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FINAL REPORT

# A STUDY AND RECOMMENDATIONS FOR SOLAR RADIATION DATA COLLECTION SYSTEMS IN THE CENTRAL AMERICAN COUNTRIES

AID Contract No. LAC-0000-C-00-1025-00

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ENERGY ALTERNATIVES
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October 21, 1981

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RE: AID Contract #LAC-0000-C-00-1025-00

Enclosed are the five (5) copies of the Final Report, "A STUDY AND RECOMMENDATIONS FOR SOLAR RADIATION DATA COLLECTION SYSTEMS IN THE CENTRAL AMERICAN COUNTRIES", as required by the above referenced contract.

It was a pleasure to work on this project, and we feel that the study was done as completely as possible within the budget and timeframe. Development of a follow-on project based on the written recommendations would be of vital interest to the Central American region in the areas of agricultural productivity and solar energy resources utilization.

If you have further questions concerning any aspects of the Final Report, we would be most pleased to address them.

Very truly yours,

Leon Cooper

Leon Cooper
Technical Director

LC/mlc

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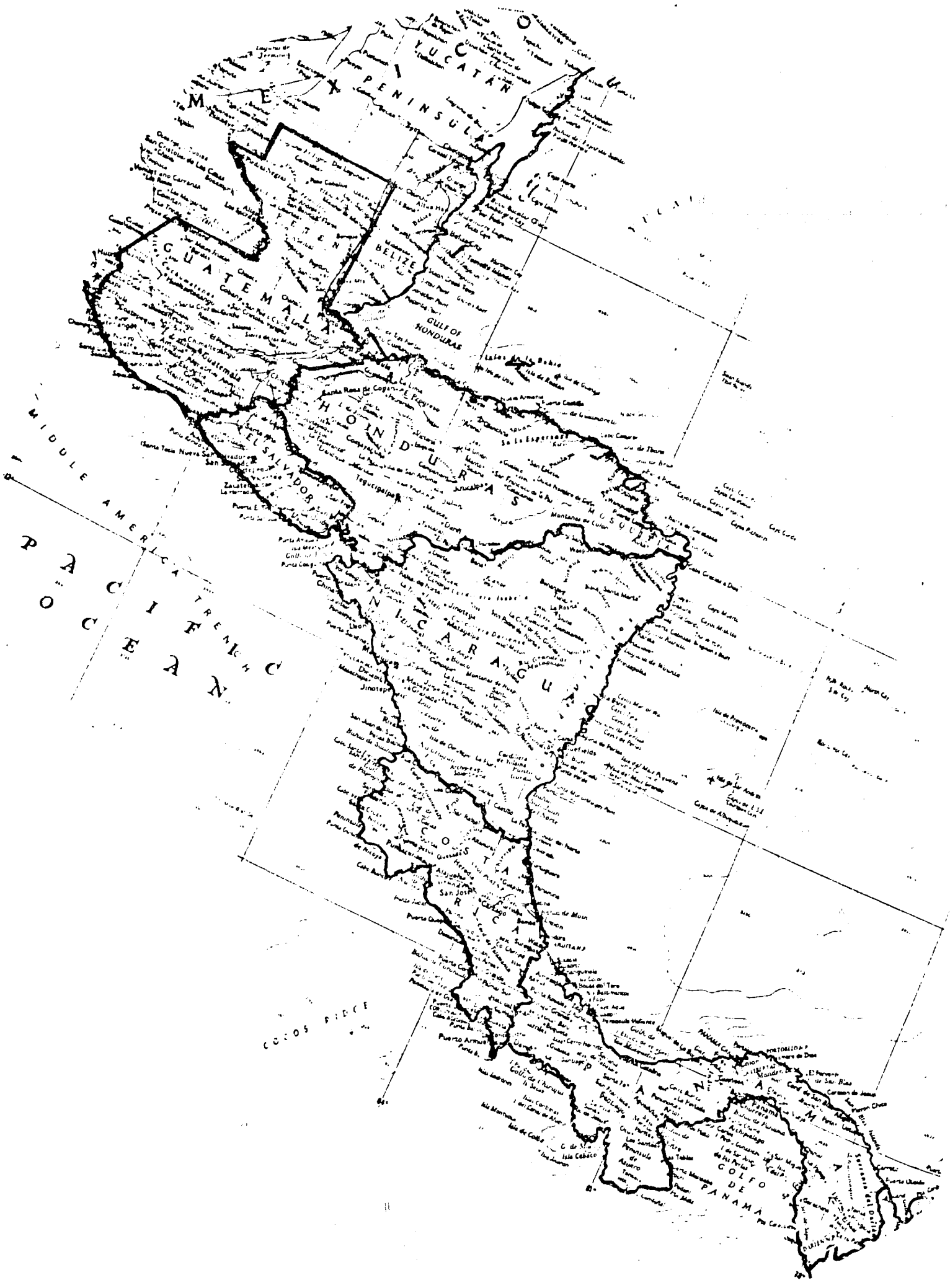
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# INTRODUCTION

It was the purpose of this project to perform a study of the existing solar radiation data collection systems in Central America*, including Panama. From this study, identification and assessment was made for each country with respect to its capability to collect adequate solar data which would apply to both national and regional networks. State-of-the-art solar radiation systems were assessed based upon site visits with key personnel in each country or, in some cases, with alternate contacts.

This study indicates that the existing solar radiation data collection capability is highly inadequate on both national and regional levels for these countries. While some countries have made progress in recent years, it has been small and there is a real need in each country to immediately upgrade its system in both instrumentation and equipment, and in personnel training. This report addresses both the study that was performed and specific recommendations which are based on numerous contacts with technical people in the United States and Central America.

*Guatemala, Honduras, El Salvador, Nicaragua, and Costa Rica

## BACKGROUND

The quality of life in the Central American region has improved little, if any, in recent years because of the ever increasing cost of living which has been brought on mostly by the energy crisis. Except for some recent petroleum finds of unknown quantity in remote parts of Guatemala, there are no significant fossil fuel deposits within the region, so all petroleum for transportation and consumptive uses must be imported from foreign countries. Prior to this crisis the quality of life had been increasing little by little, but as imported energy costs began to rise there developed an accelerating disparity between import costs and export values to the point that the international balance of payments reached disproportionately negative levels. This negative imbalance has resulted in a continuing rise in inflation, carrying with it a loss in purchasing power for the citizenry. A quick view of the situation indicates that the logical approach to finding a solution to the crisis lies not in research into producing greater exports, but in reducing the energy imports through reduction in dependence on imported fossil fuels.

Conservation and reduced usage of energy is one approach to the problem. There are a number of viable areas in which significant quantities of energy consumption can be eliminated. However, this generally places restrictions and hardships on the people. Substitution of fossil fuels with alternative energy sources can be both appropriate and cost effective. These sources include solar, wind, biomass, small hydropower, and other alternatives which are found to be available. Implementation of these energy sources in sufficient quantities can have a sizeable impact on imported energy.

Solar energy is an appropriate alternative energy source in most parts of the world. In some cases it is highly site-specific, while in others it is generally useful. There are numerous operational uses for solar energy, many of which have been implemented over recent years and proven appropriate and cost effective in various applications. These include solar water heating, space heating, refrigerative air conditioning, desalination, agricultural crop drying and others. Recent photovoltaic system demonstrations have proven to be cost effective in many instances for the production of electrical energy from solar input.

Agricultural productivity depends on the best utilization of environmental factors, including climatological and solar radiation data. An increase in agricultural production has the double effect of (1) increasing local and exportable food products and (2) providing the opportunity for production of additional crops suitable for biomass energy conversion. Agricultural wastes and/or specific crops could provide feedstock for production of fuels such as methanol or ethanol, thereby displacing quantities of imported fuels. Through the optimum utilization of climatological and solar radiation data it is prob-

able that marginal land areas could even be utilized for certain seasonal crops, grown specifically for fuels, without replacing present food producing crops. Sweet sorghum, sudan grass, and commercial sunflowers are examples of such energy crops. As the demand and prices for energy and food increase, so does the need for developing alternative energy sources and improving agricultural production. In order to meet these goals an accurate and reliable data base of solar radiation is needed on both the national and regional levels.

Approximately five years of data are required in order to begin to establish the solar radiation climate at any site. There is a necessity for developing alternative energy systems as soon as possible, so it is imperative that progress in this direction is immediate.

## SUMMARY

Solar America, Inc. has made numerous site visits throughout the region, visiting with personnel and inspecting solar radiation stations and equipment.* Most of the recorded radiation data from these countries has been studied and compared, and it is evident that the existing data base in the region is inaccurate and, for the most part, unreliable. From these investigations it has been determined that (a) there is generally a limited number of solar data collection stations within a country; (b) with rare exception, the solar radiation instruments are not functioning properly, as evidenced by degradation factors which include corrosion, peeling or flaking of absorptive surfaces, internal condensation, etc.; and (c) there has been no provision for calibration of the instruments. Solar America has been able to collect a large amount of solar radiation data from the existing data base in the region. Cross comparison of this data indicates that there are numerous inconsistencies with the data, and these problems relate directly to the above mentioned findings.

There are two types of solar radiation instruments in use at the ground-based stations. The measurements made by these instruments are (1) total solar radiation falling on a horizontal plane and (2) measurement of direct solar beam. These data are measured respectively by the "actinografo" (pyranometer) and the "heliografo" (pyrheliometer-type instrument). In nearly every case, the pyranometers have been of an older model manufactured by a German firm, "Feuss", while the pyrheliometer type instruments have been Campbell-Stokes models which actually measure duration of sun hours. The Feuss instrument is rated as a class 3 unit according to the World Meteorological Organization (WMO) classification. The Campbell-Stokes instrument is a fool-proof unit which operates well, never requires calibration, and delivers simple information. It is quite possible that the Campbell-Stokes data may prove to be more useful than the pyranometer data in any data rehabilitation efforts.

In the individual countries there are national meteorological institutions that are directly responsible for the operation and maintenance of the solar radiation data collection systems.* There is presently no collaboration between the various national institutions with respect to solar radiation data. In one country the data collection is handled by the electrical utility division, in another by the department of defense, while in others it is handled by different governmental units.

*Refer to Appendix A

The physical facilities of each national meteorological institution vary from country to country. In one case it is handled under the international airport authority, while in another it is operated at a special facility in conjunction with the meteorological institute. The national headquarter units vary from country to country, from small four-person units to large complexes with sizeable staffs. The organizational aspects of each of the countries are discussed in greater detail in Appendix B.

# SURVEY OF EXISTING INSTRUMENTATION

## 1.0 SURVEY OF EXISTING INSTRUMENTATION

1.01 The solar radiation data collection instruments previously mentioned as being in use throughout the region are the actinografo and the heliografo. The existing data base generated by these two instruments began operation in the early 1970s.

The actinografo measures the total global solar radiation on a horizontal plane. It operates on the differential expansion of alternate black and white surfaced metal strips exposed to solar radiation from both direct and diffuse sources. Total sensing and recording is through mechanical movements of the differential expansion driving a pen which marks a trailing line across a slowly moving chart operated by a clock-driven mechanism. The chart is read, then the data is manually integrated to obtain corrected daily total radiation values. The quality of the data depends entirely on the condition of the instrument and the degree to which it is maintained and calibrated. Well maintained actinografos have been found to drift as much as ±50% from reference pyranometers. This instrument has the following characteristic faults:

(1) Calibration is a function of solar elevation and azimuth, and the instrument is nonlinear.

(2) The calibration constant is a function of ambient temperature and wind.

(3) For this region the instrument is inadequately sealed from highly humid atmospheric conditions, so condensation occurs internally causing corrosion of metal parts and degradation of painted solar absorbers, thus affecting resultant accuracy. Because this deterioration is nonlinear, it is practically impossible to develop calibration curves for rehabilitation of historic data.

This instrument is classified as a third-class instrument by the WMO, and investigators who are working on solar energy programs do not rely on it for providing useful data from which to design solar energy devices. This is not to say that this instrument and its data are useless. All actinografos should be calibrated under current conditions so that at least one year of data can be obtained for comparison to data from a first-class, newly calibrated pyranometer located on-site. In this manner, it would be possible to determine how much of the historic data that was useful and refinable.

The heliografo measures direct solar beam duration through the action of magnification/concentration of the direct beam upon a sensitive paper chart. When there is direct sunlight, there is a burned spot on the chart, and when it is cloudy there is no spot. For a totally sunny day, there would be a burned track across the paper corresponding to the movement of the sun across the sky. The chart actually indicates the amount of time for the direct solar beam on a daily basis (the chart is changed each day). Because there are no moving parts and because there are no degradable parts, the instrument always operates perfectly so long as the crystal-ball beam concentrator is kept clean and the paper chart is replaced daily.

1.02 It is not known whether anyone has made an attempt to develop a model to show the relationship between the heliografo and the actinografo operating as a set. It appears that this would be the only accurate way in which to rehabilitate older data from the actinografo, and it is suggested that this action be carried out to determine its validity.

1.03 During a preliminary survey, solar radiation data was collected from most of the countries of the region. Sample data was computerized, and a method previously developed for evaluating instrument calibration change was applied to the data. From the review of the resultant information the following conclusions were drawn:

(1) The calibration of most of the actinografos reviewed has changed significantly since the instruments were installed.

