs (bayonet socket Nos. Ø - 27) and 24 digital inputs (bayonet socket Nos. 3Ø - 57) as well as the extension bus socket for additional sensor connecting blocks.

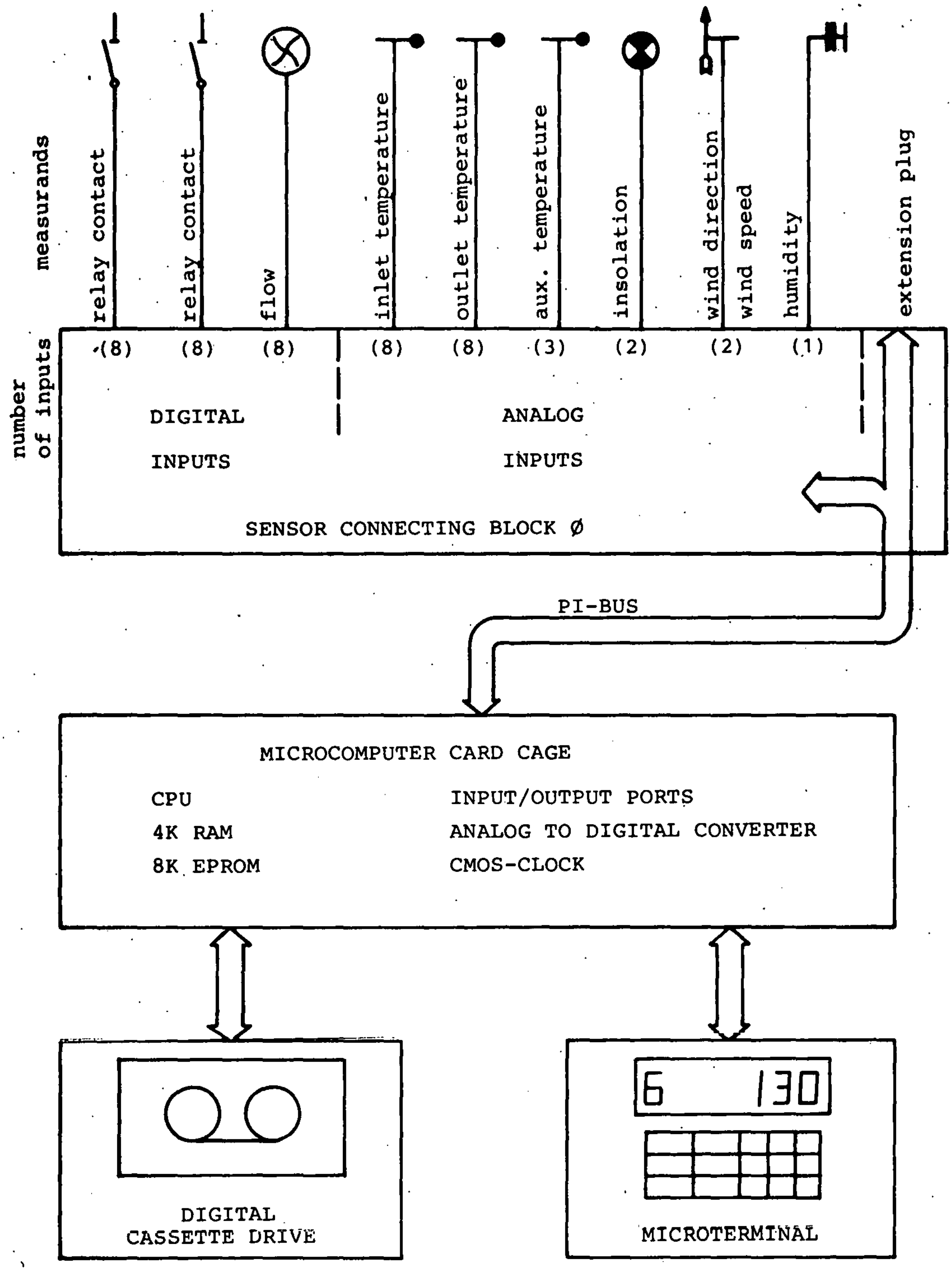


Fig.4. Block diagram of the data acquisition package HELIO-DATA

EXAMPLE

HELIO-DATA

MEASUREMENT POINT LISTING

TESTSTATION No. 16
SENSOR CONNECTING BLOCK: Ø

	measurement point No.	measurand	value number	display limit	display unit	remarks
⊗	0	ϑ_0	0	-50,0/150,0	°C	*tank temperature*
⊗	1	ϑ_1	1			*room temperature*
⊗	2	ϑ_L	2			*ambient temperature*
○	3	φ	3	0 / 100	%	*air humidity*
⊗	4	v	4	0 / 99,9	m/s	*wind speed*
⊗	5	β	5	0 / 360	alt°	*wind direction*
⊗	6	E_K	6	0 / 1500	W/m²	*insolation on collector plane*
○	7	E_S	7	0 / 1500	W/m²	
⊗	10	ϑ_{V0}	10	-50,0/150,0	°C	*collector outlet temp.*
⊗	11	ϑ_{V1}	11			*heat exchanger inlet temp.*
⊗	12	ϑ_{V2}	12			*boiler outlet temp.*
○	13	ϑ_{V3}	13			
○	14	ϑ_{V4}	14			
○	15	ϑ_{V5}	15			
○	16	ϑ_{V6}	16			
○	17	ϑ_{V7}	17			
⊗	20	ϑ_{N0}	20			*collector inlet temp.*
⊗	21	ϑ_{N1}	20			*heat exchanger outlet temp.*
⊗	22	ϑ_{N2}	22			*boiler inlet temp.*
○	23	ϑ_{N3}	23			
○	24	ϑ_{N4}	24			
○	25	ϑ_{N5}	25			
○	26	ϑ_{N6}	26			
○	27	ϑ_{N7}	27			

Fig.5. First page of the measurement point listing

0042111506000143-04501280072006402360067009802310162024303340085012602870188
01170029023402440158036902750188000000003461055782000033000674074565116896000000
000000000000012464002948000045002584064425000056
166871002536034732000067002464364666034652002646

Fig.6a. Example for a direct printout of a data block from the magnetic tape cassette

								measurand groups
0042	1115	0600						block header
0143	-045	0028	0072	0064	0236	0067	0098	8 analogue values
0231	0162	0243	0334	0085	0126	0287	0188	8 inlet temperatures
0117	0029	0234	0244	0158	0369	0275	0188	8 outlet temperatures
000000	003461	055782	000033	000674	074565	116896	000000	8 heat flow counter readings
000000	000000	012464	002948	000045	002584	064425	000056	8 electrical energy counter readings
166871	002536	034732	000067	002464	364666	034652	002646	8 electrical energy counter readings

Fig.6b. Example for a formatted data block. There are some blanks and carriage returns inserted by the evaluation computer to clarify the data structure.

APPENDIX B

THE SOLAR RADIATION MAGNETIC TAPE EVENT RECORDER (MATER) DATA ACQUISITION SYSTEM

Thorne K. Won
Atmospheric Environment Service
Environment Canada
4905 Dufferin Street
Downsview, Ontario M3H 5T4
Canada

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

THE SOLAR RADIATION MAGNETIC TAPE EVENT RECORDER (MATER) DATA ACQUISITION SYSTEM

Introduction

The Canadian Atmospheric Environment Service Radiation Network comprises 54 hourly global radiation measuring stations. Expansion of this network, both spatially and in terms of additional fields of measurement, has been hampered, firstly by economic restrictions and secondly by the requirement for additional manpower resources necessary for data processing of the increased volume of information.

Currently, the method of radiation data acquisition consists of a millivolt chart recorder coupled to a mechanical integrator which provides the input to an electro-mechanical counter (Fig. 1). The counts are printed and a timer clears the counter after a one-hour interval. Timers are set daily and counts are corrected by calibration constants varying with temperature and with each component. Dew, frost and other obstruction effects on the sensors are corrected manually; according to reference curves. Following required manual massaging, the data are keypunched for input to the archival records. This procedure is a long, labour intensive process.

The requirement clearly existed for the development of a relatively inexpensive data logger which would eliminate or reduce the amount of manual labour required for radiation data processing. To satisfy this requirement, the Atmospheric Environment Service has developed a method of data recording which is directly computer compatible to enable partial automation of data processing.

The MATER is capable of recording data from a host of sensors; including all currently used pyranometers, sunshine, temperature, windspeed and direction and tipping bucket rain gauge detectors.

The Radiation MATER

The MATER eliminates much of the manual labour of data processing, as well as the mechanical components of data recording. For radiation sensing, the output from the analogue sensors are coupled to electronic integrators (Fig. 2) which provide an event output for recording. Using two tracks on a standard cassette tape and a positive, zero, or negative pulse, there is provision for eight channels of recording (Fig. 3). With each event occurrence, the tape is advanced one increment (0.1 mm). One channel is reserved for the time pulse recorded every minute and used as a base for subsequent processing.

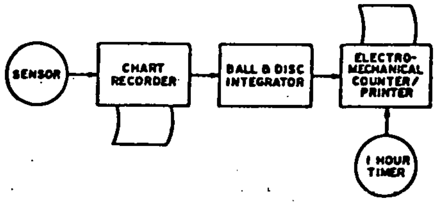


Fig. 1 Current mechanical integrator system

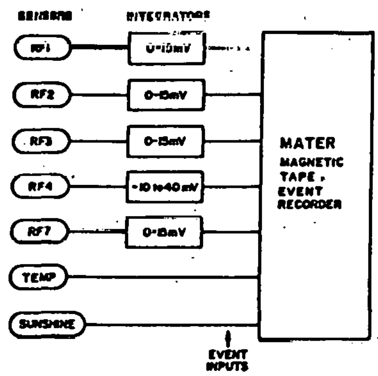


Fig. 2 MATER electronic integrator system

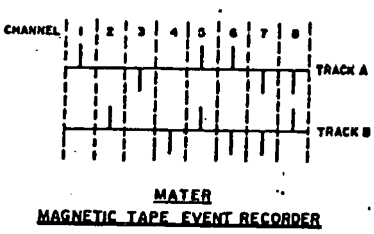


Fig. 3 Encoding tape channel signals

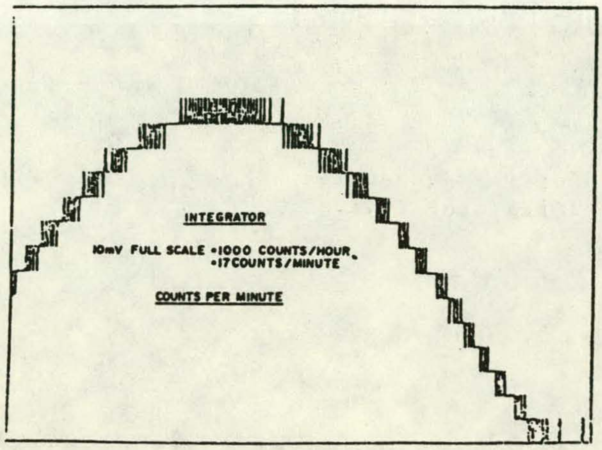


Fig. 4 Computer plotted output of raw one-minute totals

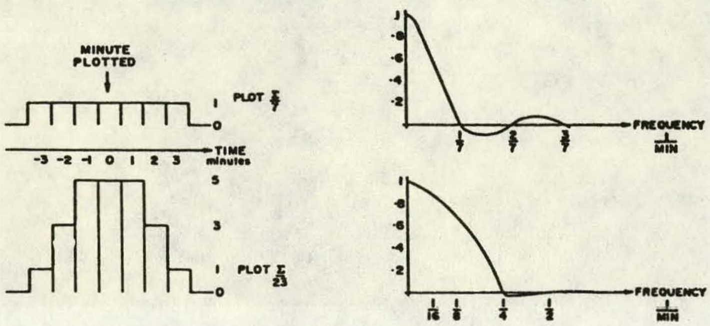
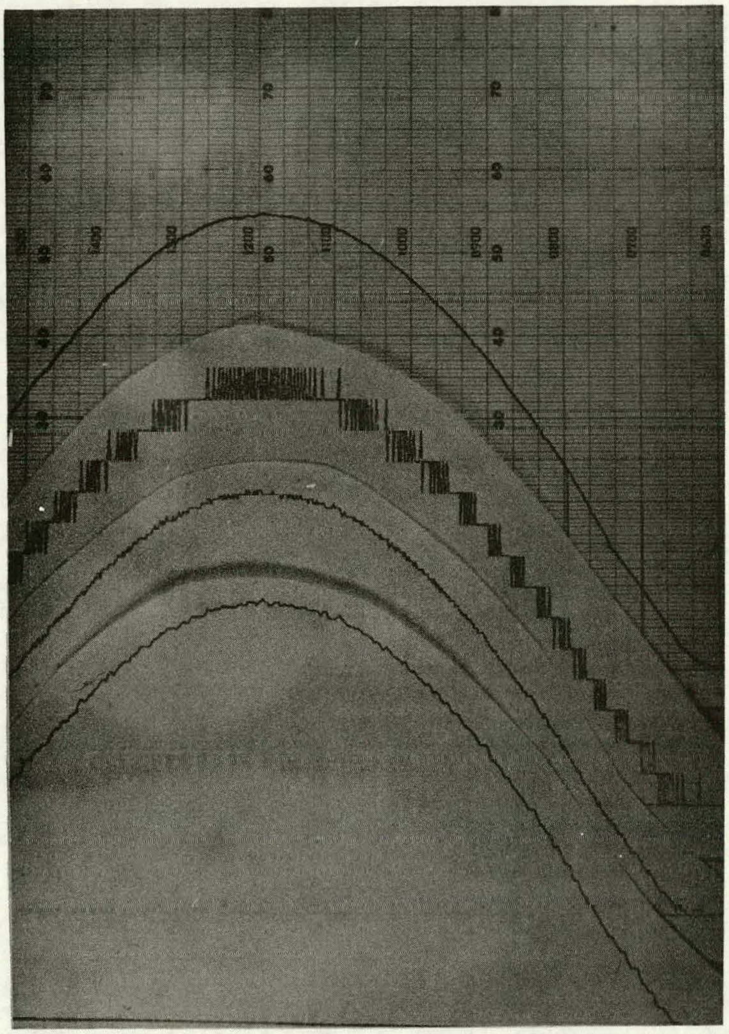


Fig. 5 Centre weighted boxcar smoothing



Curve 1

Curve 2

Curve 3

Curve 4

Fig. 6 Comparison curves of clear day radiation

Curve 1: Analogue chart trace
Curve 2: One minute unfiltered
Curve 3: Simple seven minute boxcar smoothed
Curve 4: Centre weighted seven minute boxcar smoothed

The radiation recording MATER has the capability of handling a maximum of six integrated circuits which may be scaled at 0 to 15 mV, or -10 to 40 mV depending on the radiation field measured.