(2) From the data collected, it appears impractical to predict which instruments will change, or by how much.

(3) These problems place doubt on the quality of the data base available, mostly because of the actinografo itself.

(4) A careful analysis of the data and comparison of existing instruments with pyranometers should establish the quality of the existing data base and provide data which can be used until results are obtainable from a network of newer instruments.

1.11 Guatemala

In 1980, INSIVUMEH (Instituto Nacional de Sismologia, Vulcanologia, Meteorologia, e Hidrologia) purchased a couple of Class I solar radiation instruments for use at the central headquarters in Guatemala City. An Eppley pyranometer (PSP) is in place adjacent to one of the older Fuess actinografos where a running comparison is being

made to determine correlation. From this study useful information should be obtained relative to a potential process for attempts at rehabilitation of historic data which at present is highly unreliable.

Visits were also made to the international airport (Aeropuerto Aurora) to observe the training programs in meteorology which are presented periodically through INSIVUMEH. Some forty participants from several Latin American countries were involved in a six-week session of intensive classwork in small groups.

Discussions with Ing. Claudio Urrutia, director, and Ing. Manual Aguirre, subdirector, were very informative and indicated that they are pursuing every possible avenue for improving and upgrading solar radiation data collection in Guatemala. Visits were made to other stations including Labor Ovalle in the western region, where personnel were found to be very qualified but lacked quality instrumentation and technical resources.

## 1.12 El Salvador

The Servicio Meteorologico Nacional (SMN) operates 10 solar radiation data stations in the country, with the central headquarters being located in Santa Tecla. El Salvador was the only country in the region where we found the Robitzsch actinografo instrument in use. The other countries are using the Fuess actinografo entirely. The two instruments are quite similar in both appearance and operation so therefore have the same faults and merits. The Campbell-Stokes heliografo instrument was identical to those in other countries.

There was opportunity to visit with Dr. Gelio Guzman on two occasions in Guatemala prior to making on-site visits to El Salvador. Dr. Guzman was involved in an intensive six-week study course in meteorology being offered by INSIVUMEH. The on-site visits to El Salvador were very informative as numerous solar radiation personnel were made available for the purpose of obtaining very detailed information regarding all phases of solar data processing in the country. Licenciados Rolando Martinez and Tomas Rivas Pacheco provided excellent assistance in assuring complete interaction with the various personnel, including time on the weekend.

In Santa Tecla visits were made with Jose Hernandez S. and Jose Avarenga S. at the SMN central station. Several pieces of new equipment had been purchased, including a pyrheliometer/tracker, a pyranometer, and an integrator/recorder. Various mountings had been

installed on the roof, and they were in the process of assembling these instruments so that intercomparisons could be started with the older instruments. A great deal of progress had been made since a previous visit with Jose Jimenez C. at which time the instruments had not been obtained.

It is obvious that it was difficult for the SMN to obtain the small cluster of new instruments, especially during such difficult times as the present. It is also quite obvious that the SMN places a great deal of importance on solar radiation data collection as evidenced by the high quality of the personnel working there. A sample of 1980 accumulated data (total global solar radiation on a horizontal plane s included on the following page.

The solar radiation section of the Servicio Meteorologico Nacional has real need in technical assistance in the areas of technical training, assistance in installing and calibrating instrumentation, and in long range planning and programming. Not only the SMN, but also the country, will profit through the utilization of more accurate radiation data through programs which can (1) improve agricultural production and (2) accelerate the use of solar energy in water heating, crop drying, desalination, refrigeration, and electrical generation at remote sites.

CUADRO DE PROMEDIOS MENSUALES DE RADIACION SOLAR — EL SALVADOR, C. A. — (SERIES HASTA 1980, Valores en cal/cm2/día)

| ESTACIONES | LATITUD | LONGITUD | ELEVACION | AÑOS DE REGISTRO | ENE | FEB | MAR | ABR | MAY | JUN | JUL | AGO | SEP | OCT | NOV | DIC | PROMEDIO ANUAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Beneficio La Carrera | 13°19.8′ | 88°31.5′ | 75 | 8 | 419.4 | 460.4 | 476.2 | 447.3 | 414.6 | 413.1 | 462.4 | 466.3 | 414.6 | 413.5 | 409.9 | 413.2 | 434.2 |
| La Unión | 13 19.9 | 87 52.9 | 95 | 11 | 422.3 | 465.1 | 489.8 | 472.0 | 433.0 | 442.6 | 455.0 | 449.3 | 427.2 | 427.7 | 404.1 | 405.8 | 442.0 |
| Nueva Concepción | 14 07.5 | 89 17.4 | 320 | 11 | 422.0 | 467.3 | 489.2 | 487.4 | 446.0 | 455.4 | 472.4 | 472.3 | 442.0 | 438.6 | 422.0 | 402.5 | 451.4 |
| Apastepeque | 13 42.0 | 88 44.8 | 570 | 9 | 395.3 | 445.7 | 457.3 | 439.0 | 414.4 | 406.5 | 443.0 | 447.2 | 392.8 | 387.0 | 391.8 | 376.9 | 416.4 |
| Estación Matriz | 13 41.6 | 89 08.3 | 650 | 8 | 444.7 | 488.8 | 526.7 | 510.3 | 451.5 | 463.2 | 512.3 | 490.8 | 427.8 | 407.8 | 428.7 | 426.9 | 464.9 |
| San Salvador | 13 43,3 | 89 12.4 | 710 | 12 | 418.4 | 458.4 | 479.5 | 473.0 | 413.9 | 421.4 | 473.7 | 442.4 | 390.7 | 403.3 | 411.5 | 409.0 | 432.9 |
| Ahuachapán | 13 56.6 | 89 51.6 | 725 | 11 | 493.0 | 538.2 | 561.5 | 551.2 | 451.6 | 444.0 | 487.6 | 465.8 | 408.2 | 423.8 | 432.2 | 429.6 | 474.7 |
| Planes de Montecristo | 14 23.9 | 89 21.6 | 1851 | 5 | 398.4 | 427.3 | 414.3 | 370.4 | 309.1 | 331.3 | 405.7 | 351.9 | 294.6 | 336.6 | 366.3 | 369.7 | 364.6 |
| La Galera | 14 02.6 | 88 05.2 | 1900 | 5 | 375.0 | 420.9 | 440.4 | 389.6 | 359.6 | 367.3 | 393.7 | 365.6 | 314.4 | 325.5 | 320.8 | 328.8 | 366.9 |
| Las Pilas | 14 22.4 | 89 05.3 | 1960 | 4 | 341.2 | 296.5 | 392.3 | 357.7 | 552.2 | 342.5 | 370.5 | 366.1 | 298.2 | 232.1 | 303.6 | 308.4 | 346.8 |

Santa Tecla, Junio de 1981

tipo de instrumento: Actinografo Robitsch

/ajl

## 1.13 Honduras

The solar radiation collection in Honduras is handled by the Recursos Hidricos-Hidrologia y Meteorologia through the Servicio Meteorologico Nacional (SMN) with headquarters in Tegucigalpa. Engineer Pedro Cortez is in charge of the national network and has operated a very fine system although it is poorly equipped and insufficiently staffed.

Honduras, being a relatively large country in this region, has very few solar radiation stations. This, combined with the obsolete instruments in use, indicate that there is probably greater need here than in any of the other countries of the region. On the other hand, Honduras has very fine resources in the people who live there. This includes Mr. Nabil Kawas, executive secretary of the Comite Regional de Recursos Hidraulicos (CRRH). This regional group is actively involved in agricultural resource assessment and application, and it constantly pursues the advancement of meteorological and solar radiation systems improvement. The Ministerio de Recursos Naturales is a Honduras institution which is also very active in systems improvement.

Many areas of Honduras have no capability to take solar radiation data of any kind. This is unfortunate for the country does depend greatly on exported agricultural products, and agricultural production does depend on solar radiation along with meteorological factors. It is important that future plans include expansion of the existing network to more adequately cover the country.

The major needs of Honduras at this point are in the areas of new instrumentation, calibration access, and extensive training for the personnel, both immediate and on-going. Technical assistance will also be needed in the installation, operation, maintenance and calibration processes.

## 1.14 Nicaragua

Very little information was available with respect to solar radiation data collection in the country. All the information obtained was through phone conversation with the Servicio Meteorologico Nacional (SMN) which is under the direction of the Departmento de Defensa.

There is no available solar radiation data. Nicaragua has gone through two difficult years of change during which time any accumulated data would have passed through several sets of administrative

entitites. This is not to say that they do not have any accumulated radiation data, because in all likelihood there is data of some kind on file with some institution. By the time that the various subdivisions of the government have become organized into operational units, this data should appear. It is doubtful that any data exists for the years of 1979-1981, however.

In February, 1980, three individuals from the SMN were able to attend the Regional Central American Solar Radiation Seminar held in Guatemala City. These individuals were very enthusiastic about seeking training, working industriously and pursuing first class solar radiation data collection in Nicaragua. They desperately need to acquire new instrumentation, obtain technical assistance in the installation, operation and maintenance, and calibration of the instruments, and in on-going training programs for upgrading solar data acquisition for the country.

Nicaragua has a very large potential for agricultural productivity. A reliable solar radiation data base would do much for agricultural planning and programming toward increasing production in future years. Needless to say, this is the most important phase in their rebuilding the country.

1.15 Costa Rica

Eight solar radiation stations have been in operation in the country since 1970-71 and historic data from these stations are fairly complete since that time. The distribution of the stations is fairly uniform due to preliminary planning so that a country-wide profile could be obtained. The obsolete Fuess actinografo and the Campbell-Stokes heliografo are the typical instruments in use. Visits to data collection sites indicated that the instruments have been very well maintained on a continuous basis. However, the harsh climate of Costa Rica has taken its toll and it is doubtful that any of the actinografos are currently within acceptable limits of accuracy. Corrosion has been a limiting factor since the beginning and internal water condensation is a seasonal factor during the wet months.

Visits with Lic. Gerardo Lizano previously, and with engineers Hugo Hidalgo, Hugo Herrera, and Eladio Zarate have confirmed that the Instituto Meteorologico Nacional (IMN) is staffed with the highest quality of personnel at the central headquarters in San Jose. Ing. Patricia Ramirez was on special leave and Eladio Zarate was in Guatemala in a special training course in meteorology during my recent visit there, but on the prior visits it was very evident that their tenure and leadership have been a great asset to the IMN.

Costa Rica is going through budgetary crises at this time, but the country has always been aggressive in pursuing worthwhile projects in energy related endeavors. There is indication that the government would grant funding of at least part of a major solar radiation data collection improvement program. The purchase of the needed instrumentation and equipment by the government coupled with outside technical assistance by the U.S. could certainly be achieved. This outside assistance would include training of Costa Rica personnel, assistance in setting up the new solar radiation stations, and ongoing training during the term of the upgrading program while the complete group of stations were being phased in.

It should be noted that Costa Rica is being recommended as the most appropriate site for the Central American central calibration facility for a number of reasons, the most important of which is the ready and easy access of all countries. It would not matter that ICAITI, CRRH, or some other entity might actually be in charge of the facility. Costa Rica also has direct working relationships with both universities (UCR and UNCR) and the Instituto Tecnologico in Cartago, in addition to such institution as CATIE and IICA.

1.16 Panama

Seven solar radiation data collection stations are presently operating in Panama, down from nine stations which were previously in operation, dating back to 1971 when they were first started. Five of these stations are equipped with Fuess actinografos and six have Campbell-Stokes heliografos. At one time there were eight or more of the actinografos, but the harsh climatic conditions reduced the number to five. The units which were retired from service have been scavenged for parts in order to make repairs to the ones which are still in operation. Based on previous visits, observation, and discussion with personnel, it is judged that perhaps Panama has the most harsh and damaging climate of any country in the world. Many sites maintain 100% relative humidity year-round so, when combined with the elevated temperatures, result in an extremely corrosive environment for any type of instrument. Every instrument examined (including those at the repair station at Tocumen) showed internal corrosion of working parts, peeling of black absorptive surfaces, internal condensation of parts and of protective glass dome, and general degradation of the entire instrument. At this rate, there will be no instruments remaining in very short time.

Personnel at the meteorological division of IRHE (Instituto de Recursos Hidraulicos y Electrificacion) are of very high calibre but the average tenure of technical persons is quite low because of the

better paying positions within industry. Only Ingeniera Claudia Candanedo, the director, is still in the department since the first visit during 1979. However, the operation is progressing well under these circumstances.

Panama has real and immediate needs in the areas of new instrumentation, and in technical assistance consisting of upfront and ongoing training in solar radiation data collection techniques and in solar radiation data station installation and maintenance. Without this approach, it is apparent that solar radiation data collection will cease to exist before long.

## 2.0 TYPES OF SOLAR RADIATION DATA NEEDED

The type of solar radiation data needed for a specific application will vary depending upon the application. Certain types of data are appropriate to agricultural uses, while other types of data are required for design of solar energy devices such as for water heating, refrigeration, desalination, etc. Three separate categories of data utilization are discussed in the following sections.

### 2.01 Solar Radiation Data Needed for Agricultural Applications

Agricultural users depend on a number of environmental parameters including temperatures, ground moisture, atmospheric moisture, rainfall, wind conditions, and solar radiation. The most important solar data are those which apply to photosynthesis, namely the levels of total global solar radiation required for specific crops. Some vegetable and fruit bearing crops require minimum average levels of light intensity exceeding 2,000 foot-candles at the leaf surfaces; any excess isn't necessarily beneficial. This level of solar radiation can be achieved under lightly cloudy conditions, whereas during total overcast conditions or heavy cloudiness when the minimum average levels drop to around 1,000 foot-candles these crops carry out hardly any photosynthetic activity and are therefore not very productive. However, certain other crops function better under reduced solar levels than in bright sun. In addition to the standard meteorological data, agricultural users need solar radiation data from pyranometer measurements which give the hourly total global solar radiation.

### 2.02 Solar Data Needed for Design/Evaluation of Simple Solar Applications

The designs and performance evaluations for simple solar energy applications include such examples as solar dryers, water heaters and solar stills. For the most part, the same solar radiation data that applies to agricultural use also applies to these uses. In addition to meteorological data of wet and dry bulb temperatures and wind velocity and direction on an hourly basis, the total global solar radiation hourly data from the pyranometer is sufficient for this type of application.

### 2.03 Solar Data Needed for Design/Evaluation of Moderate and Complex Solar Energy Applications

These applications include tracking collector systems, concentrating systems, refrigerative systems, photovoltaic systems, and similar applications. These systems depend upon meteorological data as

mentioned in the previous category, but the data needs much refinement. It is less important to have average daily measurements than it is to utilize hourly instantaneous data from which certain factors can be refined. For example, a concentrating collector functions only in direct sunlight while a flat plate collector functions in direct sun and in light cloudy conditions. Because of these refined data requirements, both pyranometer and pyrheliometer data are needed for this application.

# RECOMMENDATIONS FOR IMPROVING SOLAR RADIATION DATA BASES

## 3.0 RECOMMENDATIONS FOR IMPROVING SOLAR RADIATION DATA BASES

It is recommended that immediate steps be taken to improve the solar radiation data collection in each of the countries of the region in order to generate a useful and accurate data base on which planning and design for solar energy utilization can quickly become a reality. There are many short term advantages to be gained, but the long term advantages are those which can greatly assist these developing countries in improving the quality of life for the citizens. The ability of national organizations to maintain high quality solar radiation stations in operational status will be a key factor in the success of such programs of improvement. The recommended plan is applicable to individual countries, and it will succeed independently. However, regional cooperation in the form of a network will amplify the advantages to individual countries far beyond the single country concept or approach.

The recommendations for this plan have been prioritized. Within each priority group the recommendations are of equal value. Priority groups should be accomplished in order, completing one group before proceeding to the next. This allows for the plan to proceed in such a manner that at the end of each phase there would be decision points providing for implementation of new developments and/or accommodation or modifications based on gained experience.

Priority 1:

New instrumentation, along with training, management and implementation, for one category "A" station in each country.*

Development of training programs that will be used to maintain continuous levels of personnel competency.

Development of statistical models for estimating solar radiation in the various climatic regions.

Priority 2:

Regional calibration facility.

Additional instrumentation for research facilities such as technical institutes, organizations, and universities.

Electronic data-logging systems.

Additional category "C" stations.*

*Refer to Appendix C

Additional category "A" stations in locations experiencing climatic extremes in solar radiation.

Rehabilitation of existing solar radiation data as possible.

Priority 3:

Development of coordinated regional publications on solar data acquisition and evaluation.

Automated central station data reduction.

Research and potential use of satellite data.

## 3.1 Instrumentation

It is recommended that the existing actinografos be cross-referenced with a Class 1 pyranometer prior to their being retired from service. By making this comparison at each site it should be possible to establish calibration curves for each instrument which can be used to rehabilitate the existing data from that particular instrument. Following the one-year comparison, the older instruments can be recalibrated for further use until such time that they are replaced by new Class 1 pyranometers. The new instruments being recommended are for three levels of data station sophistication:

Category A stations provide hourly solar radiation data including total global radiation on a horizontal plane and direct solar beam radiation. This data is useful in the design of moderate and complex solar energy applications and for providing data from which to establish the most exact total solar patterns for a site.

Category B stations provide total global radiation which is needed for the design of the simplest solar energy applications.

Category C stations provide daily direct solar beam hours of duration.

The instrument and equipment inventory required to complete stations for each category are given in Appendix C-1. It is necessary that spare instruments be purchased for each network so that there are no sizeable lapses of solar radiation measurement during instances of instrument failure.

## 3.2 Maintenance

On-site maintenance of the solar radiation instruments is of vital importance to ensure that each will have the best possible opportunity to deliver accurate information. All instruments should be visually checked on a daily basis by a trained staff person who is familiar with their operation. Depending on the seasonal conditions, specific moisture conditions or other local influences, each instrument should be checked weekly, monthly or quarterly by a trained technician so that it performs properly. At various sites, special attention must be given to external condensation, internal condensation or moisture accumulation, dust or volcanic accumulation on the quartz dome, and other environmental conditions which will have an affect on the sensing or mechanical operation of the instruments.

## 3.3 Calibration

It is recommended that all instruments be calibrated every six months during the first two years of the program. During this period of time the accuracy of individual instruments can be established, and any instruments that indicate serious deviations from average calibration curves can either be repaired, replaced or removed from service. Following the first two years of operation, calibration should then be done on an annual basis or as experience indicates is appropriate. This periodic calibration may be different for specific stations because of such conditions as climatic influence or remote access.

A calibration facility should be established at some site that will give ready access and service to the region. One such facility would be sufficient for all six countries. This facility must be able to provide the highest quality of calibration services available in order for the regional solar radiation data to have a high level of accuracy. Two or more full-time technical persons should be in charge of the operation of the calibration facility, one of which has a respectable background of experience and training in solar radiation data collection.

Until such time that the calibration facility is operational, secondary standards can be calibrated at the U.S. National Oceanographic Administration Agency Solar Radiation Facility, located in Boulder, Colorado, USA.

The most appropriate country for location of the regional calibration facility is Costa Rica. Both ICAITI and CRRH have regional offices in Costa Rica, and it is without question the most accessible to the other countries. Continuity and accessibility of the calibration facility to all countries is a key factor in the success of a continuously upgrading solar radiation data program for the region.

3.4 Management, Personnel Training

Visits have been made on-site in five of the countries, and national solar radiation institution directors and/or major personnel have been contacted in all six countries. In every case it has been evident that competent people are performing their tasks and responsibilities very well, with less than adequate equipment and facilities. These people are the key factors in the success of any program, so it is highly important that the average tenure (less than two years on the job) for these individuals be extended significantly through improvement programs in such areas as technical training and incentives.

3.41 It is recommended that at least one full-time person of engineer calibre be assigned to each national director position within the institution charged with solar radiation data collection. This person should be backed up with quality persons of equivalent capability in order to maintain continuity in the program during periods of absence of the director. It would be expected that the director, or assistant director(s), would be away from time to time for the purpose of upgrading their skills. Also, in case of attrition, there would be no lapse in direction for the solar radiation program.

In most instances the director of the overall meteorological institution would be the one in charge of solar radiation. In these cases, it is recommended that one or more assistant directors be solar radiation specialists with the qualifications as described above.

3.42 It is important that outside experts be brought to each of the countries periodically, semi-annually or annually, in order to work with the solar radiation staff on-site in training and assisting the staff in technical improvement and personnel upgrading. This part of the program should be more intense during initial stages, then adjusted to the regional needs after such training aspects have become established.

3.43 It is also recommended that exchange training programs be implemented between the various countries, involving both administrative personnel and staff personnel, for the purpose of exchanging information, techniques, procedures and skills. Such programs would help to bring together the solar radiation teams from each nation in a common effort to continuously improve and upgrade national and regional network capabilities. This same program should also be interlaced with experts from outside the region for the purpose of introducing the latest and most appropriate solar radiation resources with respect to instrumentation, data systems and technical advances from throughout the world.

3.44 It is recommended that a regional solar radiation association be established at the beginning consisting of the national program directors, assistant directors and technical staff persons. Some provision should be made for the association to meet every six months, rotating the meeting site from country to country, for the purposes of technical improvement and promoting greater interaction on the regional level. This regional interaction will contribute to the ultimate success of the regional network.

# SITING OF SOLAR DATA COLLECTION STATIONS

## 4.0 SITING OF SOLAR DATA COLLECTION STATIONS

In each country solar radiation data has been collected for some period of time from the older instruments which will eventually be phased out. The sites have been previously selected by appropriate authorities in that country, and it should be assumed that they were so placed for reason. It is important to calibrate the older instruments in order to rehabilitate the data bases which have already been established, so eliminating some sites in favor of others is presently out of the question. However, it may develop at some point in the future that some stations should be eliminated, and such decisions would be made at that time.

4.1 Each country should carry out a study to determine its specific solar radiation patterns in order to determine if there are deficiencies in covering any zones of that country. The study might suggest that older stations be relocated or that new stations should (or should not) be sited.

It is recommended that the following criteria be used to determine whether or not new solar radiation stations should be placed:

(a) Are there areas within the country that experience pronounced climatic change over short distances, such as near mountains and/or seacoasts?

(b) Are there blank zones anywhere in the country where representative solar data is not now being taken?

(c) Are there specific sites that are potential sites for agricultural or solar energy projects where solar radiation data will be of particular importance?

(d) What are the environmental considerations for each present and/or planned solar radiation station?

(e) What is the present access to, and feasibility of operation for, each solar data station in the country?

# RECOMMENDED SOLAR RADIATION DATA NETWORK PLAN FOR CENTRAL AMERICA

## 5.0 RECOMMENDED SOLAR RADIATION DATA NETWORK PLAN FOR CENTRAL AMERICA

Solar America, Inc., recommends that:

5.1 Support be given to a solar radiation data network project for Central America, including Panama, to cover a project period of at least five years during which time the success of the project will be ensured.

5.2 ICAITI* be designated as an administrator under the sponsor's direction for this project. ICAITI has been recognized as an appropriate institution from the standpoint of regional experience, capability, and demonstrated stability.

5.3 CRRH** be designated as a manager of the project. Their regional organization is especially suited for this task because of their agricultural, meteorological and natural resources activities on the regional level, interacting with each of the countries without respect to political affiliation.

5.4 Each country purchase, on a step-by-step basis, all the equipment necessary to set up the solar data collection network as in-kind contribution to the project.

5.5 The sponsor contract with the appropriate U.S. institution having proven technical capability and Latin American experience and background for ensuring the ultimate success of the project in the areas of technical application. This institution would assist in the selection and purchase of U.S. instrumentation and equipment required for the project, setting up and operating the same, and setting up and operating the training programs for the in-country personnel. This would also include setting up the calibration station and supervising its technical operation until it is well established.

5.6 The U.S. institution be responsible for working together with the instrument and equipment suppliers in the development of a comprehensive training program built around a slide-show and cassette-tape presentation for the national training phase of the project. The training program would be continuously upgraded through the term of the project.

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* Instituto Centroamericano de Investigacion y Tecnologia Industrial

** Comite Regional de Recursos Hidraulicos

5.7 The CRRH select one individual from each country to send to the U.S. to attend comprehensive courses in solar radiation data collection, utilization, and possibly wind data study. Such courses may lead toward degree status of some type. These individuals would become involved in conducting training and upgrading seminars upon their return to Central America.

5.8 The project would operate for five years. At the end of three years an evaluation would be made of the accomplishments, and a follow-up program would be planned to continue the work at the end of the five-year project.

IMPLEMENTATION OF THE SOLAR RADIATION PROGRAM
PHASE 1

## 6.0 IMPLEMENTATION OF THE SOLAR RADIATION PROGRAM - PHASE 1

### 6.1 Task 1

A detailed plan should be prepared for each country, identifying the national organization(s) with whom the sponsor is to contract. This plan should be complete with detailed budgets, identification of in-kind contributions from the country, the roles and responsibilities of all participating parties, and a step-by-step delineation of the phases and details of the project implementation.

### 6.2 Task 2

Purchase for each country one complete set of instrumentation and equipment for one Category A station, including one set of spare instruments.

### 6.3 Task 3

Carry out testing and evaluation of the instrumentation and equipment upon its arrival in country. This should also be carried out for the purpose of training technicians in the installation, care and operation of these items, so in-country training would have begun by this time. The instrumentation and equipment should be tested under laboratory conditions for a minimum of one month during which time a full range of daily experiments would be completed for verification of the operation of every component.

### 6.41 Task 4(A)

Set up the regional calibration facility, following the same procedure as outlined in the previous tasks.

### 6.42 Task 4(B)

The first in-country station should be installed, preferably adjacent to, or very near, the main existing solar radiation data facility. This station should be thoroughly tested and evaluated under normal operating conditions so that total system performance is proven through a minimum of one year, and the station is placed on operational status.