At present, a field unit at the Toronto Meteorological Research Station records: global, diffuse, reflected and net radiation as well as sky illumination, temperature and sunshine. The temperature and sunshine sensor outputs are digital and do not require integrators. With a full compliment of sensors, one C60 cassette tape will record at least two weeks of data. The MATER will accept data at a rate of two events per second for each channel simultaneously. Power consumption is minimized by having the electronics remain in an quiescent state until an event occurs from one of the sensors.

The integrators yield a full scale of 1500 counts per hour to enable sufficient resolution for graphic analyses of output data. Accuracy of the indoor installation model (10° to 30°C) is $\pm 0.25\%$. While the extended operating range model (-40°C to $+50^{\circ}$C) is a respectable $\pm 1\%$ of full scale throughout its operating range.

The output pulses of the integrators may be monitored by lights on the integrator boards activated by a test button.

Power for the units are derived from sealed lead-acid batteries which are float charged from an AC line. For remote locations, charging power may be derived from photovoltaic cells and/or wind driven generators. Power interruptions of over ten hours may be accommodated.

Decoding of Radiation Data

Recorded cassettes are played back through a Hewlett-Packard mini-computer system which displays the output in a graphic format. Figure 4 illustrates a computer plotted graph of one minute totals of raw data from a clear day. A step-wise characteristic of the output makes the curve an unacceptable facsimile of an analogue trace obtained from a chart recorder. A smoothing function known as a moving box car is applied to the data to smooth the curve. It was found that a better performance can be achieved through a centre weighted box car shown in Figure 5. Frequency response and aliasing are noticeably improved. Comparison curves of radiation data from a clear day are reproduced in Figure 6. Used as a reference curve is an analogue chart recorder trace displayed in Curve 1. The second curve is the one minute count unfiltered. The third, a simple seven minute box car and the fourth a weighted

Curve 1

Curve 2

Curve 3

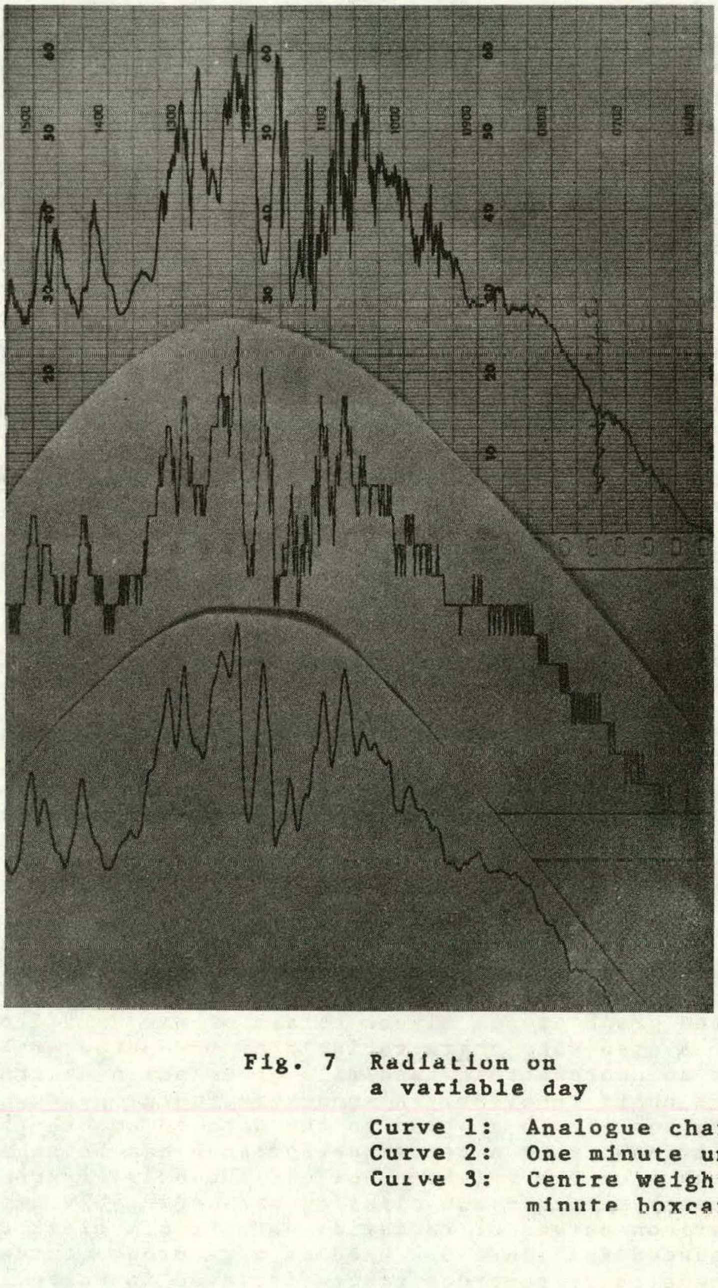
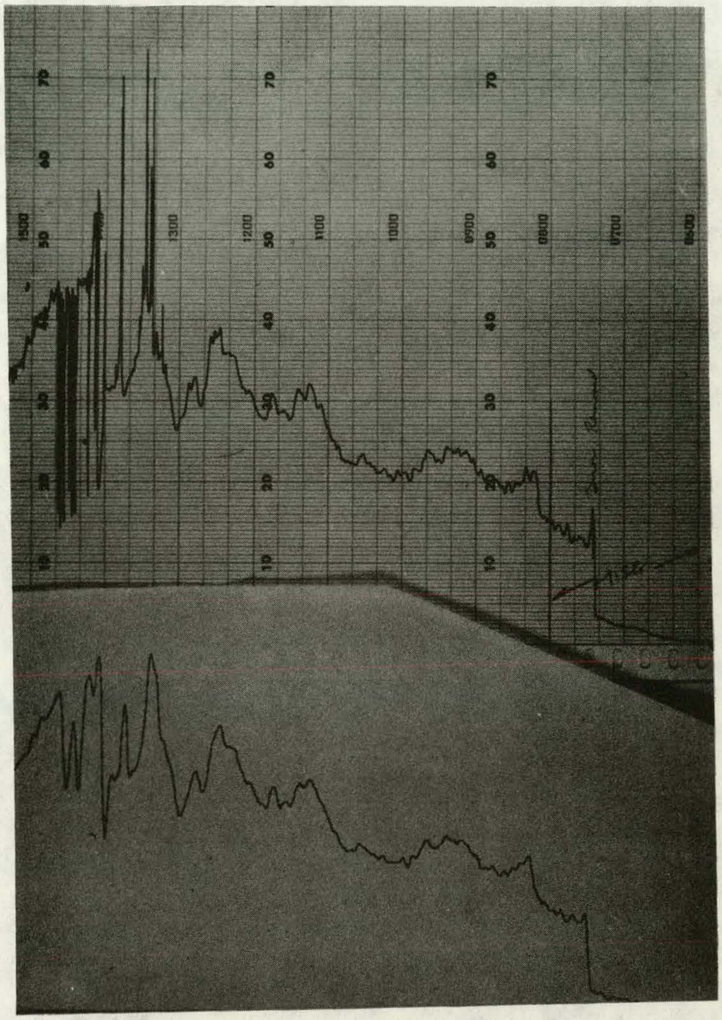


Fig. 7 Radiation on a variable day

Curve 1: Analogue chart trace
Curve 2: One minute unfiltered
Curve 3: Centre weighted seven minute boxcar smoothed

Curve 1



Curve 2

Fig. 8 Radiation trace with removal of snow cover

Curve 1: Analogue chart trace
Curve 2: Centre weighted seven minute boxcar smoothed

Curve 1

Curve 2

Curve 3

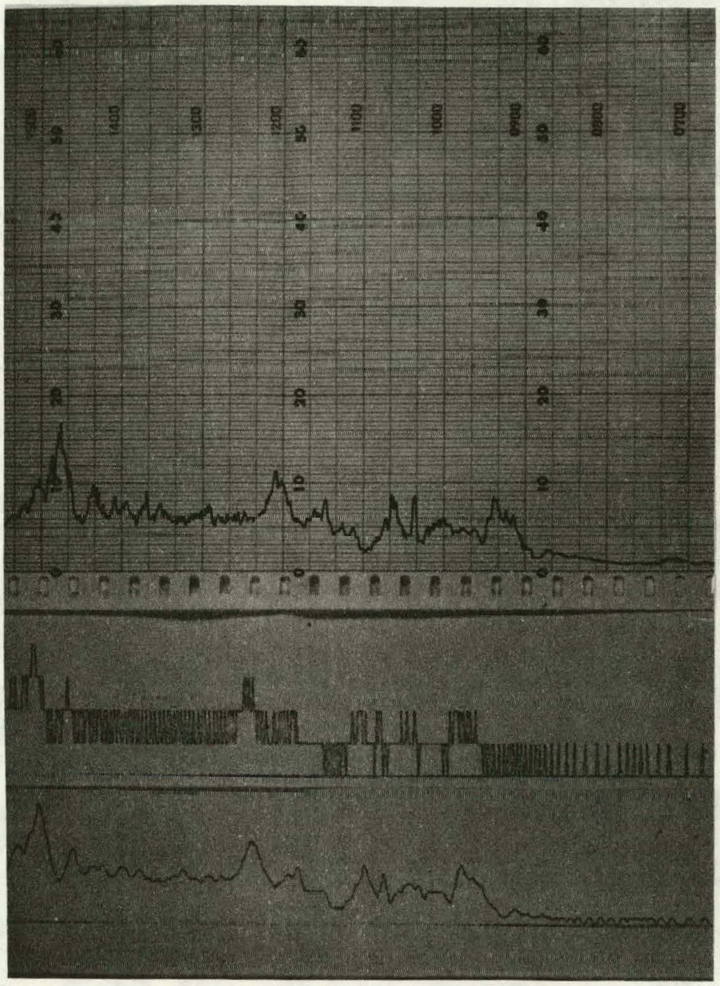


Fig. 9 Low level radiation trace

Curve 1: Analogue chart trace
Curve 2: One minute unfiltered
Curve 3: Centre weighted seven minute boxcar smoothed

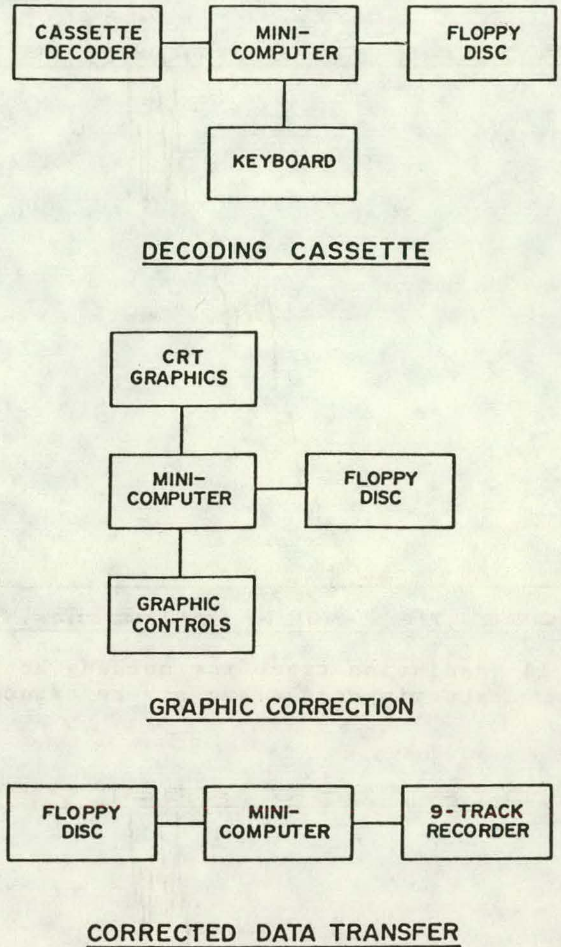


Fig. 10 Decoding and archiving procedure

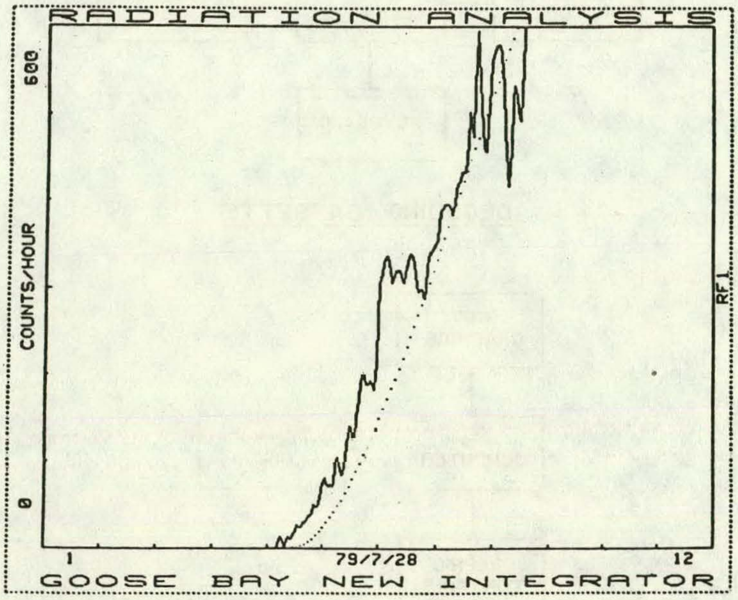


Fig. 11 Radiation trace for morning hours with superimposed clear sky reference curve

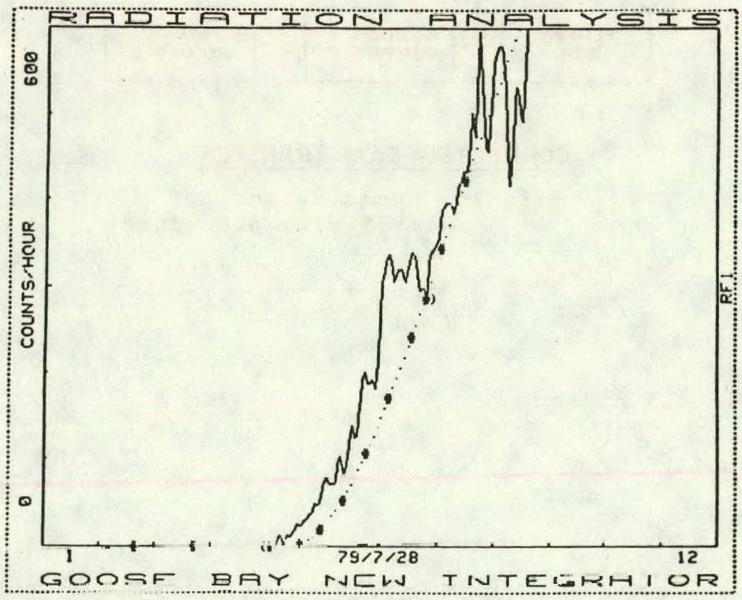


Fig. 12 Radiation trace with cursor points on clear sky reference curve

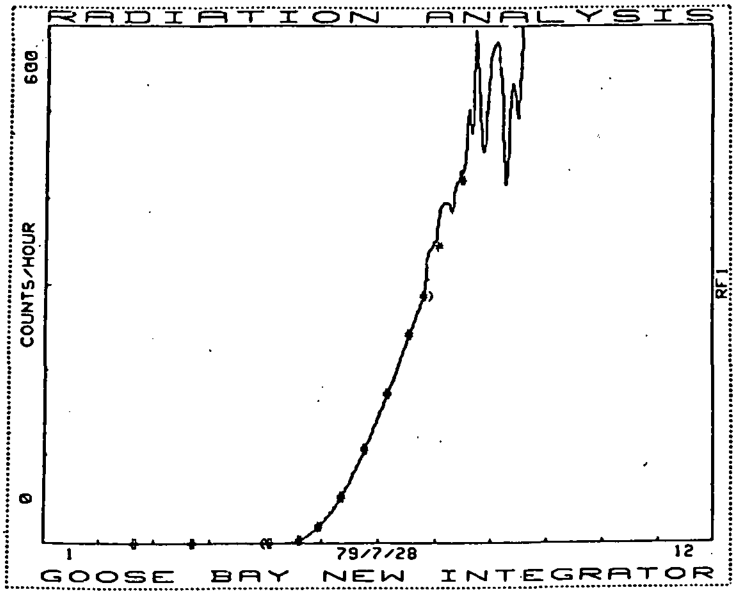


Fig. 13 Radiation trace corrected to clear sky cursor points

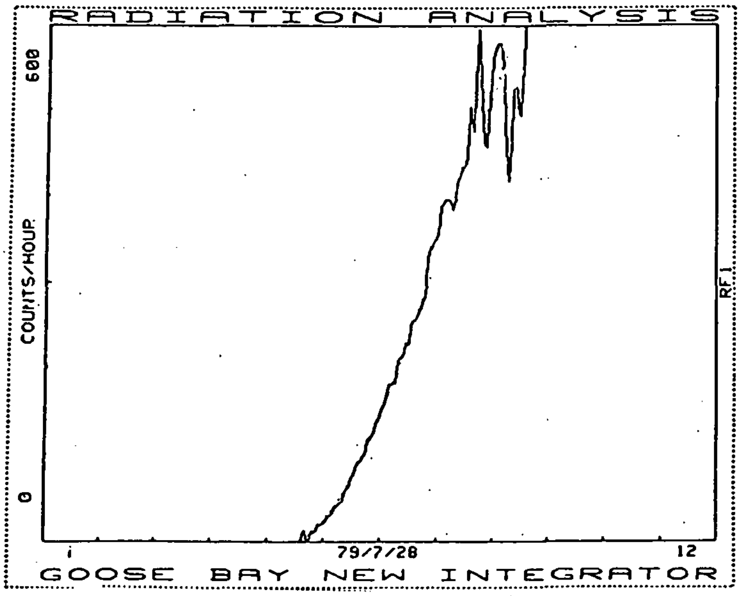


Fig. 14 Corrected radiation trace for archiving

seven minute box car. It can be seen that the weighted seven minute box car most closely duplicates the analogue trace. Figure 7 displays traces of global radiation on a variable day. The low pass filtering action of the centre weighted box car is quite apparent in the bottom trace. In Figure 8 the removal of snow cover is apparent in the morning and the filtering removes the hash in the analogue trace towards the end of the day. This system of smoothing and filtering is effective even at fairly low levels of radiation input. It is not until the occurrence of counts of less than one per seven minutes that the ripple becomes objectionable. The shape of the box car becomes obvious in those cases as illustrated in Figure 9.

Quality Control of Radiation Data

Data from recorded cassettes are transferred to a floppy disc along with station identification and start and stop times. Calibration factors, available to a mini-computer, correct the stored data which are then displayed graphically on a CRT. A clear sky reference curve calculated by a method developed by Won (1977) with +15% limits is coincidentally displayed for manual graphic editing. Corrections for dew, frost, obstructions, etc., are then applied by the quality control technician using a light pen in the zoom mode or by interpolation between points with a cursor. Scaling, timing and offset may also be corrected if required. The corrected data are then transferred to nine-track magnetic tape for publication and archiving. Figure 10 illustrates the block chart description of the decoding and archiving procedure.

Figure 11 shows a portion of a trace from Goose Bay for the early morning hours. Superimposed on the trace is the reference clear sky curve. Because of dew on the sensor, the trace shows an abnormally high reading between the hours of 0500 and 0700. The corrective procedure using cursor points is illustrated in Figures 12, 13 and 14.

System Verification

Preliminary results of system verification are shown in Table 1.

TABLE 1

Test Results

Global Radiation Raw Counts (Woodbridge)

Date	Mechanical Counts	Electronic Counts	Difference	%
Apr 29	6493	6518	25	0.39
30	7297	7337	40	0.55
May 01	6026	6058	32	0.53
02	6824	6859	35	0.51
03	7136	7167	31	0.43
04	6032	6064	32	0.53
05	1778	1783	5	0.28
06	1489	1497	8	0.54
07	7092	7125	33	0.47
08	1918	1926	8	0.42
09	2589	——*	——*	——*
10	4251	4271	20	0.47
11	6429	6452	23	0.36
	* equipment malfunction		Average	0.46

The output from the radiation sensor was hooked to both an electronic MATER integrator as well as a ball and disc mechanical integrator. The mechanical counts and the electronic counts were compared. In addition to the count comparison, output was converted to energy units using equation (1).

$$\text{Units} = (\text{COUNT} - \text{OVNC}) * \text{IF} * \text{UC} \qquad (1)$$

COUNT = number of counts per hour
OVNC = average overnight base
UC = metric conversion factor

$$\text{IF} = \left\{\frac{60 * \text{UMPV}}{\text{KE} * (\text{UMPC}-\text{ZC})}\right\} * \left\{1 + \text{TCO}(\text{TC}-\text{T})\right\}$$

UMPV = upper midpoint calibration voltage
UMPC = upper midpoint counts per hour at UMPV
ZC = counts per hour at zero voltage
KE = calibration factor
TCO = temperature coefficient
TC = calibration temperature
T = temperature of sensor

The average figures for the period of the test are shown in Table 2.

TABLE 2

Test Results

Average Values in MJm^{-2}

Mechanical Integrator	Electronic Integrator	Difference	%
17.653	17.512	0.142	0.80

From these preliminary results the system appears to be acceptable. Further tests will be conducted as field data become available. At the present time, units are operational at Goose Bay, Newfoundland; Quebec City, Quebec; Elora, Ontario; and Winnipeg, Manitoba; as well as those at Woodbridge. Four additional units are planned to be installed this spring in British Columbia at Prince George, Cranbrook, Kamloops and Victoria.

The decoder unit, capable of processing a full cassette in twelve minutes and displaying the output graphically on a CRT, will be operational in the early summer of 1980.

Unit Costs

The approximate cost for a MATER recorder including one integrator and a temperature sensor is $2.5K Canadian. Integrators for additional radiation fields are approximately $200 Canadian each. In comparison to the mechanical system currently in use, a one sensor system amounts to approximately 40% of the previous cost. For five sensors, the cost is reduced to about 13% of that of the similar currently used system. The savings encountered in implementing the MATER is therefore, not only restricted to manpower savings but economic savings as well.

The MATER is protected by Canadian Patents and Developments Limited. It has been licensed for production by:

Aero-Aqua Incorporated
850 Magnetic Drive
Downsview, Ontario M3J 2C4
Canada.

Orders and inquiries may be forwarded directly to Aero-Aqua.

Future Plans

It is the intention of the Atmospheric Environment Service to deploy MATER units at all present radiation network stations in Canada. It is hoped that implementation of the MATER system will facilitate expansion of the radiation network both in terms of a number of fields being measured and the number of stations in operation.

Acknowledgements

The author gratefully acknowledges the valuable assistance and advice given by Messrs. John Cook and Dave Stewart of the Instruments Branch within the Atmospheric Environment Service. Mr. Cook is one of the principals involved in the design of the MATER system and Mr. Stewart has developed the decoding procedures.

References

Atmospheric Environment Service, 1979; *MATER Specifications*, Atmospheric Instrument Branch.

Cook, J.M., 1975; *MATER Magnetic Tape Event Recorder*, Technical Conference in Automated Meteorological Systems, (TECAMS), WMO, February, Washington, D.C., 11 pp.

Cook, J.M., 1977; *Radiation MATER*, Instruments Branch, Atmospheric Environment Service, Downsview, Ontario, 3 pp.

Won, T.K., 1977; *The Simulation of Hourly Global Radiation from Hourly Reported Meteorological Parameters-Canadian Prairie Area*, Third Conference, Canadian Solar Energy Society, Edmonton, Alberta, 23 pp.

Won, T.K., 1978; *Use of the MATER (Magnetic Tape Event Recorder) in the AES Radiation Network*, Atmospheric Environment Service, Downsview, Ontario, 5 pp.

Definition of Radiation Fields

RF1 - global solar radiation; the downward direct and diffuse solar radiation has received on the horizontal surface from a solid angle of 2π (Wm^{-2}, MJm^{-2} $hour^{-1}$, MJm^{-2} day^{-1}).

RF2 - diffuse solar radiation; the downward short-wave radiation received on a horizontal surface from a solid angle of 2π with the exception of the radiation originating from within 3^{o} of the centre of the solar disc (Wm^{-2}, MJm^{-2} $hour^{-1}$, MJm^{-2} day^{-1}).

RF3 - reflected solar radiation; the upward solar radiation reflected by the earth's surface and diffused by the atmospheric layer between the ground and the point of observation (Wm^{-2}, MJm^{-2} $hour^{-1}$, MJm^{-2} day^{-1}).

RF4 - net radiation; the net flux of downward and upward total (solar, terrestrial, surface and atmospheric) radiation (Wm^{-2}, MJm^{-2} $hour^{-1}$, MJm^{-2} day^{-1}).

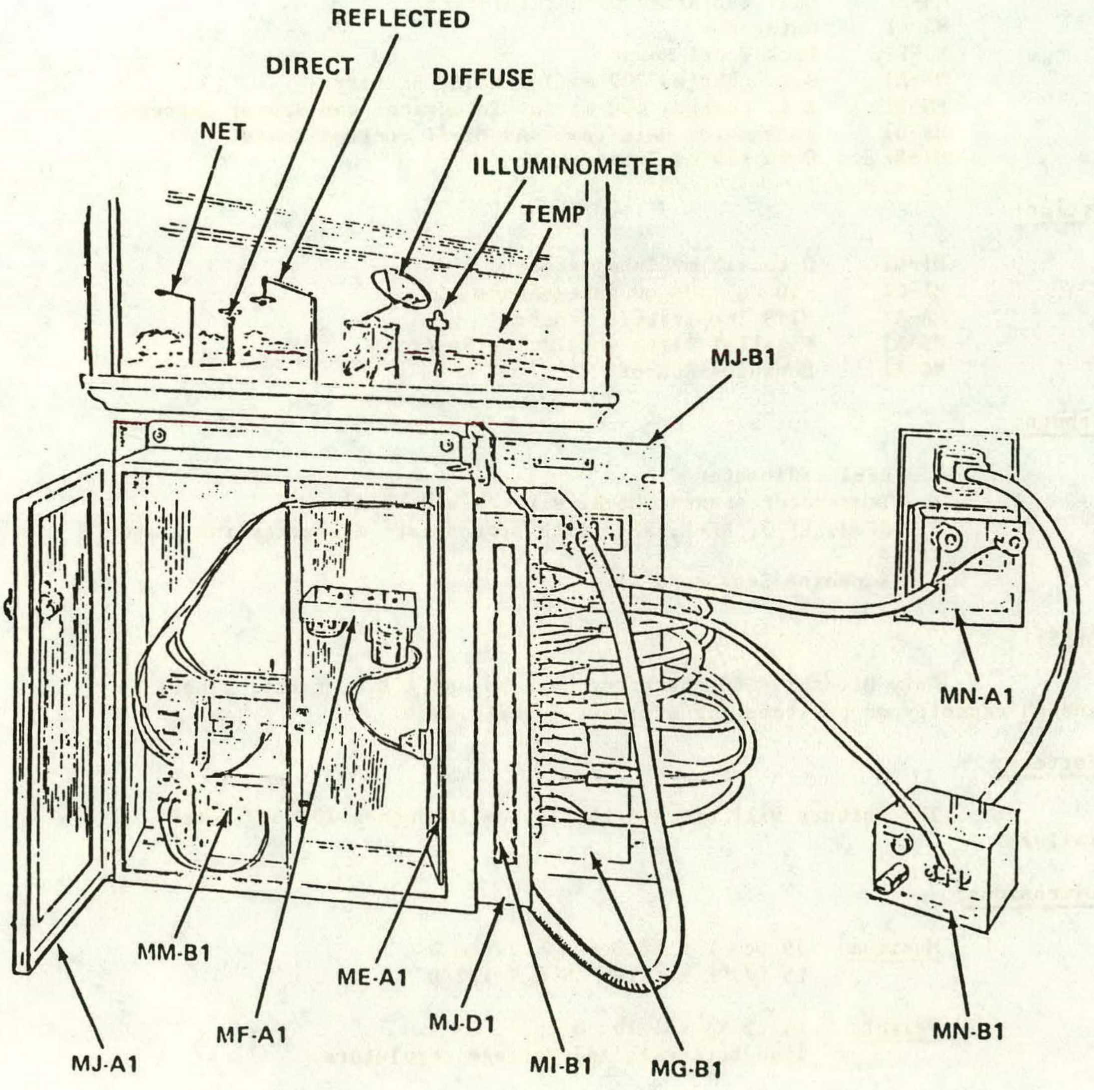
RF7 - sky illumination; the quantity of total (sun and sky) daylight illumination on a horizontal surface (kilolux $hour^{-1}$).