### 6.5 Task 5

Start up solar radiation data collection from the new system, and establish the data reduction procedures and the data storage/reference system for this station. The performance goals for each operational system are:

(a) less than 20% of total hours with missing/invalid data through the first year of operation (greater than 50% is indication that the program should re-evaluated);

(b) less than 10% missing/invalid data by the end of the third year; and

(c) less than 5% missing/invalid data by the end of the fifth year.

# APPENDIX A

## SOLAR RADIATION STATIONS, EQUIPMENT, PERSONNEL, AND ADMINISTRATIVE INSTITUTIONS

APPENDIX A-1

COSTA RICA: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| San Jose | 9°56' | 84°05' | 1971-pres. | * | * | (*) |
| Puntarenas | 9°58' | 85°50' | 1970-pres. | * | * | |
| Nicoya | 10°09' | 85°27' | 1971-pres. | * | * | |
| Limon | 10°00' | 83°03' | 1971-pres. | * | * | |
| Puriscal | 9°51' | 84°19' | 1975-pres. | * | * | |
| Volcan Irazu | 9°59' | 83°42' | 1970-pres. | * | * | |
| Palmar Sur | 8°57' | 83°28' | 1973-pres. | * | * | |
| Taboga | 10°21' | 85°09' | 1971-pres. | * | * | |
| Turrialba (IICA) | 9°53' | 83°38' | 1966-1974 | * | * | |
| Cobal | 10°15' | 83°40' | 1970-1977 | * | * | |
| La Pinera | 9°11' | 83°20' | 1970-1977 | * | * | |
| Central | 10°01' | 84°16' | 1963-1975 | * | * | |

*Eppley PSP pyranometer

ADMINISTRATIVE INSTITUTION: Instituto Meteorologico Nacional, San Jose, Costa Rica

STAFF PERSONNEL: Lic. Eladio Zarate, Director
Lic. Gerardo Lizano
Ing. Patricia Ramirez
Ing. Hugo Hidalgo
Ing. Hugo Herrera

APPENDIX A-2

EL SALVADOR: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| Santa Tecla | 13°42' | 89°18' | | | | (*) |
| Planes de Montecristo | 14°33' | 89°22' | 1976-pres. | * | * | |
| Ahuachapan | 13°56' | 89°52' | 1970-pres. | * | * | |
| San Salvador (ITIC) | 13°43' | 89°13' | 1969-pres. | * | * | |
| Estacion Matriz | | | 1973-pres. | * | * | |
| Nueva Concepcion | 14°08' | 89°18' | 1969-pres. | * | * | |
| Apastepeque | 13°42' | 89°45' | 1972-pres. | * | * | |
| La Carrera | 13°20' | 88°32' | 1972-pres. | * | * | |
| La Union Beneficio | 13°20' | 87°53' | 1970-pres. | * | * | |
| La Galera | 14°03' | 88°06' | 1976-pres. | * | * | |
| Las Pilas | 14°22' | 89°05' | 1977-pres. | * | * | |

*Eppley PSP pyranometer

ADMINISTRATIVE INSTITUTION: Servicio Meteorologico Nacional, Santa Tecla, El Salvador

STAFF PERSONNEL: Dr. Gelio Guzman, Director
Lic. Rolando Martinez
Lic. Tomas Rivas
Ing. Jose Hernandez
Ing. Jose Avarenga
Lic. Jose Jimenez

APPENDIX A-3

GUATEMALA: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| Cd. Guatemala | 14°35' | 90°32' | 1972-pres. | * | * | (*) |
| El Porvenir | 14°57' | 91°55' | 1972-pres. | * | * | |
| Labor Ovalle | 14°52' | 91°30' | 1971-pres. | * | * | |
| Huehuetenango | 15°19' | 91°28' | 1969-pres. | * | * | |
| Coban | 15°26' | 90°22' | 1971-pres. | * | * | |
| Panzos | 15°24' | 89°39' | 1971-pres. | * | * | |
| Pto. Barrios | 15°42' | 88°35' | ? -pres. | * | * | |
| La Fragua | 14°57' | 89°33' | 1971-pres. | * | * | |
| Esquipulas | 14°34' | 89°27' | 1974-pres. | * | * | |
| Montufar | 13°49' | 90°09' | ? -pres. | * | * | |

*Eppley PSP pyranometer operating adjacent to older actinografo

ADMINISTRATIVE INSTITUTION: INSIVUMEH, Observatorio Nacional, Cd. Guatemala, Guatemala

STAFF PERSONNEL: Ing. Claudio Urrutia, Director
Ing. Manual Aguirre
others

APPENDIX A-4

HONDURAS: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| Tegucigalpa | 14°04' | 87°13' | 1969-pres. | * | | |
| San Pedro Sula | 15°30' | 87°55' | 1970-pres. | * | | |
| (and others, ? ?) | | | | | | |

ADMINISTRATIVE INSTITUTION: Recursos Hidricos-Hidrologia y Meteorologia, Servicio
Meteorologico Nacional
Tegucigalpa, Honduras

STAFF PERSONNEL: Ing. Pedro Cortez
Ing. Luis Medina
and others

APPENDIX A-5

NICARAGUA: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| Managua | 12°08' | 86°10' | (intermit.) | | | |
| Chinandega | 12°37' | 87°06' | (intermit.) | | | |
| Rivas | 11°25' | 85°50' | (intermit.) | | | |
| Juigalpa | 12°05' | 85°21' | (intermit.) | | | |
| Dulces | (miss.) | (miss.) | (intermit.) | | | |
| Puerto Cabezas | 14°03' | 83°22' | (intermit.) | | | |

ADMINISTRATIVE INSTITUTION:

Servicio Meteorologico Nacional
Departmento de Defensa
Managua, Nicaragua

STAFF PERSONNEL:

Lic. Leon Olivarez
Ing. Jaime Hernandez
Mirna Jerez
Cesar Lopez

Instituto Nicaraguaguense de Energia
Managua, Nicaragua

Ing. Miguel Mapupe

APPENDIX A-6

PANAMA: SOLAR RADIATION STATIONS

| Station | Lat. | Long. | Records | Actino | Helio | Other |
|---|---|---|---|---|---|---|
| David | 8°25' | 82°25' | 1971-pres. | * | | |
| Anton | 8°23' | 80°16' | 1971-pres. | * | * | |
| Tocumen | 9°03' | 79°22' | 1971-pres. | * | * | |
| Real | | | 1974,75,77 | * | * | |
| Los Santos | 7°57' | 80°25' | 1974-pres. | * | * | |
| La Raya | 8°08' | 80°48' | 1971-1975 | | * | |
| Santa Rosa | 8°11' | 80°40' | 1973-pres. | | * | |

ADMINISTRATIVE INSTITUTION: Instituto de Recursos Hidraulicos y Electrificacion, Panana, Panama

STAFF PERSONNEL: Ing. Claudia Candanedo, Director and others

# APPENDIX B

## SOURCES AND COST DATA FOR SOLAR RADIATION EQUIPMENT

EPLAB

# Normal Incidence Pyrheliometer

The Eppley Normal Incidence Pyrheliometer, as its name implies, was designed for the measurement of solar radiation at normal incidence. In effect, it may be considered a thermoelectric version or variation of the Smithsonian Silver Disk Pyrheliometer, as it incorporates in its design some of the basic features of that instrument.

The sensitive element of the pyrheliometer is a E 6 type wire wound thermopile with a thermistor temperature compensating circuit if required, embedded in heat sink of thermopile. The receiver is coated with 3M Velvet Black.

The thermopile is mounted at the base of a brass tube, the aperture of which bears a ratio to its length of 1 to 10, subtending an angle of 5° 43'30". The inside of this tube is blackened and suitably diaphragmed. The tube is filled with dry air at atmospheric pressure and sealed at the viewing end by a removable insert carrying a crystal quartz window 1 mm. thick. Two flanges, one at each end of the pyrheliometer tube, are provided with a sighting arrangement for aiming the instrument directly at the sun. A manually rotatable disk which can accommodate three filters (such as Schott OG1, RG2 and RG8) and leave one aperture free for total spectrum measurements is provided.

For periodic readings, the Pyrheliometer should be attached to a mount with provision for varying the elevation and the azimuth settings. If a continuous record is required, the pyrheliometer must be mounted on a power driven equatorial mount such as the Eppley Solar Tracker.

## SPECIFICATIONS

**Sensitivity:** 8 microvolts per watt meter$^{-2}$ approx.

**Impedance:** 200 ohms approx.

**Linearity:** ± 0.5 percent from 0-2800 watts meter$^{-2}$

**Response time:** 1 second (1/e signal)

**Mechanical vibration:** capable of withstanding up to 20 g's

**Size:** 11 in. long

**Temperature dependence:** ±1 percent over ambient temperature range -20 to +40°C (temperature compensation of sensitivity can be supplied over other ranges within the limits -70 to +50°C at additional charge).

**Calibration:** reference Epoley primary standard group of pyrheliometers

**Weight:** 5 pounds

Standard Model with wheel to accommodate three filters

Model NIP

EPLAB

# Electronic Integrator

These electronic integrators accept an analog signal from a typical Eppley solar radiometer and convert it to an output pulse rate proportional to the input signal. This output train is then counted and totalized to produce the integral of the input signal. The totalized count is displayed on a digital counter.

Adjustable to the radiometer sensitivity, the output is displayed in direct energy units in either watt-hours per meter$^2$, BTU's per foot$^2$ or other preferred units. Another feature is the analog output signal representing instantaneous radiation values which can drive a millivolt recorder or other display.

Recently redesigned features include: use of lead lengths up to 400 feet between integrator and radiometer; low power circuitry permitting operation from standard line voltage or 12 volt batteries; dual channel unit; and various accessories to permit interfacing with data acquisition systems, computers and microprocessors.

**Model 413 Electronic Integrator with electronic counter**

The Model 412 employs a mechanical counter which can be manually reset and incorporates the provision to operate from either standard line voltages or 12 volt battery. Also included is a float charger for Gould Gelyte battery Model PB1260. The display is 5 mm high with a count capacity of 999 999.

The Model 412-2 incorporates the above features as well as handling two radiometers simultaneously with two mechanical counters.

The Model 413 has an electronic counter and BCD output, 8421 positive logic. The display is 13 mm high 7 segment LED with a count capacity of 99 999.

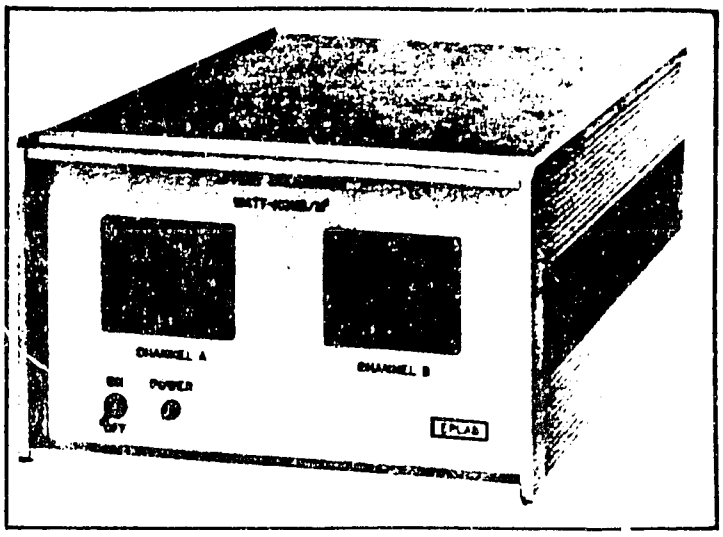
The Model 413-6140 is a complete system with digital printer. With an electronic counter with BCD output, the system has the advantage of integration as a function of time automatically, since the printer has a built in crystal clock to record real time. The printer, also, has a selectable time interval print command for print control. Selectable print time intervals include 1, 10, or 60 minutes or other intervals as requested by the customer. The printer is a 18 column and automatically resets to zero at midnight unless otherwise specified.