RF8 - direct solar radiation; normal incident short-wave radiation originating from the vicinity of the sun within 3^{o} of the centre of the solar disc (Wm^{-2}, MJm^{-2} $hour^{-1}$, MJm^{-2} day^{-1}).

Environment Canada / Environnement Canada
Atmospheric Environment / Environnement atmospherique
4905 Dufferin Street
Downsview, Ontario, M3H 5T4

FUCI

RADIATION MATER



RADIATION MATER

1. SPECIFICATIONS

Consists of:

MG-Bl	Radiation Interface
ME-Al	Indoor Electronics
MF-Al	Indoor Tape Recorder
MM-Bl	Dual Batteries with regulators
MJ-Al	Mater Box
MJ-Bl	Rack Panel Mount
MN-Al	A.C. charges 200 ma for MATER Battery
MN-Bl	A.C. charges 600 ma for Integrator and Sensor Battery
MJ-Dl	Integrator Mainframe and MI-Al control board
MI-Bl	0 to +15 mv Integrator

Option:

MI-BI	0 to +15 mv Integrators
MI-CI	-10 to +40- mv Integrators
NA-AI	MITS Temperature Sensor
NB-Al	Parallel Plate shield for NA-AI
NG-Al	Sunshine Sensor

Inputs:

1. RF-1 radiometer
2. Temperature sensor NA-Al with shield NB-Al
3. RF-2, RF-3, RF-4, RF-7 with appropriate MI-series integrator cards.
4. Sunshine Sensor NG-Al.

Tape:

Only Hitachi C-60 cassettes have passed A.E.S. tests. There is enough capacity on one tape for at least 2 weeks data.

Battery:

The battery will operate the system through a 10 hour power failure.

Dimensions:

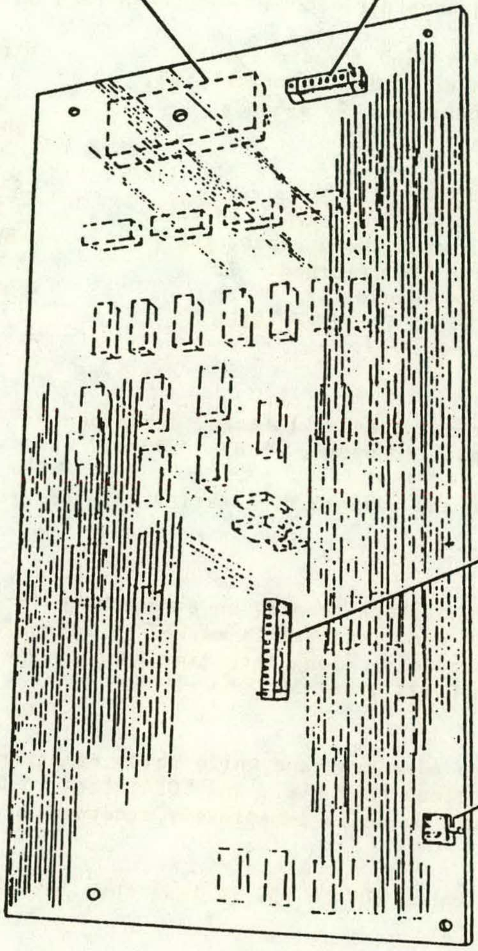
Maximum: 39.5cm H x 68.3cm W x 26cm D
15 1/2"H x 19" W x 9 1/2"D

Weight: 14.25 Kg (31 lb. 6 oz.)
less batteries and Voltage regulators.

Canada Atmospheric Environment
Canada Environnement atmospherique
4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MEA1

ELECTRONICS - INDOOR



1. SPECIFICATIONS

Standard Electronics:

Operating Temp. Range: +50 C to -40 C (-10 C with MF-A1 Standard Tape Deck).

Inputs: Use prewired MG series labeled Interface Terminals where possible.

Seven optical coupler inputs: 5 to 20 Volts, 10 msec contact time, less than two closures per second repetition rate on each channel.

One relay input for wind speed only: 5 to 20 Volts 10 msec minimum contact time, less than one closure per 25 seconds repetition rate.

One wind logic input pin: no connection = wind, OV = no wind. In the wind mode, upon a wind speed input, the direction channels are recorded. If only one direction channel is activated, then it is recorded twice (see table):

Wind	Records
N	NN
NE	NE
E	EE
SE	SE
S	SS
SW	SW
W	WW
NN	NW

Outputs:

(1) 4 min. time out contact 15 msec. duration.
Max. Ratings: 10 watts, 100V, 500 ma.

(2) Will record and advance MF-A series tape deck only. (+40 C to -10 C).

Clock:

Crystal controlled clock records on time channel at one minute intervals. 1024 min. interval is marked by advancing tape for 32 steps without recording (long term time sync). The crystal is accurate within 0.02% from +50 C to -50 C.

Controls:

Reset pushbutton advances tape while held, resetting 1 min. clock to 0 min.; 4 min. clock to 2 min.; and 1024 clock to 0 min. When released a minute pulse is immediately recorded on the tape.

Power Consumption:
Power Consumption at 10V to 15V is less than 1ma plus motor current during motor step.

Mounting:
Bolts into MJ-A1 MATER box with 5 pan head 8-32 X 1/4 stainless steel screws.

Dimensions:

Max: 31.8 cm H x 17.8 cm W x 4.4 cm D
12 1/2" H x 7" W x 1 3/4" D

Weight: 0.36 Kg (13 oz).

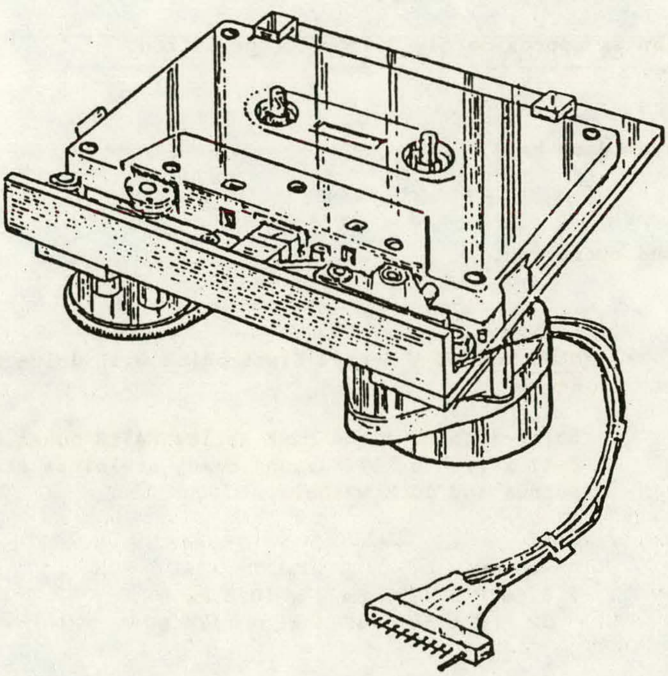
MF A1

Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

TAPE DECK INDOOR



Indoor Tape Deck

1. SPECIFICATIONS

Operating Temperature Range: +50°C to -10°C .

Tape:

Tape deck does not erase; use only virgin cassettes.

Only Hitachi C-60 Low Noise cassettes have passed AES tests.

One C-60 cassette holds 860,000 events.

Motor Drive:

Two phase drive, 12V, 1 amp, 10 msec.

One step is approximately 0.1mm of tape motion.

Tape Head:

Two track data head.

Loading:

One hand operation.

Compatibility:

(1) ME-C and ME-A Series Electronics will drive this tape deck.

(2) Bolts into MJ-A and MJ-E series MATER boxes with two 8-32 x 1/4" or 1/2" round head, stainless steel machine screws and lock washers.

Dimensions:

Max: 7.6 cm H x 12.1 cm W x 10.8 cm D
3" H x 4 3/4" W x 4 1/4" D

Net Weight: 0.33 Kg (12 oz).

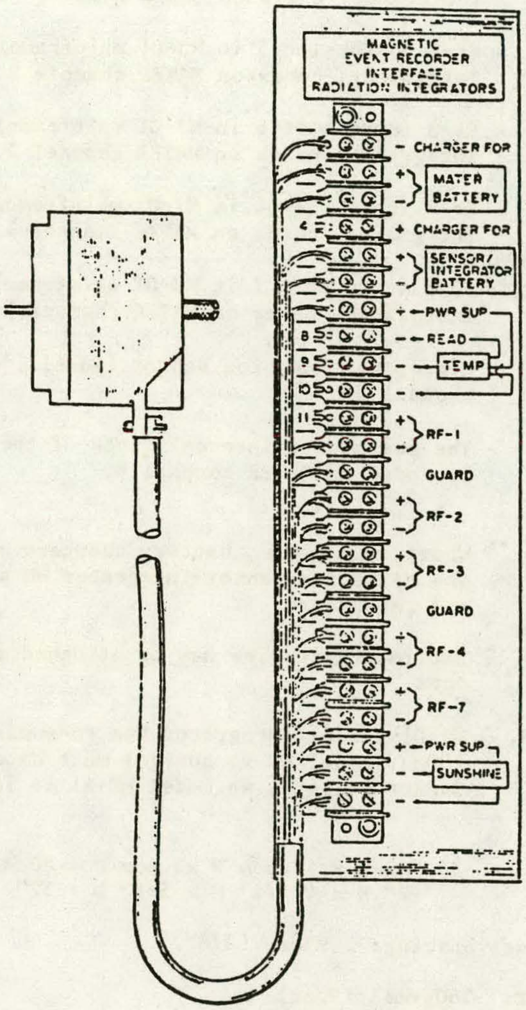
Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MGBI

INTERFACE TERMINAL FOR RADIATION INTEGRATORS



RADIATION INTERFACE

1. **SPECIFICATIONS**

Accepts Sensors:

(1) Model NA-A1 Micropower Integrating Temperature Sensor (MITS), codes on MATER channel 7.

(2) RF-1 (card slot 3 in MJ-D1 mainframe) 0 to 15mv Integrator, codes on MATER channel 1.

(3) RF-2 (card slot 5 in MJ-D1 mainframe) 0 to 15mv Integrator, codes on MATER channle 2.

(4) RF-3 (card slot 6 in MJ-D1 mainframe) 0 to 15mv Integrator, codes on MATER channel 3.

(5) RF-4 (card slot 4 in MJ-D1 mainframe) -10 to +40mv Integrator, codes on MATER channel 4.

(6) RF-7 (card slot 1 in MJ-D1 mainframe) 0 to 15mv Integrator, codes on MATER channel 5.

(7) Micropower Sunshine Sensor (NG-A1), codes on MATER channel 8.

(8) The one minute internal clock of the MATER electronics is coded on MATER channel 6.

POWER:

(1) Where applicable, battery chargers may be attached for the MATER and Sensor-Integrator MM series batteries and regulators.

(2) External batteries may be attached instead of internal ones.

N.B. MJ-D1 series integrator box consumes approximately 200ma. Model MN-B1 charger must be used to charge the Sensor battery, as model MN-A1 is insufficient.

DIMENSIONS

Max: 30.5cm H x 11.5cm W x1.6cm D + 80cm cable and connector
12" H x 4 1/2" W x 5/8" D + 32" cable and connector

Terminal Spacing: .95cm (3/8")

Weight: 560grms (20oz)

2. <u>Technical Description</u>: (see appropriate system drawings)

<u>Pin No.</u>	<u>Function</u>
1.	Positive terminal for the MATER battery charger MN-A1. There is an internal voltage regulator.
2.	Positive terminal of internal MATER battery. If there is no internal battery, the external power supply may be attached to these pins.
3.	Negative and common terminal of the MATER battery and battery charger.
4.	Positive terminal of Sensor-Integrator battery charger (600ma charger MN-B1).
5.	Positive terminal of the Sensor-Integrator battery.
6.	Negative and common terminal of the Sensor-Integrator battery and charger.
7.	Applies the positive sensor supply to the temperature sensor NA-A1.
8.	Applies the update command (OV) to the temperature sensor.
9.	The temperature sensor brings this pin to OV, pin 10, to send data to MATER.
10.	Connects the OV or common of the sensor battery to the temperature sensor.
11.	RF-1 positive lead (integrator card number 3).
12.	RF-1 negative lead.
13.	Guard connects to shield of RF-1 and RF-2.
14.	RF-2 positive lead (integrator card number 5.
15.	RF-2 negative lead.
16.	Positive lead of RF-3 (integrator card number 6).
17.	Negative lead of RF-3.
18.	Guard connects to the shield of RF-3, RF-4 and RF-7.
19.	Positive lead of RF-4 (integrator card number 4.
20.	Negative lead of RF-4.
21.	Positive lead from the RF-7 sensor (integrator card number 1).
22.	Negative lead from the RF-7 sensor.
23.	Applies positive sensor supply voltage to the sunshine sensor NG-A1.
24.	The sunshine sensor NG-A1 pulls this point to OV (pin 25), to send data to MATER.
25.	Applies the common OV of the sensor supply to the sunshine sensor.

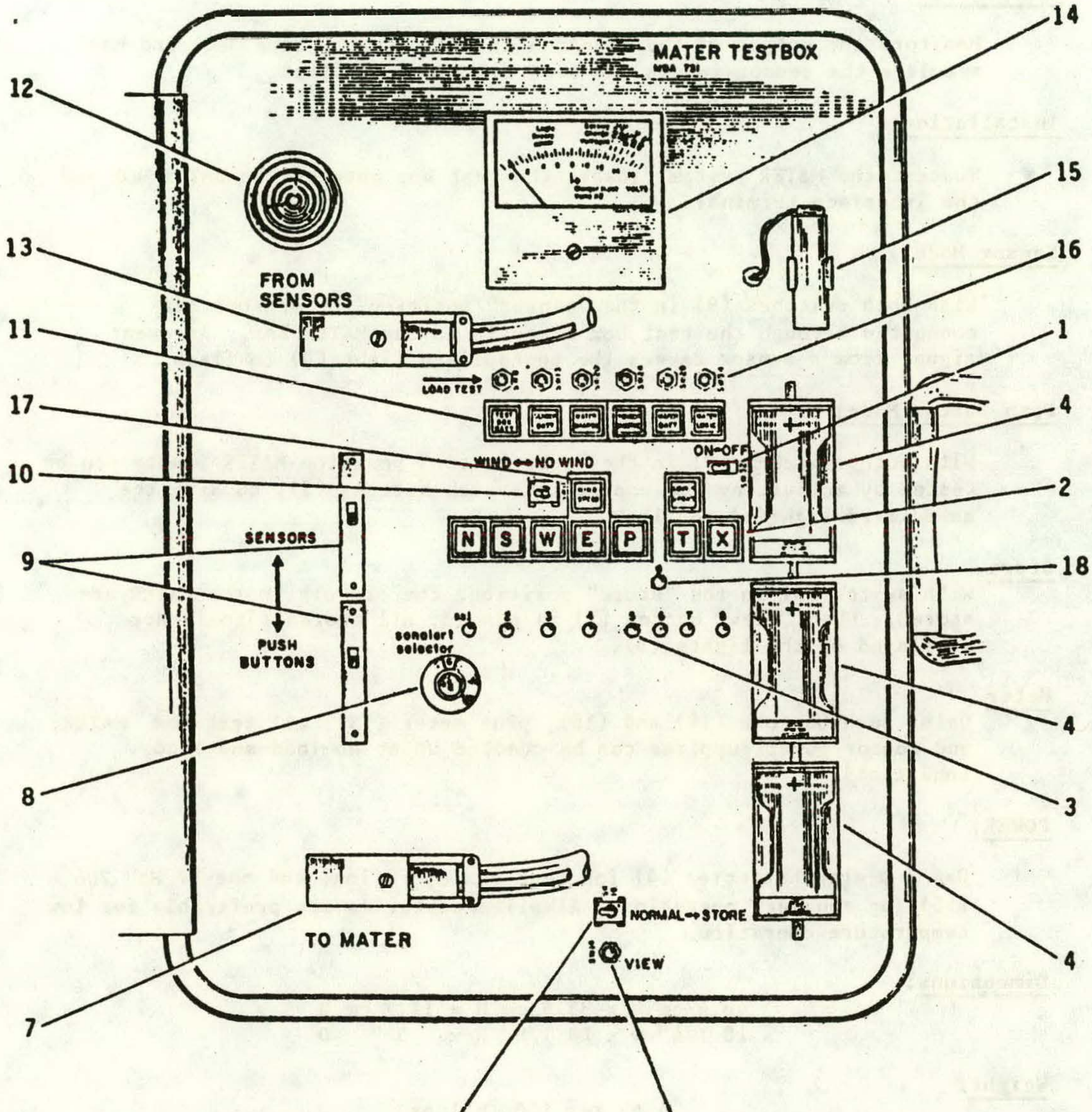
Environment Canada — Environnement Canada

Atmospheric Environment — Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MHA1

TEST BOX



TEST BOX

1.

SPECIFICATIONS

Application:

Monitors the output of the electronics board to the tape deck and can simulate the sensor inputs and test all power supplies.

Installation:

To test the MATER system, insert the test box between the MATER BOX and the interface terminal.

Sensor Mode:

With both switches (9) in the "sensor" position the sensors are connected through the test box directly to the MATER box. An event signal from a sensor causes the appropriate light (3) to flash.

Push Button Mode:

With both switches (9) in the "push button" position MATER inputs can be tested by activating the appropriate push buttons (2), causing the associated light(s) to flash.

Store

With switch (6) in the "store" position, the signals to the MATER are stored. When "view" button (5) is pushed, all stored signals are displayed on the lights (3).

Meter

Using push buttons (11) and (16), plus meter (14), all test box, MATER, and sensor power supplies can be checked under no-load and load conditions.

POWER:

Use 3 D-size batteries (4) for test box operation, and one 9V No. 2U6 (15) for sonalert operation. Alkaline batteries are preferable for low temperature operation.

Dimensions:

46.4 cm W x 35.9 cm H x 12.7 cm D
18 1/4" W x 14 1/8" H x 5 " D

Weight:

4.57 Kg (10 lb 1 oz).

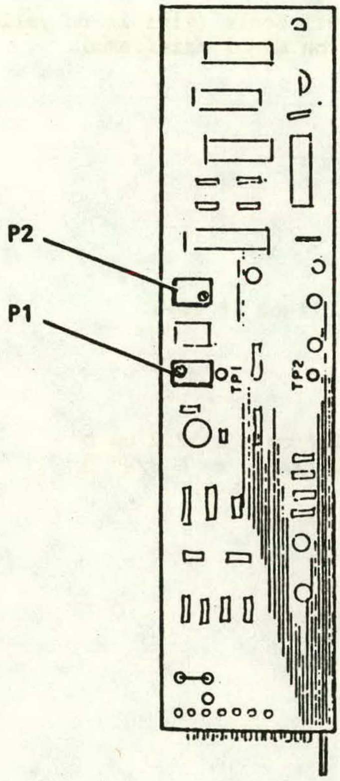
Environment Canada
Atmospheric Environment

Environnement Canada
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MIB1

0 TO +15mV INTEGRATOR



<u>0 to +15 mV INTEGRATOR:</u>

Sonotek part no. A098Y.

1. <u>SPECIFICATION</u>

<u>Input</u>:

0 to +15 mV.

<u>Output</u>:

0 to 1500 counter/hour full scale (visible on yellow L.E.D. if activated by view button on MJ-D1 mainframe).

<u>Accuracy</u>:

±0.3%.

<u>Power Consumption</u>:

18 ma + 28 ma for L.E.D. light if used.

<u>Dimensions</u>:

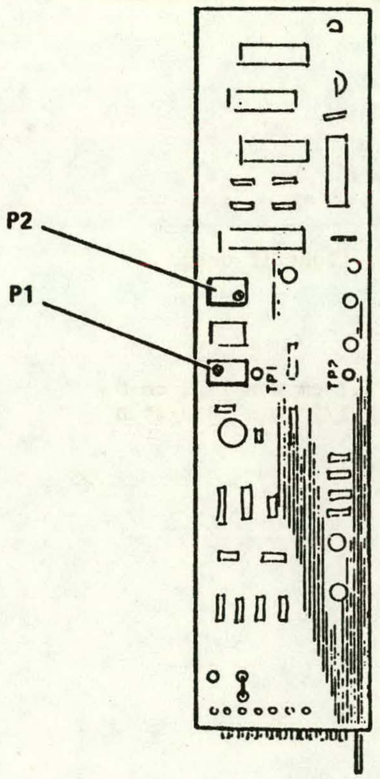
<u>Maximum</u>: 1.3 cm H x 3.7 cm W x 17.2 cm D
1/2" H x 1 1/2" W x 6 3/4" D

<u>Weight</u>: 42 g (1.5 oz).

Environment Canada
Environnement Canada
Atmospheric Environment
Environnement atmospherique
4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MIC1

-10 TO +40MV INTEGRATOR



-10 to +40 mV INTEGRATOR

Sonotek part no. A098G

1. SPECIFICATIONS

Input:

-10 to +40 mV.

Output:

0 to 1500 counts/hour full scale (visible on green L.E.D. if activated by view button on MJ-Dl mainframe).

Accuracy:

±0.3%.

Power Consumption:

18 ma + 28 ma for L.E.D. light if used.

Dimensions:

Maximum:	1.3 cm H x 3.7 cm W x 17.2 cm D
	1/2" H x 1 1/2" W x 6 3/4" D
Weight:	42 g (1.5 oz).

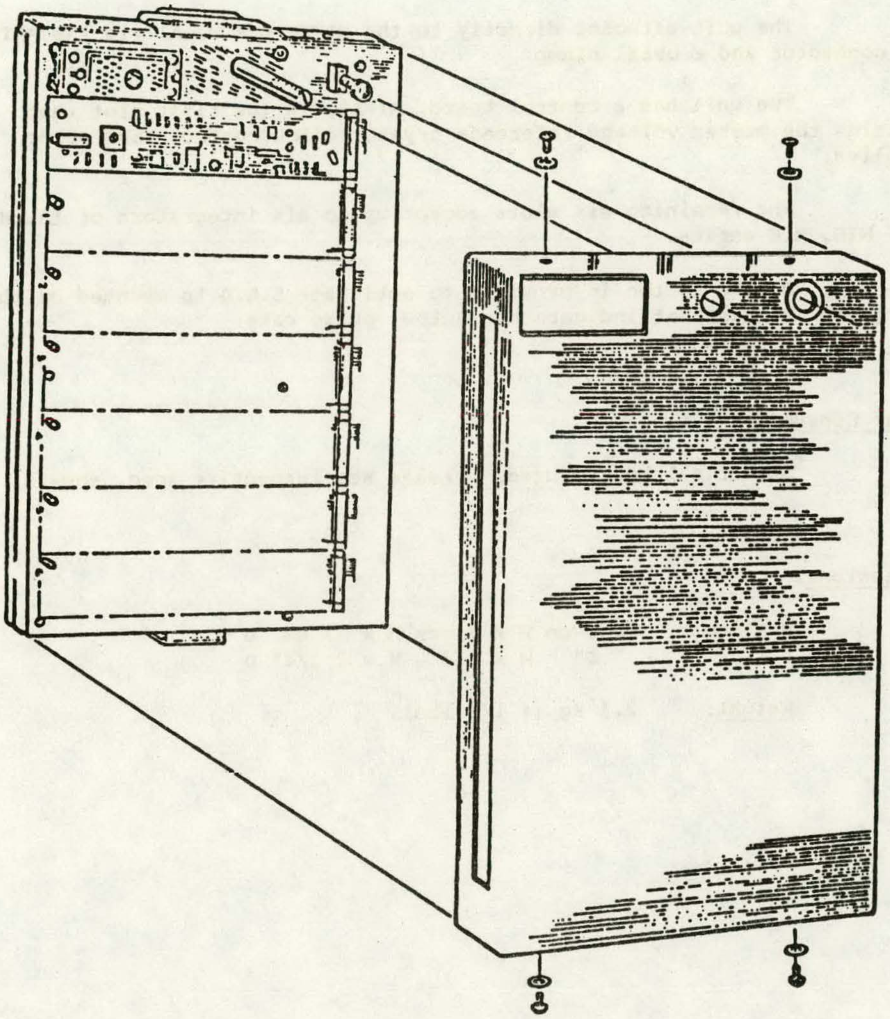
Fisheries and Environment Canada
Pêches et Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MJDI

INTEGRATOR MAINFRAME AND CONTROL BOARD



INTEGRATOR MAINFRAME AND CONTROL BOARD (includes one MI-A1)

Sonotek Model No. RI 4000 - See drawing MDA 589.

1. SPECIFICATIONS

Mainframe:

The unit attaches directly to the MATER box MJ-A1 via the MATER 56 pin connector and a metal clamp.

The unit has a control board, MI-A1, in the first slot that contains the master voltage reference crystal clock control, and power supplies.

The remaining six slots accept up to six integrators of the MIB, MIC, MID, MIE series.

A push button is provided to activate L.E.D.'s mounted on the integrator boards that indicate the output pulse rate.

Power Consumption:

Sum of all boards used. Please see respective spec. sheets.

Dimensions:

Maximum:	20.5 cm W x 33 cm H x 7 cm D
	8" W x 13" H x 2 3/4" D
Weight:	2.1 Kg (4 1/2 lbs).

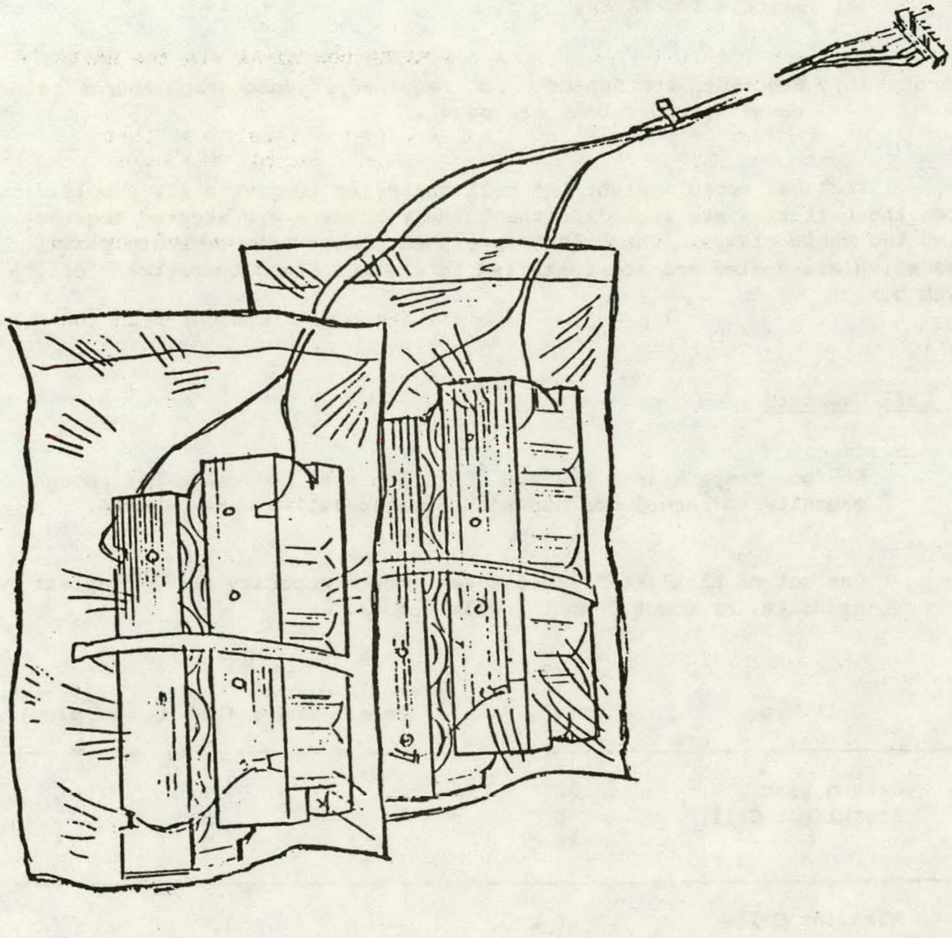
Environment Canada — Environnement Canada

Atmospheric Environment — Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MKB1

"D" CELL BATTERY BAGS



'D' Cell Battery Bags

1. **SPECIFICATIONS**

Application:

(a) Black - for MATER.