## SPECIFICATIONS

| | |
|---|---|
| **Accuracy** | Better than ±½% |
| **Count Rate** | Adjustable to radiometer sensitivity to give reading of energy per unit area 1 count = 1 Watt-Hour/M$^2$, 1 count = 0.1 BTU/Ft$^2$ or other customer requested setting |
| **Signal Lead Length** | Up to 400 ft. between radiometer and integrator |
| **Analog Output** | 10 MV to drive potentiometer recorder unless otherwise specified |
| **Operating Temperature** | 0-50°C |
| **Power Requirements** | 105-125, 210-230 VAC 50-60 Hz integrator 15 Watts 12 V DC, Model 412 only, 0.2 Watts per channel |
| **Size** | 8 1/2 in. wide 5 1/8 in. high 11 in. deep |
| **Weight** | 6 pounds, printer weight: 13 pounds |

The Model 412 BCD 5-Digit BCD Counter Board is mounted in its own enclosure and separate to the integrator. These boards can accept the output pulse train from the integrator, count the pulses and provide 5-digits of buffered BCD output which can be used to drive printers or other devices requiring BCD.

| | |
|---|---|
| Technical Specifications: | one board per channel. |
| Input: | Compatible to output pulses from integrator. |
| Output: | 5 digits of BCD (8421) buffered latched data outputs TTL compatible. |
| Control Lines: | Reset Line - resets the BCD counters.<br>Clock Line - controls the latches |




**Model 412-2 2 Channel integrator**

The Model 412 BIN 16 Bit Binary Data Output Board is mounted in its own enclosure and separate to the integrator. These boards can accept the output pulse train from the integrator, count the pulses and provide 16 bits of binary digital output data, for interfacing to computers and microcomputers.

| | |
|---|---|
| Technical Specifications: | One board required per channel. |
| Input: | Compatible to output pulses from integrator. |
| Output: | 16 bit binary, latched data. |
| Control Lines: | Same as BCD board. |

The Model 413 D/A Digital to analog converter board is a 3-1/2 digit digital to analog converter to be used with an Eppley Model 411 or 413 Integrator to convert the BCD output data which represents the solar radiation integral into equivalent analog form. The analog signal can then be handled by any analog data acquisition system. The board is mounted in its own enclosure.

| | |
|---|---|
| Technical Specifications: | |
| Input: | Compatible to BCD output from Model 411 or 413 Integrator. |
| Output: | 3-1/2 digits corresponding to 1.999V. Therefore, 1999 counts = 1.999V. |
| Control Lines: | Reset Line - resets the BCD counters in the integrator to zero. When held low, resets and holds counter at zero. Must be high for normal counting. Latch Strobe - When low, data in latches follow the data in the counter. When high, the data in the latches are held constant, and the counter operates independently. |
| Power Requirement: | 105/125, 210/230 VAC, 50-60 Hz. |

| | |
|---|---|
| **Model 412** | **Electronic Integrator with mechanical counter** |
| **Model 412-2** | **Electronic Integrator with mechanical counter, 2 channel** |
| **Model 413** | **Electronic Integrator with electronic counter & BCD output.** |
| **Model 413-6140** | **Electronic Integrator complete with printer** |
| **Model 412 BCD** | **5 Digit BCD counter** |
| **Model 412 BIN** | **16 Bit Binary counter** |
| **Model 413 D/A** | **3-1/2 Digit Digital to Analog converter** |
| **19 14673** | **Printer paper packs lasts over 1 month at 10 min print interval** |
| **19 14729** | **Printer Ribbon** |

**THE EPPLEY LABORATORY, INC.**

**12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020**

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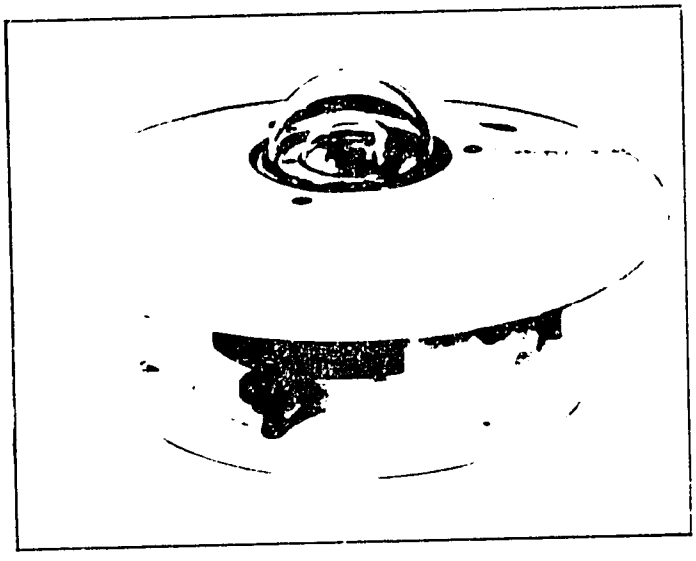
# Precision Spectral Pyranometer

This pyranometer is for the measurement of sun and sky radiation totally or in defined wavelength bands. It comprises a circular multi-junction Eppley thermopile of the wire-wound type. The thermopile has the added advantage of withstanding severe mechanical vibration and shock. Its receiver is coated with Parsons' black lacquer (nonwave-length-selective absorption). This instrument is supplied with a pair of removable precision ground and polished hemispheres of Schott optical glass. Both the inner and outer hemispheres of clear WG295 glass which is uniformity transparent to energy between about 285 to 2800 millimicrons.



Other Schott colored glass outer hemispheres include (clear) GG395, (yellow) GG495, (orange) OG530, (red) RG630, and (dark red) RG695. For special applications, other Schott glasses and Infrasil II quartz hemispheres are available.

Included is a spirit level, adjustable leveling screws and a desiccator which can be inspected readily. The instrument has a cast bronze body with a white enameled guard disc and comes with a transit or storage case.

A calibration certificate traceable to the World Radiation Reference is included with conversion factors for various energy units.

## SPECIFICATIONS

**Sensitivity:** 9 microvolts per watt meter$^{-2}$ approx.

**Impedance:** 650 ohms approx.

**Receiver:** circular 1 cm$^{-2}$, coated with Parsons' black optical lacquer

**Temperature dependence:** ± 1 per cent over ambient temperature range -20 to + 40°C (temperature compensation of sensitivity can be supplied over other ranges at additional charge)

**Linearity:** ± 0.5 per cent from 0 to 2800 watts m$^{-2}$

**Response time:** 1 second (1/e signal)

**Cosine:** ±1 per cent from normalization 0-70° zenith angle ±3 per cent 70-80° zenith angle

**Orientation:** no effect on instrument performance

**Mechanical vibration:** tested up to 20 g's without damage

**Calibration:** integrating hemisphere (approx.1 cal cm$^{-2}$ min$^{-1}$, ambient temperature + 25°C)

**Size:** 5¾ in. diameter, 3¾ in. high

**Weight:** 7 pounds

EPLAB

**The Eppley Laboratory, Inc.**
12 Sheffield Avenue
Newport Rhode Island 02840, U.S.A.
Tel.: (401) 847-1020

Model PSP

**Standard Model (as described above)**

4-1

EPLAB

# Shadow Band Stand

The Eppley Shadow Band Stand has been designed for use with Eppley pyranometers to permit continuous measurement of diffuse sky radiation by shielding the sensing element of the pyranometer from direct solar radiation and correcting for the portion of sky screened by the band.

The unit is ruggedly constructed of anodized aluminum to withstand harsh environments with high winds. Engraved markings for latitude and solar declination make the device relatively easy to set up. Shown to the right with a precision spectral pyranometer, which is not included in the price, it has a band approximately 25 in. in diameter, 3 in. wide. The shadow band stand has a net weight of 24 pounds and a shipping weight of 75 pounds.

Standard model for latitudes 0-60° North or South
Other model available for 60-90° (polar regions)

Model SBS

EPLAB

**The Eppley Laboratory, Inc.**
12 Sheffield Avenue
Newport, Rhode Island 02840, U.S.A.
Tel.: (401) 847-1020

SOLAR AMERICA, INC.

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., Newport, R. I. 02840, U.S.A. Telephone 401 847-1020

1981
DATE RECEIVED

EPLAB
Scientific Instruments for Precision Measurements Since 1917

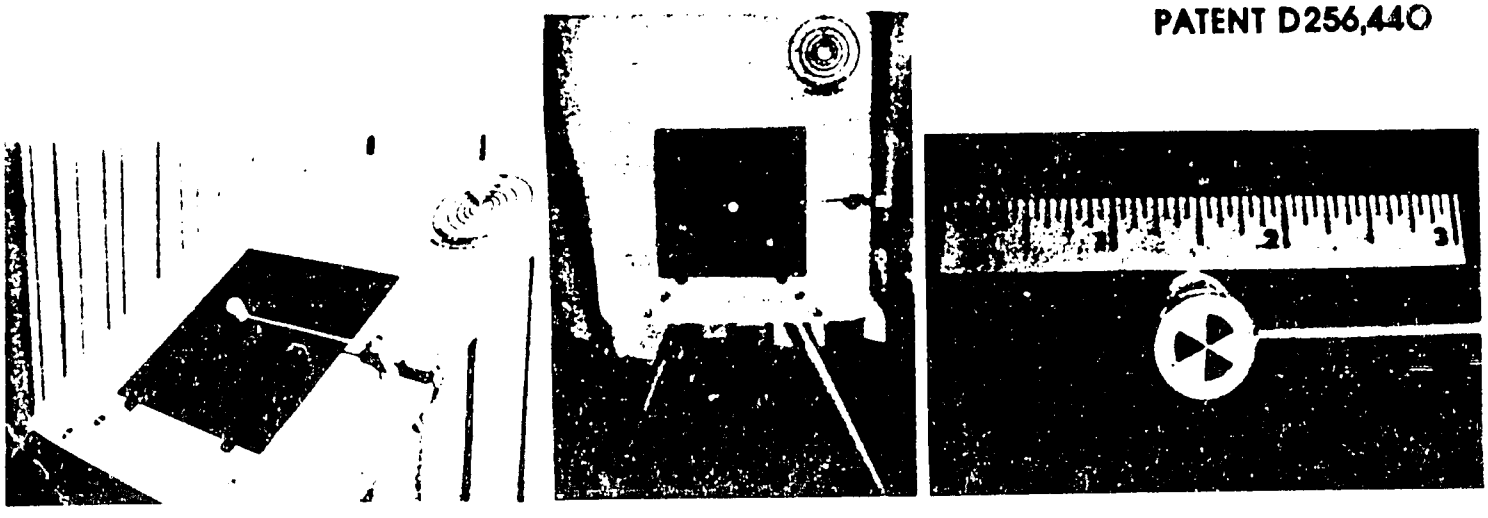
# SOLAR RADIATION INSTRUMENTS
## PRICE LIST

| | | |
|---|---|---|
| *Precision Spectral Pyranometer, Model PSP | | |
| With Schott WG7 (WG295) Glass Hemispheres | $ 1,190.00 | |
| With Schott Colored Glass Outer Hemisphere | 1,325.00 | |
| Extra Schott WG7 (WG295) Glass Outer Hemisphere | 160.00 | |
| Extra Schott Colored Glass Outer Hemisphere | 295.00 | |
| Black and White Pyranometer, Model 8-48 | 725.00 | |
| Shadow Band, Model SBS | 925.00 | |
| *Normal Incidence Pyrheliometer, Model NIP | 1,140.00 | |
| (If filter wheel not required deduct $40.00) | | |
| Shelf Stand | 40.00 | add'l |
| Schott Glass Filters | 35.00 | each |
| Solar Tracker, Model ST-1 | 925.00 | |
| For 220V 50Hz | 45.00 | add'l |
| Solar Tracker, Model ST-3 | | |
| (To accomodate up to three pyrheliometers) | 1,350.00 | |
| For 220V 50Hz | 45.00 | add'l |
| Ultraviolet Radiometer, Model TUVR | 1,300.00 | |
| Precision Infrared Radiometer, Model PIR | 1,490.00 | |
| Angstrom Pyrheliometer, Model ANG | 1,875.00 | |
| Control Unit with Digital Meter, Model 402 | 1,950.00 | |
| Eppley Cavity Self-Calibrating Radiometer, Model H-F | | |
| With Associated Control Unit, Model 405 | 5,750.00 | |
| Electronic Integrator with mechanical counter, Model 412 | 750.00 | |
| Electronic Integrator with mechanical counter, 2 channel, Model 412-2 | 975.00 | |
| Electronic Integrator with electronic counter & BCD output, Model 413 | 1,050.00 | |
| Electronic Integrator complete with printer, Model 413-6140 | 2,050.00 | |
| 5 Digit BCD counter, Model 412 BCD | 350.00 | |
| 16 Bit Binary counter, Model 412 BIN | 350.00 | |
| 3 1/2 Digit Digital to analog converter, Model 413 D/A | 450.00 | |
| Printer paper packs (Lasts over 1 month at 10 min. print interval) 19 14673 | 5.00 | each |
| Printer ribbon, 19 14729 | 7.00 | each |
| *Extended Range Temperature Curve Within The Limits -70 to +50°C | 100.00 | add'l |

FOB Newport, RI
December 1980

# D&S ALPHATOMETER MODEL 1A

PATENT D256,440



## One Device to Measure Solar:

## Radiation

## Absorptivity

## Reflectivity

## Transmissivity

Devices & Services Model 1A Alphatometer is a miniaturized thermopile type pyranometer. Its unique size, 5/8" in diameter, makes possible routine and rapid measurements of solar reflectivity, absorptivity, and transmissivity. It can also be used to measure solar radiation. The detector comes with a mounting board which provides a convenient support for absorbing and transparent materials. A solar incidence angle indicator on the mounting board allows the user to observe the variation of solar properties with angle of incidence. The mounting board is made to fit any standard photographic tripod which is supplied as an option. The D & S Scaling Digital Voltmeter, Model RD1, is the recommended readout device for the Alphatometer.

A special package is available for measurements on solar collectors in place, walls, ground, roofs, etc. This, identified as the 1A/RD1 Package, includes the Alphatometer Detector, the Scaling Digital Voltmeter (RD1) fitted with a clip for the Alphatometer detector, and a small independent shadow type angle of incidence indicator.

Measurements are easily made. For example: To obtain reflectivity of a surface the Alphatometer is first aimed toward the sun and the RD1 is adjusted to read 1.00 (100%). The Alphatometer is then aimed at the surface of interest and the RD1 indicates reflectivity directly.