(b) Black-Red for Sensor - not required if anemograph and/or rain gauge recorder only are used .

Each bag accepts eight 'D' cell batteries to give a 12V supply. After the batteries are installed the battery holders are secured together using two cable clamps. The holders are then placed into separate plastic bags which are sealed and are installed in the left hand compartment of the MATER box.

'D' Cell Capacity

At room temperature, one set of carbon zinc 'D' cells has enough capacity to record one month's climat data.

One set of Alkaline 'D' cells has enough capacity for a complete cassette, or about 3 months climat data.

Cell Type	Temp.	Ampere Hours (500 mA Stepping)
Carbon Zinc Flashlight Cell	20 C	1
	0 C	.5
	-10 C	.3
Alkaline Cells	20 C	3.6
	0 C	2.9
	-10 C	2.2
	-40 C	.54

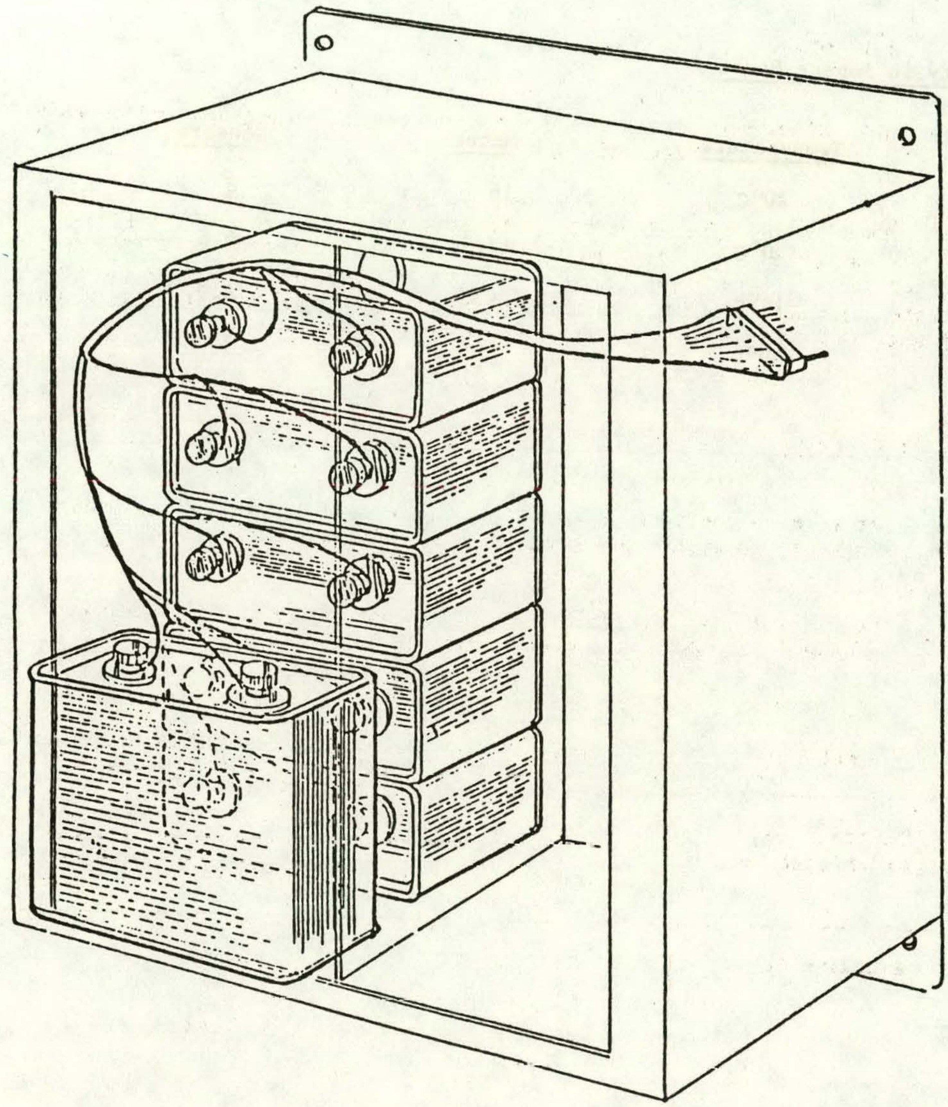
Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MLBI

ALKALINE LANTERN BATTERY HARNESS



MATER - ALKALINE LANTERN BATTERY HARNESS (Prototype Only)

1. SPECIFICATIONS

Six Eveready type 731-W batteries are used. The red and black wires are connected to positive and negative respectively.

Capacity in Ampere-Hours

Temperature	Mater	Sensors
20°C	16	8
0°C	12.9	6.5
-10°C	9.8	4.9
-40°C	2.4	1.2

Environment Canada | Environnement Canada

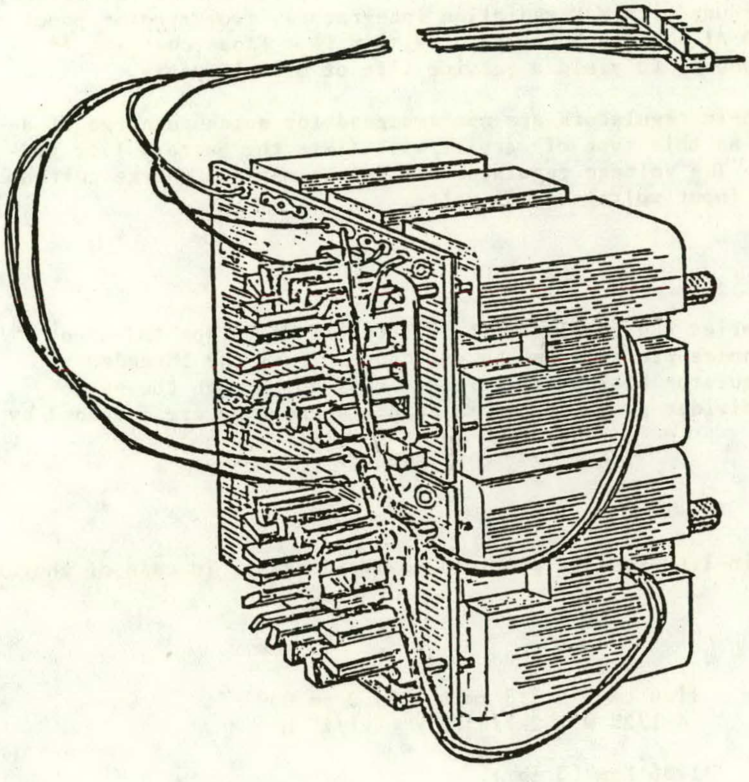
Atmospheric Environment | Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MMBI

RECHARGEABLE BATTERY SET

C/W REGULATOR



1. SPECIFICATIONS

RECHARGEABLE MATER/SENSOR BATTERIES AND REGULATORS

Two lead acid type batteries of 2.5 AH capacity at 20°C are supplied. Each battery has its regulator to maintain the battery fully charged through the temperature range of -50°C to +50°C.

Charger:

N.B. The system is designed to be float charged from the AC line, (MN-A, 200 ma one per battery) (MN-B, 600 ma one per battery for use with MJD radiation integrator), from a solar panel (MO-A1 one per battery) or wind mill. Float charging is expected to yield a service life of over 10 years.

The built-in regulators are not designed for quick recharge of a discharged battery, as this type of service will limit the battery life to less than one year. The voltage regulator limits the maximum charge current to 650 ma. Maximum input voltage is 35 volts.

Application:

The batteries and regulators bolt into the MATER box (MJ-A1 or MJ-E1) through the holes provided in the enclosure. From the threaded standoffs in the regulator board, the threaded rods go through the battery holes, through the divider panel of the MATER box where they are fastened by wing nuts.

Fuse:

A 5 amp in-line fuse is provided to avoid damage in case of shorts.

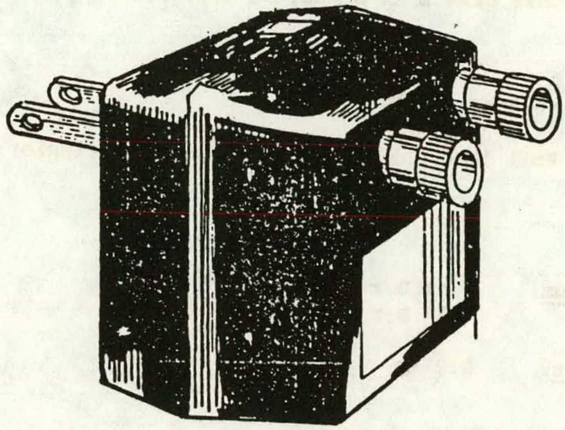
Dimensions:

Maximum:	11.4 cm W x 7.3 cm D x 14.0 cm H 4 1/2" W x 2 7/8" D x 5 1/2" H
Weight:	1.36 Kgm (3 lb.).

Environment Canada / Environnement Canada
Atmospheric Environment / Environnement atmosphérique
4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MNAI

A.C. CHARGER 200 MA



200 ma AC CHARGER (ARMACO Part No. A274)

1. **SPECIFICATIONS**

Application:

This unit may be used to keep the MATER or sensor battery MM-A1 Charged. In the normal climatological application, two chargers are required.

N.B. This charger has insufficient current capacity for a sensor battery when used with the radiation integrator MJ-D. In this case a MN-B must be used for the sensor battery.

Output: No load: 32V.

Full load: 20V, 200 ma, (2V pp-pk ripple)

Dimensions:

Maximum: 8 cm D x 6.5 cm H x 5 cm W
3" D x 2 1/2" H x 2" W

Weight: 0.2 Kg (1/2 lb).

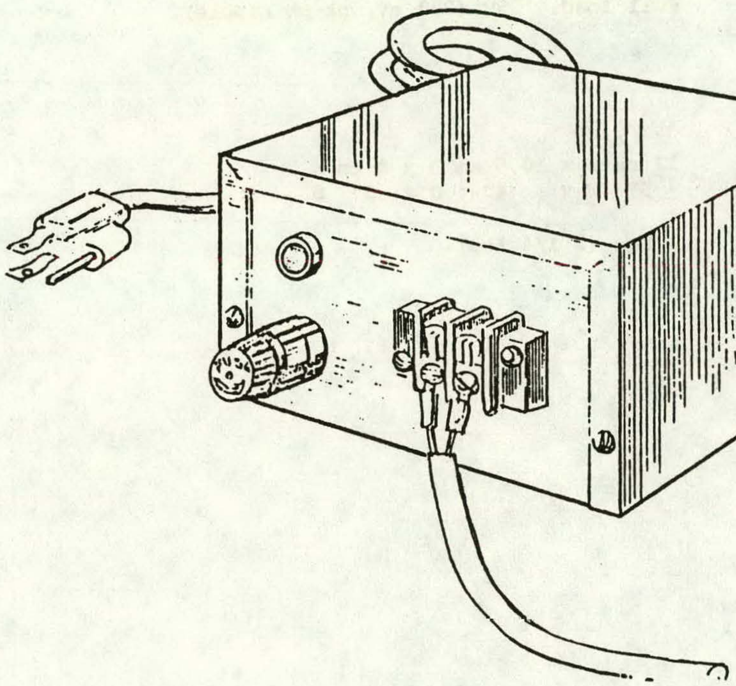
Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmosphérique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MNBI

A.C. CHARGER 600mA.



600 ma AC CHARGER

1. SPECIFICATIONS

Application:

This supply is required for the sensor battery in a MATER system with integrators MJ-D1. Model MN-A1 is still used to charge the MATER battery.

Output: No load: 30V.
Full load: 25V (250 mv, pk-pk ripple).

Dimensions:

Maximum:	13 cm W x 10.5 cm D x 8 cm H
	5" W x 4" D x 3" H
Weight:	1 Kg (2 1/4 lbs).

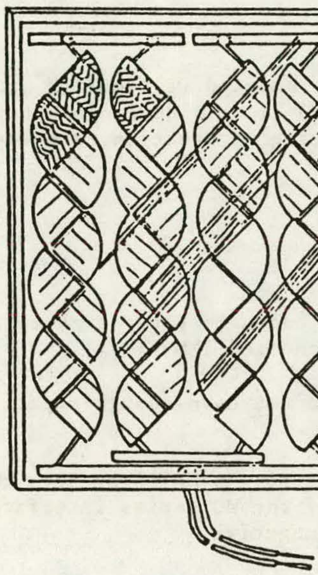
Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

MOAI

SOLAR PANEL



SOLAR PANEL

1.

SPECIFICATIONS

SOLAREX No. 420

Output: Minimum output with bright sun at right angles, 100 ma with full charging voltage from MM series voltage regulator.

Mounting:

The unit is normally mounted vertically, and facing South on the right panel of the MJ-C1 outside enclosure. This provides snow shedding, easy mounting, protection, and adequate output in unshaded areas.

Application:

Two units will give adequate power to keep a MATER recorder battery and sensor battery charged (MM-B1).

N.B. One panel does not have enough capacity for integrator module MJ-D1.

The unit is attached to the MATER battery charger or sensor battery charger terminals of the MC series interface terminals. Red is positive, black is negative.

Dimensions:

Maximum:	24 cm H x 28 cm W x 1.3 cm D 9 1/2" H x 7" W x 1/2" D
Weight:	0.6 Kg (1.4 lb).

SOLAR PANEL

1.

SPECIFICATIONS

SOLAREX No. 420

Output: Minimum output with bright sun at right angles, 100 ma with full charging voltage from MM series voltage regulator.

Mounting:

The unit is normally mounted vertically, and facing South on the right panel of the MJ-C1 outside enclosure. This provides snow shedding, easy mounting, protection, and adequate output in unshaded areas.

Application:

Two units will give adequate power to keep a MATER recorder battery and sensor battery charged (MM-B1).

N.B. One panel does not have enough capacity for integrator module MJ-D1.

The unit is attached to the MATER battery charger or sensor battery charger terminals of the MG series interface terminals. Red is positive, black is negative.

Dimensions:

Maximum:	24 cm H x 28 cm W x 1.3 cm D 9 1/2" H x 7" W x 1/2" D
Weight:	0.6 Kg (1.4 lb).

Environment Canada / Environnement Canada

Atmospheric Environment / Environnement atmospherique

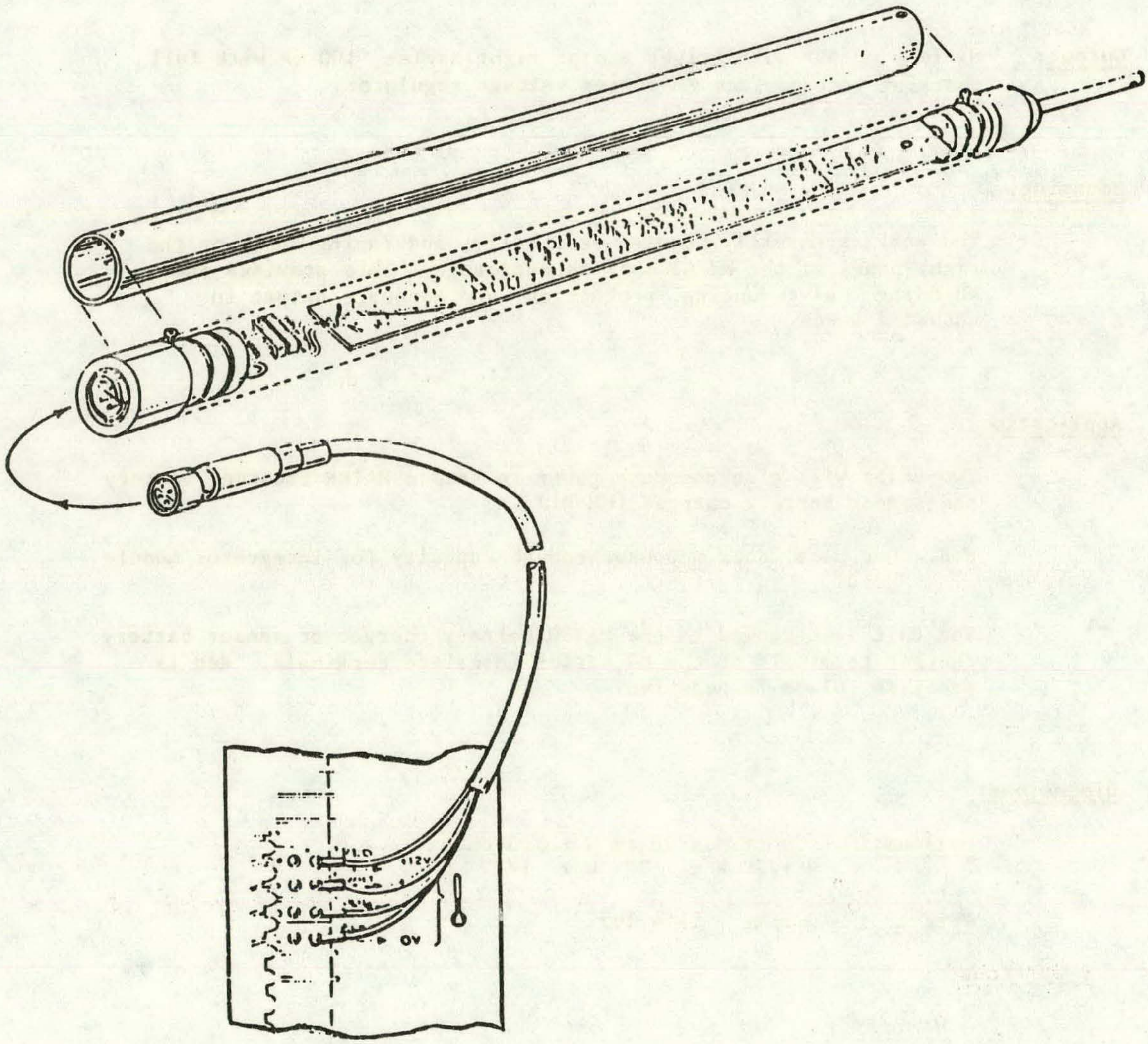
4905 Dufferin Street
Downsview, Ontario, M3H 5T4

NAAI

MITS

MICROPOWER INTEGRATING TEMPERATURE SENSOR

FOR MATER



MITS FOR MATER

Micropower Integrating Temperature Sensor for Use with the Magnetic Tape Event Recorder

1. **SPECIFICATIONS**

The sensor includes built-in electronics.

Performance:

Range: -59.9°C to +50°C.
Max. Error: ±0.2°C -30°C to +30°C
±0.5°C -50°C to +50°C.
Resolution of internal accumulator: ±0.05°C.

Output:

Upon update command (return to ground of -12V greater than 10 msec.), each output pulse (return to ground of -12V) is 5°C. Each output pulse is the overflow of an internal accumulator which accumulates to the nearest 0.05°C.

Output rate is approximately 1 second per pulse.

Output delay is 1 to 22 seconds after end of update command.

The output pulse train always ends at approximately 23 seconds after the end of the update command.

Power: 12V nominal 10-15V maximum range.
Less than 100 uA standby.
Less than 50 ma during reading.

Application:

a. Connection to MATER is as follows:

MITS Connector Pin	Wire Colour	Function	Symbol
2	Red	+ Power Supply	+12V
4	White	Update Time	t
3	Green	Temperature Signal	
1	Black	Power Supply Common	-OV

b. Each data pulse in a 20 minute period (5 update cycles) is 1°C above -60°C.

Dimensions:

Maximum: 57 cm L x 3.2 cm Diam.
22 3/8" L x 1 1/4" Diam.

Weight: .7 Kg (1.6 lbs).

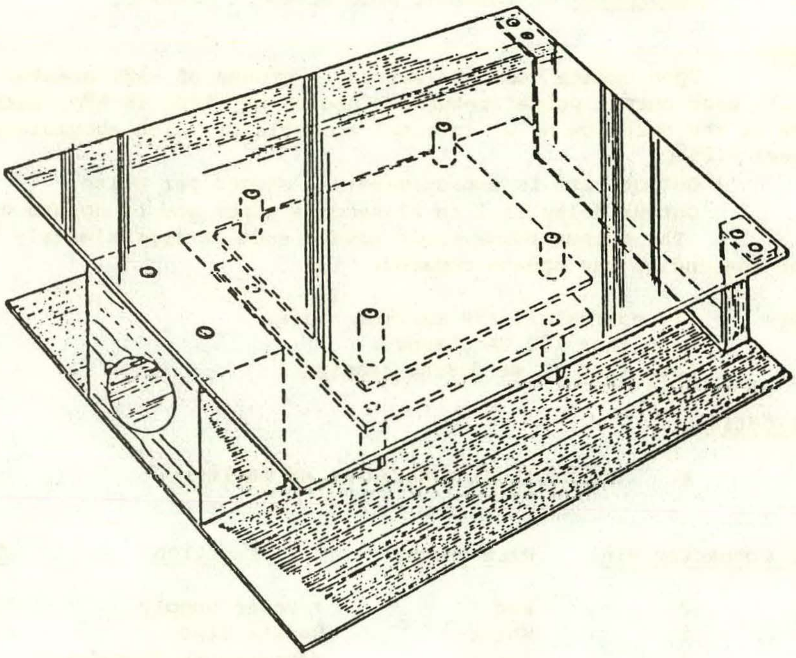
Environment Canada | Environnement Canada

Atmospheric Environment | Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

NBAI

MITS PARALLEL PLATE RADIATION SHIELD



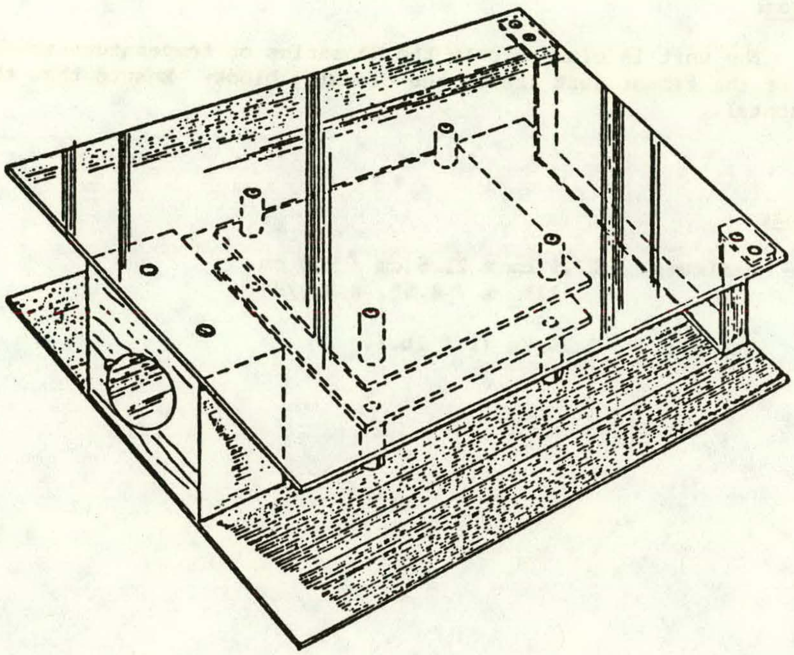
Environment Canada
Environnement Canada

Atmospheric Environment
Environnement atmospherique

4905 Dufferin Street
Downsview, Ontario, M3H 5T4

NBAI

MITS PARALLEL PLATE RADIATION SHIELD



MITS PARALLEL PLATE SHIELD

1. SPECIFICATIONS

Performance:

The unit performs at least as well on the Standard Stevenson Screen with errors of actual air temperature, typically less than $\pm 0.5^{\circ}C$.

Application:

The unit is clamped onto the NA series of temperature sensors, with the bolt of the sensor just inside the clamping block. Ensure that the plates are horizontal.

Dimensions:

Maximum:	27.9 cm x 21.6 cm x 6.0 cm 11" x 8.5" x 2 3/8"
Weight:	0.50 Kg (1.1 lb.).

APPENDIX C

MANUFACTURERS AND DISTRIBUTORS OF SOLAR RADIATION MEASURING INSTRUMENTS

Introduction

The Development of solar radiation measuring instruments is not as advanced as many instruments used to sense atmospheric parameters. The instrument requirements are unique and have been discussed elsewhere in this handbook.

The purpose of this appendix is to identify manufacturers and distributors of solar radiation measuring instruments. Since this is the first attempt for such a list by an international organization, it may not be complete and it was difficult to differentiate between manufacturers and distributors. Some corrections may be necessary.

No attempt is made in this appendix to list types of instruments nor to evaluate performance. The manufacturers' performance data for many of the instruments are included in a U. S. Department of Energy report, *Catalog of Solar Radiation Measuring Equipment.*[1]

A format has been developed to list the primary performance considerations of instruments, either from manufacturers' specifications or from independent laboratory testing. The format is included in the appendix to assist in comparing and evaluating various instruments.

[1] Carter, E. A., Breithaupt, W. G. and Patel, A. M. 1977. *Catalog of Solar Radiation Measuring Equipment.* Energy Research and Development Administration (now U. S. Department of Energy), Division of Solar Energy, ORO/5362-1, April 1977.

APPENDIX C

MANUFACTURERS AND DISTRIBUTORS OF SOLAR RADIATION MEASURING INSTRUMENTS

Australia

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

† Middleton Instruments
75-79 Crockford Street
Port Melbourne, Victoria 3207
Australia

Rauchfuss Instruments Division of Analite Pty., Ltd.
352-368 Ferntree Gully Road
Notting Hill
Melbourne, Victoria
Australia

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

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

Austria

* Philipp Schenk
Ges. M.B.H. Wien & Co., KG
Jedleseerstrasse 59
1212 Wien,
Austria

Canada

† Enercorp Instruments, Ltd.
P. O. Box 20 Stn. U
Toronto, Ontario M8Z 5M4
Canada

Denmark

* Siemen Ersking
Instrument Maker
Rørsangervej 7
Federikssund, DK 3600
Denmark

Finland

* VAISALA Oy
PL 26
SF 00421 Helsinki 42
Finland

France

* Enertic Schlumberger
1 Rue Nieuport,
Velizy-Villacoublay F-78140
Paris, France
Tel. 1-946-9650
Telex SISVIL 698201

Germany

* Adolf Thiess GmbH & Co., KG
Klima -, Mess-und Regeltechnik
3400 Gottingen - Geismar
Hauptstrasse 76
Federal Republic of Germany

* Dr. Bruno Lange GmbH
Königsweg 10
D-1000 Berlin 37
Federal Republic of Germany

Wilhelm-Lambrecht KG
Friedländerweg 65
D-34 Gottingen
Federal Republic of Germany

Germany (cont.)

Wolters U. Möhring
Lutzowstrasse 102-104
D-1000 Berlin 30
Federal Republic of Germany

Italy

* Assing
Ingegneri Associati
Via A. De Pretis, 70
00184 - Roma
Italy

* Italglas S. P. A.
Piazza Rossetti 4-18
16129 - Genova
Italy

* Montedel - Laben
Via E. Bassini, 15
20133 - Milano
Italy

* Sielco S. R. L
Via Carlo Poma, 4
00195 - Roma
Italy

* Soc. Salmoiraghi
Piazzale Kennedy
16129 - Genova,
Italy

* Soc. Siap
Via Massarenti 412-2°
40138 - Bologna
Italy

* 3 G Electronics
Via del Perugino, 9
20135 - Milano
Italy

Japan

* EKO Instrument Trading Co., Ltd.
21-8 Hatagaya 1-chome
Shibuya-ku, Tokyo
151 Japan

Japan (cont.)

† Ishikawa Trading Co., Ltd.
4-6-13 Shinkawa
Mitaka, Tokyo, 181,
Japan

* Nekano Scisakusho Ltd.
Higashi Mita 1525
Ueno-City Mie prefecture
Japan (518)

The Netherlands

* Kipp and Zonen
P. O. Box 507
Delft, The Netherlands

Sweden

The Swedish Meteorological & Hydrological Inst.
SMHI, Fack
S-601 01 Nörrkoping
Sweden

Switzerland

Dr. C. Frolich
Physico-Meteorological Observatory
CH-7270
Davos-Platz, Switzerland

Haenni and Company
CH-3303 Jergenstorf b.
Bern, Switzerland

U. S. S. R.

* Mashpriborintorg
Smolenskaya - Sennaya Square 32-34
Moscow, U. S. S. R.