SPECIFICATIONS ON REVERSE SIDE

Devices & Services Co.
10911 DENNIS RD., SUITE 405 - DALLAS, TEXAS 75229 - (214) 484-3344

SPECIFICATIONS:

READOUT: The D & S Scaling Digital Voltmeter, Model RD1, or any other high impedance, liquid crystal display voltmeter with a resolution of 0.01 millivolts is required.

OUTPUT: 1.8 millivolts/(Langley/min), Nominal

RESISTANCE: 75 Ohms, Nominal

TIME CONSTANT: 3 seconds

COSINE RESPONSE: +/-2%, 0-60 degrees incidence angle

TEMPERATURE DEPENDENCE: +/-1.5% between 4C and 38C (40F to 100F)

SPECTRAL RESPONSE: The radiation detector is a black and white 42 junction thermopile. The black is a flat black paint and the white is barium sulfate. This combination insures that the detector will have a near constant response to radiation in the range of solar wavelengths (0.3 to 2 microns). This is essential when measuring reflected radiation since the reflectivity of many surfaces is a strong function of wavelength.

EFFECT OF ORIENTATION: Because of the small size there is little convection generated inside of the protective bubble, therefore the calibration does not change as the detector is tilted with respect to the horizontal. Since the calibration does not change with tilt angle the Alphatometer is ideal for measuring solar radiation incident on tilted surfaces or for reflected radiation from buildings or from the ground.

DESICCANT: The Alphatometer sensor body contains a small chamber filled with indicating dessicant to prevent internal condensation.

TEST SAMPLE SIZE: Minimum 20 centimeters square.

Alphatometer Model 1A includes:
Detector and support, five feet shielded cable, mounting board with solar incidence angle indicator, hardware for absorptivity and transmissivity measurements, instruction manual and technical notes.

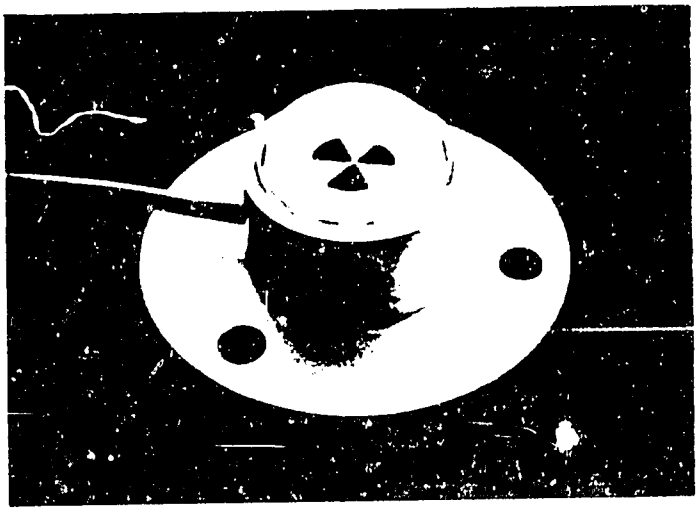
OPTIONS:

Model 1A/RD1:
Alphatometer, 1A, detector with Scaling Digital Voltmeter, RD1, detector mounting clip and small (2.5 x 2.5 cm) 0-80 degrees shadow type angle of incidence indicator.

Model 1A-T:
Tripod

# SOLAR RADIATION: MEASURE AND TOTALIZE

## MEASURE WITH THE 354 PYRANOMETER



The Model 354 Pyranometer is a black and white thermopile type with a hemispherical glass cover and anodized aluminum body. Stable 3M black and white coatings are used on the thermopile measuring sectors. A user serviceable desiccant chamber protects against internal condensation. These features make the Model 354 ideal for continuous outdoor use.

### SPECIFICATIONS

Output: nominally 7 microvolts/watt-$m^{-2}$

Temperature Dependence: ±1% from 0 to 50°C

Cosine Response: ±2% from 0 to 60°

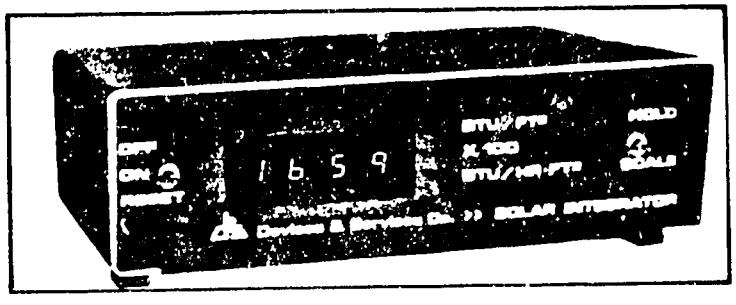
Tilt Response: ±1% for 0 to 180° tilt from horizontal

Response Time: 5 second time constant

Size: 7 cm. diameter (mounting flange) x 3 cm. high

Cable: supplied with 1.5 m. of cable and weatherproof connector. Extra cable available.

## TOTALIZE WITH THE RD2 SOLAR INTEGRATOR



The Solar Integrator totalizes the solar energy as measured by the Model 354 or other pyranometer. Three scales for total and one scale for instantaneous solar energy are front panel switch selectable. Integration is not affected by changing scales. Long term drift and bothersome offset adjustments are eliminated by automatic electronic compensation. Add the ***DATA SAVER*** option and the Solar Integrator operates continuously through short power losses for reliable totalization. Standby batteries switch in when the A.C. power fails. Analog, pulse and BCD output are also available as options.

### SPECIFICATIONS

| Scales: | Btu option* | kw option* |
|---|---|---|
| Int. Tot. | 99.99 Btu/$ft^2$ | .9999 kw-hr/$m^2$ |
| Int. Tot. | 9999. Btu/$ft^2$ | 99.99 kw-hr/$m^2$ |
| Int. Tot. | 9999x$10^2$ Btu/$ft^2$ | 9999. kw-hr/$m^2$ |
| Inst. | 500 Btu/hr-$ft^2$ | 1.8 kw/$m^2$ |

Linearity: Typically 0.3%

Zero Offset: Less than 1/2 least significant digit of the instantaneous reading.

Power Required: 110 VAC, 100 ma

Size: 18 x 23 x 6.5 cm. Weight: 1.4 kg.

* Please specify either Btu or kw option and pyranometer to be used.

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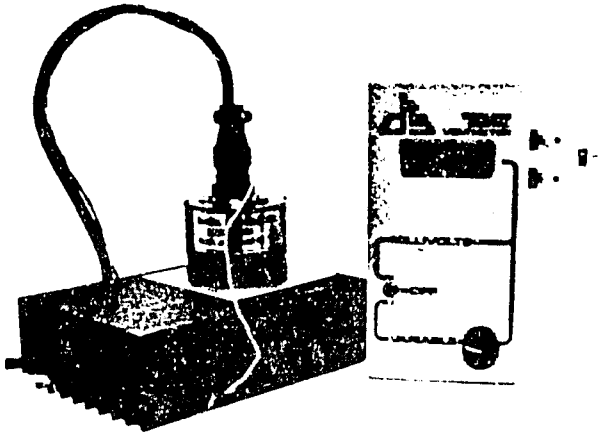
# D&S EMISSOMETER MODEL AE



- **Accurate**
- **Easy to Operate**
- **Rapid Measurements**
- **User Maintainable**
- **Inexpensive**

The D & S Emissometer is a special purpose instrument for measuring emissivity. The outstanding features of this Emissometer are:

REPEATABILITY. Better than ± 0.01 emissivity units.

EASY TO OPERATE. The detector portion of the instrument is electrically heated so that the sample does not have to be heated. No temperature measurements are needed. Only one high emissivity standard is needed for measurements. Samples can be as small as 2¼" square.

RAPID MEASUREMENTS. After an initial warmup period of about 30 minutes, emissivity values can be determined about every two minutes.

USER MAINTAINABLE. With low and high emissivity standards which are provided, the user can recalibrate the instrument periodically by means of a setscrew adjustment, instead of factory recalibration.

INEXPENSIVE. Devices available to make comparable measurements cost much more.

Total hemispherical emissivity ($\varepsilon$) at about 65C (150F) is measured with a differential thermopile. The detector responds only to radiation heat transfer and is designed to have a voltage output that is linear with emissivity rather than heat flux. The D & S Scaling Digital Voltmeter, Model RD1, is used as a readout device for the Emissometer.

Emissivity is obtained in two steps. (1) With the Emissometer resting on the standard sample ($\varepsilon$=0.93) set the RD1 to read 0.93, (2) Place the Emissometer on the sample to be measured (adjacent to the standard sample) and read emissivity directly on the RD1 (as pictured above).

SPECIFICATIONS ON REVERSE SIDE

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SPECIFICATIONS:

Readout: The D & S Scaling Digital Voltmeter, Model RD1, or any other high impedance voltmeter with a resolution of 0.01 millivolts is required.

Output: Nominal 2.4 millivolts ($\varepsilon$=0.93)

Resistance: 150 ohms, nominal

Linearity: The detector output is linear with emissivity to within $\pm$.01 units

Time Constant: 10 seconds, nominal (time to reach 63% of final value).

Heat Sink: A heat sink is provided to keep both a calibration standard and the unknown at the same temperature.

Drift: The output will change with time due to changes in ambient conditions. This effect is negligible over the time required to make the measurement.

Standard Samples: Two samples of flat black paint are provided as high emissivity standards to set instrument calibration. One should be stored and the other used as a working standard. Also provided are two samples of bare aluminum for use as a low emissivity standard for periodic instrument adjustment.

Emissometer, Model AE, includes Emissometer detector, standard dual banana plug connector and power cord, heat sink, two high emissivity standards (flat black paint), two low emissivity standards, and instruction manual.

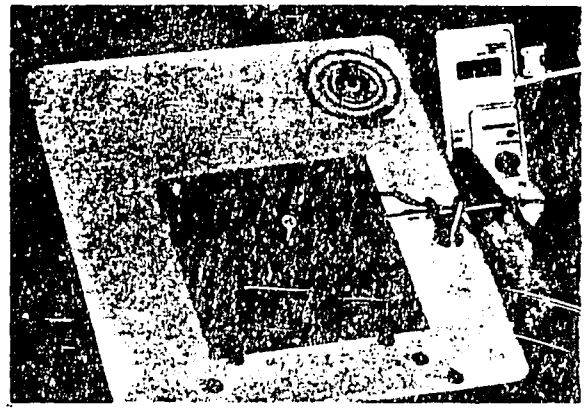
Optional: Scaling Digital Voltmeter, Model RD1.

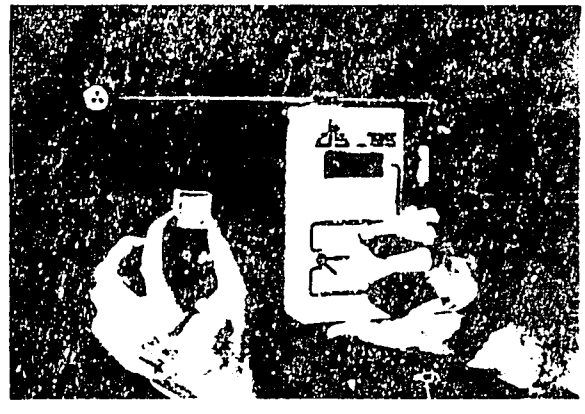
# SOLAR ENERGY EDUCATION

**PACKAGED EXPERIMENTS TEACH PRINCIPLES OF SOLAR ENERGY CONVERSION**

## ED1 Package

- Many different experiments can be carried out and no additional equipment is required.
- Experiments can be carried out by individuals or small groups.
- Solar energy - transmissivity - reflectivity - absorptivity are determined.
- Instruments in this package are now used in industry, and laboratories, for research, development, quality control, and energy management.

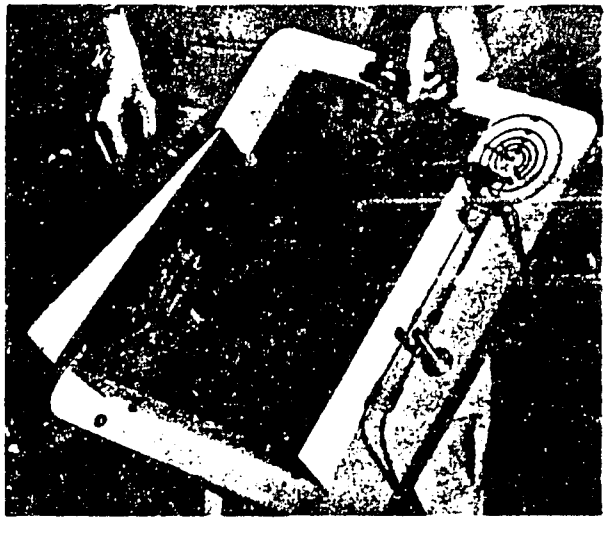




The ED1 Package consists of:

1. 1A thermopile pyranometer - ALPHATOMETER.
2. RD1 liquid crystal display - scaling digital voltmeter - includes direct reading of transmissivity and reflectivity.
3. Sample and Alphatometer support board with incidence angle indicator.
4. Shadow type incidence angle indicator and Alphatometer detector mounting clip for Scaling Digital Voltmeter.
5. Tripod.
6. Starter samples (absorbers and transmitting materials).
7. Instructions and technical notes.