United Kingdom

* C. F. Casella and Co., Ltd.
Regent House
Britannia Walk
London, N1 7 ND, England

United Kingdom (cont.)

* Lintronic Limited
54-58 Bartholomew Close
London, ECIA 7 HB
England

United States of America

* Belfort Instrument Co.
1600 South Clinton Street
Baltimore, MD 21227, U. S. A.

* C. W. Thornthwaite Associates
Route 1, Centerton
Elmer, NJ 08318, U. S. A.

Devices & Services Co.
3501-A Milton
Dallas, TX 75205, U. S. A.

* Eppley Laboratory, Inc.
12 Sheffield Avenue
Newport, RI 02840, U. S. A.

* Gamma Scientific, Inc.
3777 Ruffin Road
San Diego, CA 92123, U. S. A.

* Hy-Cal Engineering
12105 Los Nietos Road
Santa Fe Springs, CA 90670, U. S. A.

* Kahl Scientific Instruments Corp.
P. O. Box 1166
El Cajon (San Diego), CA 92022, U. S. A.

* LI-COR, Inc.
4421 Superior Street
P. O. Box 4425
Lincoln, NE 68504, U. S. A.

† Matrix, Inc.
537 South 31st Street
Mesa, AZ 85204, U. S. A.

Molectron Corporation
177 N. Wolfe Road
Sunnyvale, CA 94086, U. S. A.

U. S. A. (cont.)

* Rho Sigma
15150 Raymer Street
Van Nuys, CA 91405, U. S. A.

† Science Associates, Inc.
230 Nassau Street
P. O. Box 230
Princeton, NJ 08540, U. S. A.

* Spectran Instruments
P. O. Box 891
La Habra, CA 90631. U. S. A.

* Spectrolab
12500 Gladstone Ave.
Sylmar, CA 91342, U. S. A.

† Sun Systems, Inc.
P. O. Box 347
Milton, MA 02186, U. S. A.

† Technical Measurements, Inc.
P. O. Box 838
La Canada, CA 91011, U. S. A.

† Teledyne Geotech
3401 Shiloh Road
Garland, TX 75041, U. S. A.

† WeatherMeasure Corporation
P. O. Box 41257
Sacramento, CA 95841, U. S. A.

† WEATHERtronics, Inc.
2777 Del Monte Street
P. O. Box 1286
West Sacramento, CA 95691, U. S. A.

† Yellow Springs Instrument Co.
Yellow Springs, OH 45387, U. S. A.

* = manufacturer
† = retail distributor
(no annotation = the manufacturing capability is unknown.)

APPENDIX D

INSTRUCTIONS FOR INSTRUMENT DESCRIPTION AND PERFORMANCE FORM

1. **LETTERHEAD/LOGO**: In the space provided, attach a camera-ready mechanical of manufacturer or distributor 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.

2. **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.

3. **PRODUCT DATA**. In the space provided, type answers to questions listed:

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

   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. *Net Pyranometer:* An instrument for the measurement of the net flux of downward and upward solar radiation.

      4. *Pyrgeometer:* An instrument for the measurement of atmospheric radiation on a horizontal upward-facing black surface at the ambient air temperature.

      5. *Pyrradiometer:* An instrument for the measurement of both solar and terrestrial radiation (total radiation).

      6. *Net Pyrradiometer:* An instrument for the measurement of the net flux of downward and upward total (solar, terrestrial, surface and atmospheric) radiation.

   c. **Sensor Type**

      1. *Calorimeter*

      2. *Thermocouples or thermopiles*

      3. *Bimetallic*

      4. *Photovoltaic, photo conductive or photoemissive cells*

      5. *Black Body*

      6. *Pyroelectric cell*

      7. *Others (specify)*

   d. **Sensor Surface Coating**: Coating applied on the surface of the sensing element.

   e. **Windows**: Declare the number of windows, the window material, the radii of windows (flat window: $r = \infty$), and the exchangeability.

   f. **Aperture**: Declare the full viewing angle in case of pyrheliometers (e.g., $6^\circ \times 3^\circ$).

4. **GENERAL FEATURES**: In the space provided, type answers to the questions listed:

   a. **Dimensions**: Declare the maximum dimensions (in cm).

   b. **Weight**: Declare the total weight (in kg).

   c. **Provision for Levelling**: Declare the indicator (e.g., spirit level) and the method of adjustment of the indicator (mechanical or optional).

   d. **Weatherproof**: Check mark "yes" if the instrument is suitable for long-time outdoor operation without any additional devices. Declare the desiccant used.

e. **Additional Equipment**: Declare available additional or optional equipment, e.g., filter glasses, blowers for ventilating the windows, shadow rings for measuring sky radiation, solar tracker for pyrheliometers.

5. **DEVELOPMENT STATUS**: Self explanatory.

6. **RESPONSE CHARACTERISTICS**: In space provided, type answers to the questions listed:

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

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

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

d. **Spectral Response**: Declare the spectral range by the wavelength of 50% response. Provide, if available, a curve of the absolute or relative sensitivity of the receiver. Alternatively, provide the spectral transmittance of the used window and spectral absorptance of the used sensor surface coating (in case of normal incidence).

e. **Time Response** (seconds): Declare the time of 90% step response for increase *and* decrease.

f. **Temperature Dependence** (%/°C): Specify the temperature coefficient of change of response over the expected temperature working range (about 240 - 320 K). Provide a typical curve of the temperature dependence of the coefficient, if available. Alternatively, declare the coefficient for about 295 K and the total change over the whole range.

g. **Linearity** (%): Specify the dependence of sensitivity of the intensity in the range of 100 mW cm^{-2} and 5 mW cm^{-2}, as percent deviation from the result in case of the upper limit. Provide a curve, if available. Alternatively, declare the maximum error and the limits of the corresponding intensity range and the inclination of the receiver.

h. 1. *Cosine Response:* Specify the deviation (in %) of response at a different angle of incidence i (related to response at normal incidence) from cos i. If possible, show the deviation as a function of α by a curve. Alternatively, declare the deviations for i = 20°, 40°, 60° and 80°.

2. *Azimuth Response:* Specify the deviation of response (in %) when the sensor rotated through 360° azimuth for radiation incident at i = 60° or 70°. If possible, provide a curve. Alternatively, declare the deviations at about 8 different azimuth angles.

3. *Attitude Response:* Specify the deviation of response (in %) when the receiver is tilted from horizontal (= 0°) to 45°, 90° and 180°; if possible for different constant radiation intensities (e.g., 100 mW cm^{-2} and 20 mW cm^{-2}).

i. **Calibration Accuracy**: Specify the calibration standard and the calibration method (source of radiation intensity range, angle of incidence, angle of tilt). Declare the range of variation (in %) of the calibration factor delivered.

7. **QUALITY CONTROL**: Provide information on quality test routine, if available. Use for abbreviation of quality in point 6, **RESPONSE CHARACTERISTICS**, (e.g., 7-e stands for "control of time response").

8. **APPLICATION DATA**: In the matrix provided, check mark the space for which the 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 disc 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 disc.

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 disc on a surface perpendicular to the axis of this cone, comprising mainly unscattered and unaffected solar radiation.

e. **Solar and 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 in all directions.

9. **ECONOMIC DATA**: In the space provided, type answers to the 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.

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

INSTRUMENT DESCRIPTION AND PERFORMANCE FORM

1. Letterhead/Logo

2. Contact for Further Information:

3. Product Data

Model/Part No.:

Instrument Classification:

Sensor Surface Coating:

Windows: r =

Exchangeable:

Aperture:

4. General Features

Dimensions (cm):

Weight (kg):

Provision for Leveling:

Weatherproof: Yes ☐ No ☐ Desiccant:

Additional Equipment:

5. Development Status

	Yes	No
Prototype Built & Tested:	☐	☐
In Production:	☐	☐

6. Response Characteristics

a. Sensitivity ($mV/mW\ cm^{-2}$):

b. Stability (%/Year):

c. Impedance (Ohm):

d. Spectral Response: From: To:

e. Time Response (s): Incr.: Decr.:

f. Temperature Dependence (%/°C): Total: %

Tilt: °

g. Linearity (%): Range:

h. Cosine Response:

Degrees					
α	20	40	60	80	
%					

Azimuth Response:

Degrees									
A	0		90		180		270		
%	0								

Attitude Response:

Degrees					
δ	0	45	90	180	
%	0				

i. Calibration Accuracy:

Source:

Calibr. Standard:

Angle of Incidence: Tilt Angle:

7. Quality Control:

7-a
7-b
7-c
7-d
7-e
7-f
7-g
7-h
7-i

8. Application Data

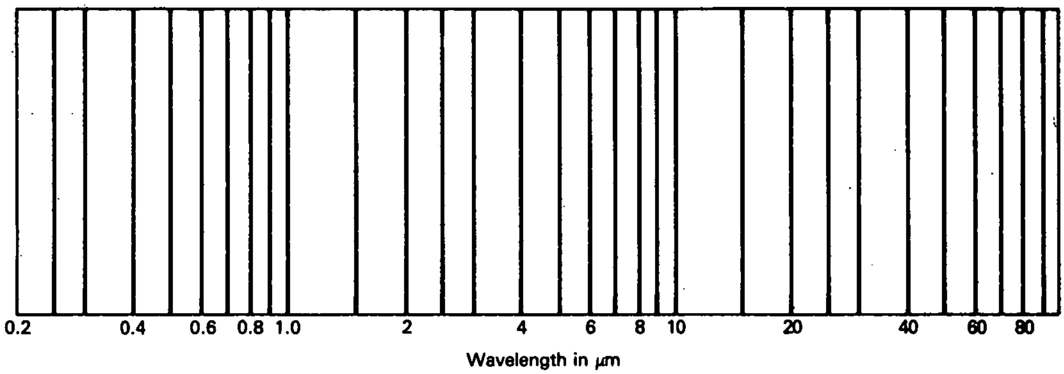
	Global Solar	Diffuse Solar	Spectral Solar	Direct Solar	Solar & Infrared	Infrared	Net
Horizontal							
Tilted							

9. Economic Data

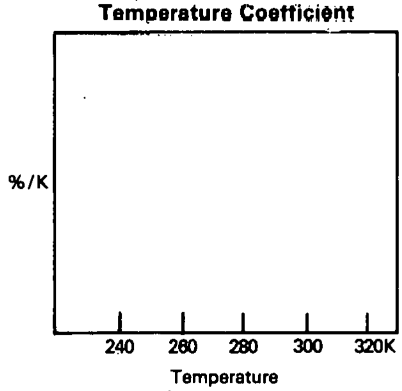
As of Date ________ Cost ($/Unit)		Warranty (Months)	
Recalibration Cost ($/Unit)		Delivery Time (Days)	

10. Comments

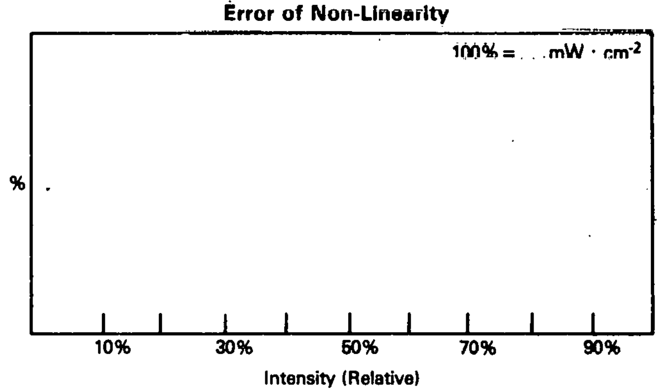
Relative Spectral Sensitivity (Spectral Transmittance, Spectral Absorptance)



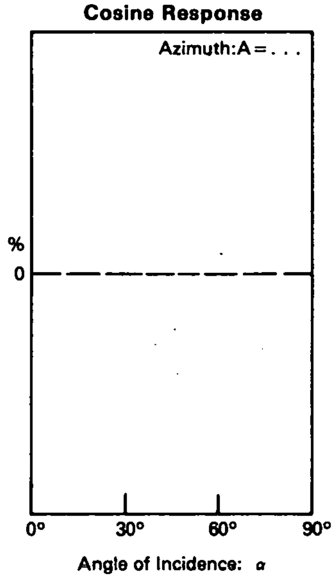
Temperature Coefficient



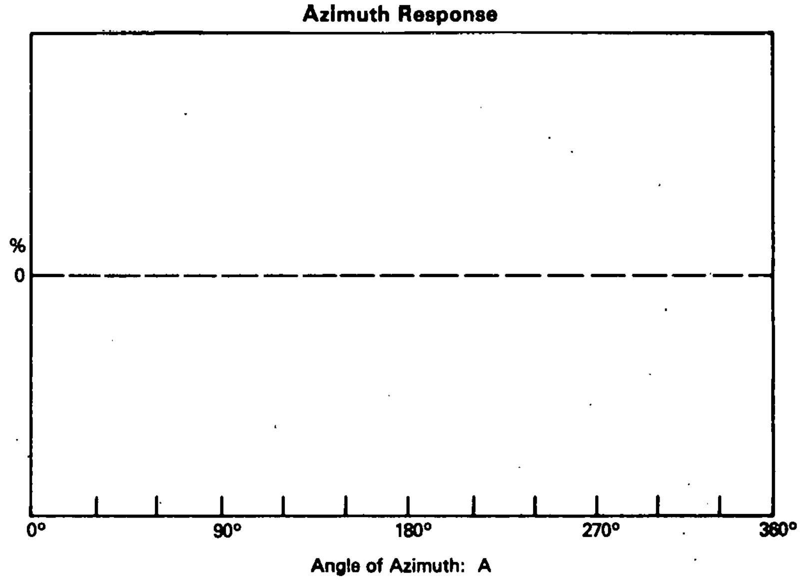
Error of Non-Linearity



Cosine Response



Azimuth Response



United States
Department of Energy
Washington, DC 20585

FIRST—CLASS MAIL
POSTAGE & FEES PAID
U.S. DEPT. OF ENERGY
PERMIT NO. G 20

FIRST CLASS MAIL

Official Business
Penalty for Private Use, $300