## ED2 Package



- A wide variety of solar collector experiments can be performed with the small "no load" collector, as well as those provided by the ED1 Package.
- Principles of solar to thermal energy applications, thermodynamics and heat transfer, are illustrated for students of varying educational levels.

The ED2 Package consists of:

1. ED1 Package.
2. No load collector housing.
3. Absorber samples (flat black and selective included) with attached copper-constantan thermocouples.
4. Covers.
5. Specialized technical notes.
6. Carrying case.

# Description of Solar Energy Education Packages

The two education packages described below offer flexibility in that there are many experiments that can be done by students with each package. Many principles of heat transfer, thermodynamics, optics, solar energy applications, and measurements can be illustrated. The instruments included in the packages are used in industry as well as research because they are easy to use and provide accurate, useful information.

## Education Package ED1

Students measure solar energy (total and diffuse), reflectivity, and transmissivity with an accurate thermopile type pyranometer, and read results on a liquid crystal scaling digital voltmeter designed for these purposes. The experimental measurements are easily and rapidly made so that several ideas and principles can be illustrated in a single laboratory period. Starter samples of metal and transmitting materials are provided.

Written material that is part of this package include instructions for measurements, a list of ideas for possible laboratory use, as well as technical notes. Five notes are included in this package, each describing a group of experiments. The technical notes are:

(TN78-4) Determination of Transmissivity, Absorptivity, and Reflectivity of Solar Transmitting Materials.
(TN79-9) Basic Reflectivity Measurements on Flat and Irregular Surfaces Using the D & S Alphatometer.
(TN79-10) Basic Solar Radiation Measurements: Total, Direct, Diffuse, and Reflected, on Horizontal and Tilted Surfaces.
(TN79-12) Energy Transmission Through Windows: ASHRAE Considerations.
(TN79-13) Building Solar Energy Absorption: Energy Management Considerations.
(TN79-15) Applications for Alphatometer with Scaling Digital Voltmeter.
(TN79-18) Solar and Thermal Heat Loads Through Walls and Roofs.
(TN80-3) 1A/RD1 Package

## Education Package ED2

ED2 consists of package ED1 plus a flat plate collector simulator. The simulator is a small flat plate collector with no provision for removing heat from the absorber. The collector can be set up to simulate various solar collector configurations. For example, the cover system can consist of zero, one, or two covers and the absorber could have flat black, selective, or any other surface coating. Covers and absorber samples with copper-constantan thermocouples and attached connectors are included.

Students monitor both the incident solar energy with the pyranometer and the absorber temperature with a thermocouple, using the digital voltmeter. The idea is to provide students with the opportunity to convert basic sensor outputs to temperature and solar energy while learning about energy balances, heat losses, solar energy conversion efficiency, flat plate collector performance, transient behavior of absorbers, effects of coatings on solar properties of metals.

There are many more advanced studies that can be accomplished with the ED2, and of course, recorders and other data processors can be added.

This package contains additional technical notes that apply to the "no load" collector experiments. Objectives, background, procedures, calculation approaches, and actual experimental results are included. Technical notes included are:

(TN79-1) Use of Solar Collector Simulator to Determine Thermal Energy Losses and Efficiency.
(TN79-2) A Thermal Response Method for Measuring Solar Absorptivity.
(TN79-6) Effect of Thermal Capacitance on Useful Energy Collected.

## Emissometer Option

For students and laboratories interested in emissivity of flat materials and selective coatings, the Emissometer AE is an option offered for both packages. Technical notes included.

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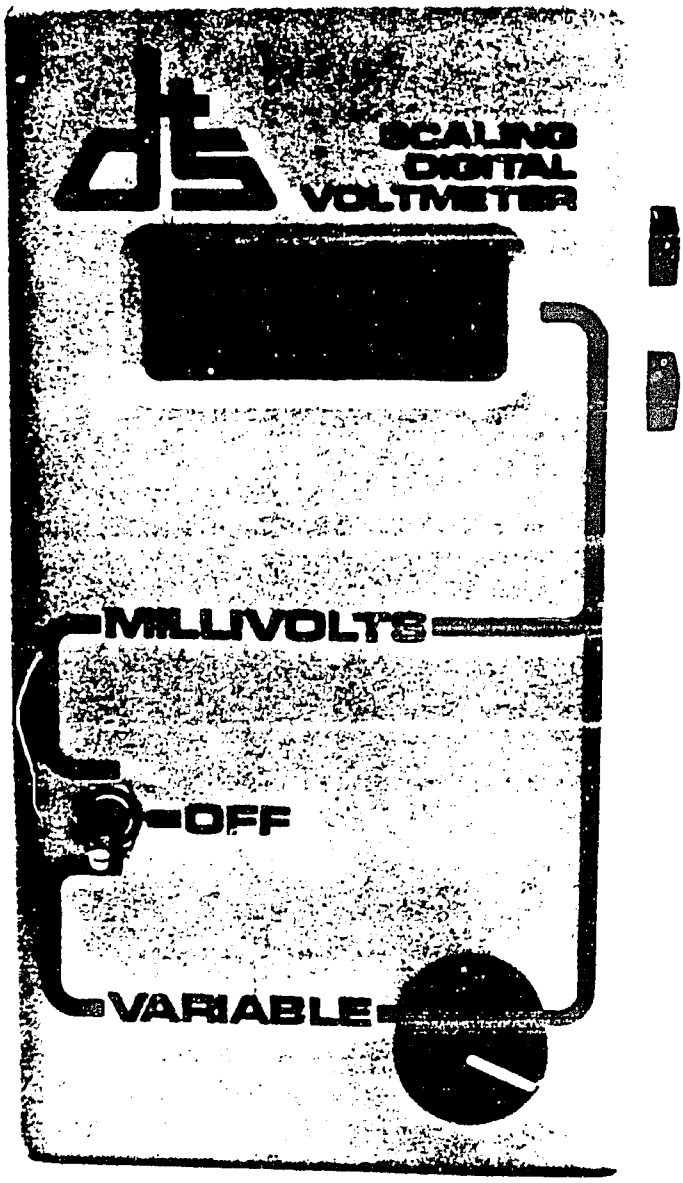
# SCALING DIGITAL VOLTMETER – RD1

**For use with the D&S Alphatometer, Emissometer, and thermopile type pyranometers.**




## *Shown Actual Size*

**3 1/8" wide – 6" long – 2" deep**

## *Liquid Crystal Display*

**Easy to read indoors and out.**

## *Input Jacks*

**Dual banana**

## *Fixed Scale*

**Customer specified, to read either millivolts or solar radiation in engineering units.**

## *Battery*

**Standard 9 Volt battery lasts over 100 hours.**

## *Variable Scaling*

**Allows direct reading of reflectivity, transmissivity, and emissivity.**

**COMPLETE SPECIFICATIONS ON REVERSE SIDE**

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## SPECIFICATIONS:

Variable Scaling: Continuously variable from 15 millivolts to 100 millivolts full scale. Full scale is 2000 counts.

Fixed Scale: Internally adjustable scale can be specified to any value within the range of the variable scaling. Unless otherwise specified the fixed scale will be set to read millivolts.

Resolution: 7.5 microvolts at maximum sensitivity.

Accuracy: Fixed scale ±(0.3% of reading + 1 digit).

Temperature Coefficient: 0.003% of reading per °C (with offset nulled).

Zero Offset Temperature Coefficient: Less than 2μV/°C.

## GENERAL INFORMATION:

Display: 3½ digit Liquid Crystal Display with ½ inch high characters.

Temperature Operating Range: -10 to +40°C.

Maximum Input Voltage: 100 mV (with input overvoltage protection).

Conversion Rate: 3 measurements per second.

Overrange Indication: Display blanks except for a 1 in the left digit and a decimal.

Physical Dimensions: 8cm x 15cm x 5cm (3 1/8" x 6" x 2")

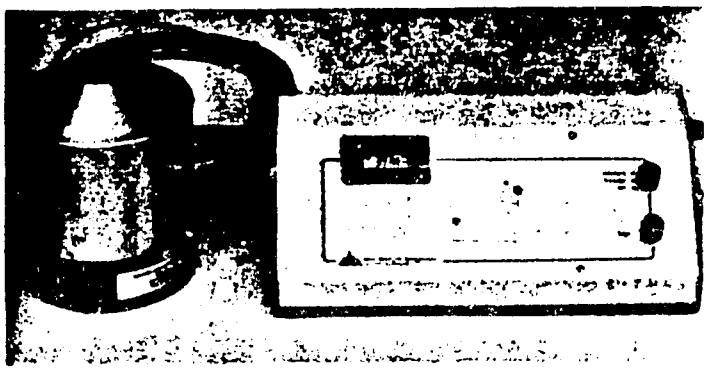
Weight: Actual = 0.37 kg (13 oz.)
Shipping = 0.57 kg (1 lb. 4 oz.)

Power: Standard 9 Volt transistor battery good for over 100 hours.

Battery Condition Indication: Low battery condition is indicated on the display.

Zero Offset Adjust: External set screw adjustment provided.

Scaling Digital Voltmeter - RD1 includes: meter; shorting plug; battery; screwdriver; instructions.



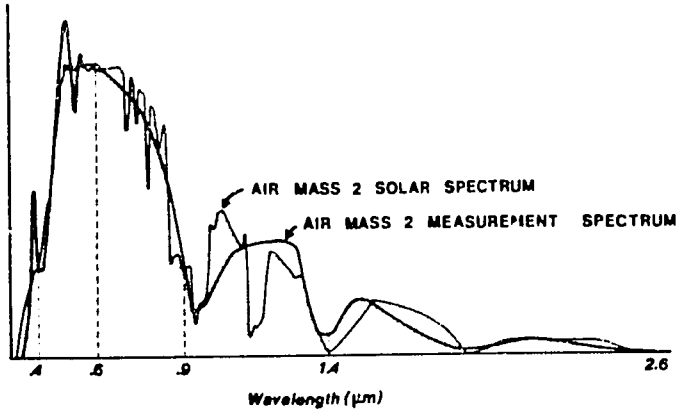
# SOLAR SPECTRUM REFLECTOMETER

## PRICE AND PERFORMANCE BREAKTHROUGH FOR THE MEASUREMENT OF SOLAR REFLECTIVITY

Repeatable, accurate, and rapid solar reflectivity measurements are possible with Devices and Services Company new Solar Spectrum Reflectometer. This instrument features an air mass two measurement spectrum that maintains accuracy even for wavelength selective surfaces such as Black Chrome. With direct digital readout of solar reflectivity, no calculations are required. Electronic drift compensation and automatic zeroing produce the remarkable resolution of 0.001 reflectivity units and repeatability better than 0.003 units, making it possible to detect small changes in reflectivity due to variations in manufacturing processes or weathering. These features also enable operation for extended periods of time with only occasional calibration checks with a single reflectance standard. Ease of operation and moderate price make the reflectometer ideal for use on the production line, as well as in the laboratory. This unique instrument represents both a price and performance breakthrough for the measurement of solar reflectivity.

### SOLAR MEASUREMENT SPECTRA

Radiation reflected by the sample is measured with four filtered detectors, consisting of three photovoltaic cells designated 'UV', 'Blue', 'Red', and a lead sulfide 'IR' detector, the designation indicating the primary wavelength range each covers. The relative response of each detector (in combination with the lightsource) has been determined as a function of wavelength, based on measurements with a Beckman DK2A Spectrophotometer. By electronically summing the four detector outputs in the appropriate proportions, the solar measurement spectrum is achieved. The instrument comes set to match Thekaekara's air mass two solar spectrum.




Other terrestrial solar spectra can be matched by a simple adjustment of the detector weightings. In addition, each detector output can be displayed separately providing spectral information about the sample.

### AUTOMATIC ZEROING

The resolution and repeatability of the instrument are achieved through automatic zeroing. In normal operation the sample is illuminated for 30 seconds during which time measurements can be made. In autozero the lamp is off for about four seconds and detector offsets are nulled. The appearance of the colon on the display indicates when the instrument is in the autozero mode.

If the instrument should fail to autozero, this condition is indicated by an arrow in the upper left corner of the display. A diagnostic circuit with LED indicators enables the user to adjust the range of autozero and bring the instrument back into normal operation.

### INSTRUMENT OPERATION

Even with all of these features, the instrument is still easy to operate. Reflectivity is measured by simply placing the sample over the port. Only occasional calibration checks with a reflectance standard are required. After initial warm-up, the drift in reflectance is less than 1% for four hours continuous operation. For making special measurements, adjusting the measurement spectrum, or servicing the instrument, the required switches and trimming potentiometers are located behind a removable front panel.

Optional outputs available include a 10 volt full scale analog output of reflectivity, and logic outputs that indicate when the instrument is in autozero and if autozero is functioning.

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## SPECIFICATIONS

Resolution: 3½ digit liquid crystal digital display reads reflectivity to 0.001 reflectivity units.

Repeatability: ±0.003 reflectivity units. (Note: some surfaces such as rolled aluminum, show variations in reflectivity with azimuth angle.)

Accuracy: Typically ±(2% of reflectivity + 0.003) for the measurement spectrum.

Drift: After thirty minutes warmup, drift is less than ±(1% of reflectivity + 0.003)/ 4 hrs.

Measurement: A single tungsten halogen lamp provides diffuse illumination at the measurement port. The energy reflected from a sample placed over the port is measured at an angle of 20° to the normal to the surface. By a reciprocity relationship this measurement corresponds to the reflectivity of the surface for direct radiation incident at 20° from the normal.

Measurement Spectrum: To match the solar spectrum the weightings for the four detectors are chosen such that the relative contribution in five wavelength bands match the solar spectrum with the least error. The resulting measurement spectra are compared to Thekaekara's air mass one and air mass two spectra below.

| | Wavelength (μm) | | | | |
|---|---|---|---|---|---|
| | .3-.4 | .4-.6 | .6-.9 | .9-1.4 | 1.4-2.6 |
| AIR MASS 1 | | | | | |
| Measurement Spectrum | 4.1% | 28.6% | 34.6% | 22.3% | 10.4% |
| Solar Spectrum | 4.1 | 28.3 | 34.3 | 21.1 | 12.2 |
| AIR MASS 2 | | | | | |
| Measurement Spectrum | 2.8 | 26.8 | 37.5 | 22.5 | 10.4 |
| Solar Spectrum | 2.8 | 26.3 | 37.3 | 21.0 | 12.7 |

Detector Adjustment Range: With the overall gain adjustment centered, the individual detector weightings can be adjusted to read in these ranges: (with the Barium Sulfate standard over the port).

| | |
|---|---|
| UV | 0.018 - 0.080 |
| Blue | 0.15 - 0.30 |
| Red | 0.30 - 0.60 |
| IR | 0.20 - 0.40 |

Any of the detectors can be switched off.

Calibration Standards: The standard of absolute reflectance used is a Kodak barium sulfate white reflectance paint. The reflectivity value used to calibrate the instrument is based on spectral reflectance measurements made by F. Grum and G. W. Luckey, (Applied Optics, Vol. 7 No. 11, p. 2289, Nov. 1968). A working standard, calibrated against the barium sulfate standard, is also provided for routine calibration.

Measurement Port: The aperture of the port is 1.9 cm (3/4") in diameter. The sample rests on a thin gasket around the port. The gasket is recessed from the edge of the port, so that for repeated measurement on delicate samples, the measured area is not marred. Minimum sample size is about 2.5 cm (1") in diameter

Lamp: Plug in replaceable tungsten-halogen lamp.

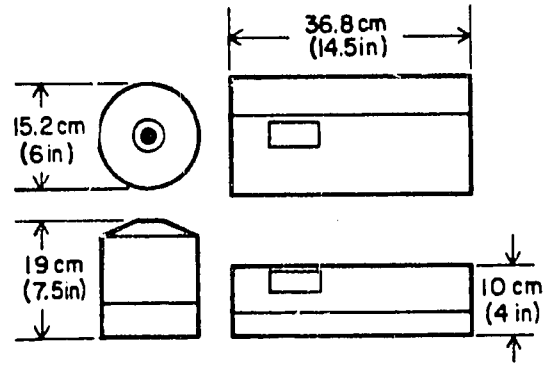
Cable: Standard cable length is 1.5 meters (five feet). Extra cable length on special order.

Power Requirement: 110 VAC ±10%, 35 VA nominal.

Option Package: Option package for use with recorders or automatic controls includes:

1. Analog output, $V_{out}$ = 10 x Reflectivity
2. Analog input (ground referenced), -1.000 to 1.000 volts.
3. Two logic outputs requiring external 15 K-ohm pull up resistors. Both outputs are normally low. One is high during autozero and the other is high if autozero fails.

Physical Dimensions:




Weight: Measurement head, 0.9 kg (2 lbs.)
Electronics assembly, 3.6 kg (8 lbs.)

Ordering Information: Specify Model SSR Solar Spectrum Reflectometer, and if the option package or additional cable is required.

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# INSTRUMENTATION PRICE LIST

9-5-80

| MODEL | DESCRIPTION | PRICE |
|---|---|---|
| 1A | Alphatometer with large mounting board and hardware | $ 720.00 |
| | Options: | |
| 1A-T | Tripod for large mounting board | 80.00 |
| 1A/RD1 | 1A/RD1 Package: Includes Alphatometer Detector, Scaling Digital Voltmeter, Angle of Incidence Indicator and Clip to mount the Alphatometer to the RD1 | 1000.00 |
| 354 | Thermopile Pyranometer | 625.00 |
| AE | Emissometer | 745.00 |
| ED1 | Education Package: Includes 1A/RD1 Package, 1A Mounting Board with Sun Angle Indicator, 1A-T, Samples, Instructions and Technical Notes | 1200.00 |
| ED2 | Education Package: Includes ED1, "no load" collector, Thermocouple / Solar Energy Switch, Covers, Absorbers with attached Copper-Constantan Thermocouples, Special Technical Notes and Carrying Case | 1700.00 |
| RD1 | Scaling Digital Voltmeter | 315.00 |
| RD2 | Solar Integrator | 925.00 |
| | Options: | |
| RD2-A | Analog Output | 75.00 |
| RD2-B | BCD Output | 150.00 |
| RD2-P | Pulse Output | 75.00 |
| SSR-ER | Solar Spectrum Reflectometer (SSR-E + SSR-R) | 8000.00 |
| | Options: | |
| SSR-E | Electronics Assembly | 3500.00 |
| SSR-IO | Input/Output Package (Analog Input, Analog Output and Logic Outputs) | 300.00 |
| SSR-R | Reflectance Measurement Head | 4500.00 |
| SSR-T | Transmissivity Measurement Attachment | 4700.00 |

## TERMS

1. FOB Dallas, Texas
2. Inquire about quantity discounts
3. 2% discount for prepayment
4. 30 days net with approved credit
5. Export: Please inquire for specific quotation.

Note: Prices subject to change without notice.
TECHNICAL NOTES LIST ON REVERSE SIDE

## LIST OF TECHNICAL NOTES - MARCH 1981

| NUMBER: | TITLE: | PREPAID PRICE * |
|---|---|---|
| TN 78-1 | Alphatometer Model 1A | $ 1.00 |
| TN 78-2 | Emissometer Model AE | 1.00 |
| TN 78-3 | Solar Reflectivity Measurements on Flat Plate Collectors | 3.00 |
| TN 78-4 | Determination of Transmissivity, Absorptivity, and Reflectivity of Solar Transmitting Materials | 1.00 |
| TN 78-5 | Temperature Measurement by Thermocouple | 1.00 |
| TN 79-1 | Use of Solar Collector Simulator to Determine Thermal Energy Losses and Efficiency | 3.00 |
| TN 79-2 | A Thermal Response Method for Measuring Solar Absorptivity | 2.00 |
| TN 79-6 | Effect of Thermal Capacitance on Useful Energy Collected | 2.00 |
| TN 79-9 | Basic Reflectivity Measurements on Flat and Irregular Surfaces Using the D&S Alphatometer | 2.00 |
| TN 79-10 | Basic Solar Radiation Measurements: Total, Direct, Diffuse and Reflected, on Horizontal and Tilted Surfaces | 2.00 |
| TN 79-12 | Energy Transmission Through Windows: ASHRAE Considerations | 3.00 |
| TN 79-13 | Building Solar Energy Absorption: Energy Management Considerations | 1.00 |
| TN 79-15 | Applications for Alphatometer with Scaling Digital Voltmeter | 1.00 |
| TN 79-16 | The Solar Spectrum Reflectometer | 4.00 |
| TN 79-17 | Emissivity Measurements for in Place Surfaces and for Materials with Low Thermal Conductivity | 2.00 |
| TN 79-18 | Solar and Thermal Heat Loads Through Walls and Roofs | 2.00 |
| TN 80-1 | An Improved Copper Oxide Selective Coating Process | 2.00 |
| TN 80-2 | Theory and Design of Selective Absorbers | 3.00 |
| TN 80-3 | Small Angle of Incidence Indicator with 1A/RD1 Package | 1.00 |
| TN 81-1 | Use of Emissometer for Semi-Transparent Materials Measurements | 1.00 |
| COMPLETE SET | | $29.00 |

* Postage paid in Canada, Mexico, and U.S.A. For other countries add $15.00 for airmail and handling.

# DIGITAL INTEGRATING PYRANOMETER S43



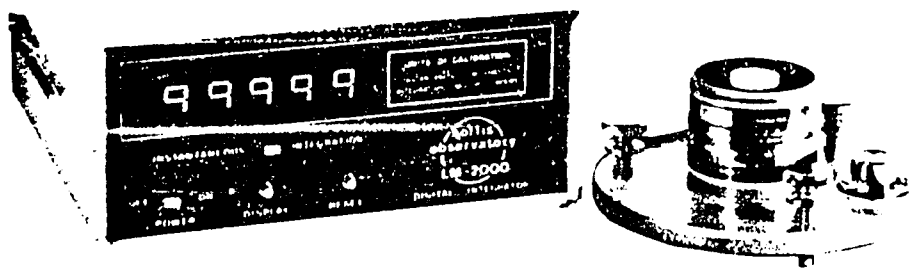
THE MODEL S43 DIGITAL INTEGRATING PYRANOMETER is an instrument used to determine the radiant energy falling on a particular location, detecting both energy arriving directly from the sun as well as scattered, reflected and re-radiated energy. The intensity of radiant energy can be expressed in BTU/ft.$^2$/hr., cal./cm$^2$/min., or watt-hours/m$^2$ over a band-width of 0.28 to 2.8 microns.

The Model S43 Digital Integrating Pyranometer (manufactured by Hollis Observatory) detects the energy incident on the pyranometer head, sums this information over time and displays it on a digital readout. The instantaneous rate of energy reception can also be displayed on command; such display does not affect the integration function.

The voltage output of the pyranometer head is electronically amplified and filtered, and then converted to a digital pulse train the frequency of which is proportional to the input voltage. Each pulse, then, is equivalent to an increment of energy as detected by the pyranometer head. When the appropriate number of pulses has been accumulated, the digital display is advanced one count.

The pyranometer head is a silicon response, temperature compensated unit. The head is weatherproof to permit outdoor installation. The response of the head obeys the cosine law with respect to the angle of incidence of impinging energy; i.e. energy arriving from the zenith, or directly above the cell will produce a maximum response, while the response will be 70.7% of the maximum for the same amount of energy arriving at a 45° angle, and zero for that same energy arriving from the horizon, or 90° down. Note that this rule generally applies to all flat plate solar collectors.

INFORMATION REQUIRED UPON ORDER:
Scale: BTUs, Cals, Watts. Operating environment, temperature.




## SPECIFICATIONS:

**Operating Power:** 105 to 125VAC 60Hz; 10 to 14 VDC.
**Input Device:** Model S40 (Hollis Observatory MR–5A) compensated silicon response pyranometer.
**Display:** 5-digit LED
**Controls:** Power ON; Display; Reset.
**Accuracy:** Instantaneous, ±1%; Integration, 1 count ±0. 1% of reading.
**Resolution:** Instantaneous, 0.1 BTU/ft$^2$/hr.; Integration, 1 BTU/ft$^2$.
**Response Time:** dependent on intensity
**Stability:** ±2% first year.
**Unattended Operating Period:** until counter overflow.
**Ambient Instrument Temp. Range:** Electronics, 0 to 40°C; Pyranometer head, −20 to 40°C
**Dimensions:** Display unit, 6"w x 2 1/2"h x 6 1/4"d; Sensor, see spec.
**Weight:** 1 lb.
**Connectors:** Sensor input, barrier strip to accept AWG #12 or smaller wire; Three-prong AC power plug.
**Maintenance:** Recalibrate system yearly.
**Special Requirements:** External lightning arrestor recommended.



**Natural Power Inc.** *Specialists in Electronics for the Renewable Energy Industry*
FRANCESTOWN TNPK, NEW BOSTON, NEW HAMPSHIRE 03070 603-487-5512



Specifications subject to change.

Domestic Retail Price List
Effective: May 15, 1981

**Natural Power Inc.**
New Boston New Hampshire 03070 603-487-5512

## WIND SURVEY and SITE ANALYSIS INSTRUMENTS

| Model | Description | | Price |
|---|---|---|---|
| | Wind Recording Instrument, Single Channel: | | |
| A10-101 | Speed | 115V AC | $375.00 |
| -201 | Run | " | 410.00 |
| -95 | Special Weather Housing Option | | 175.00 |
| | Wind Recording Instrument, Dual Channel: | | |
| A11-111 | Speed/Speed | 115V AC | $800.00 |
| -121 | Speed/Run | " | 835.00 |
| -131 | Speed/Direction | " | 875.00 |
| -141 | Speed/RPM | " | Contact NPI |
| -151 | Speed/Power | " | 1000.00 |
| -221 | Run/Run | " | 870.00 |
| -231 | Run/Run | " | 910.00 |
| -95 | Special Weather Housing Option | | 175.00 |
| Unregulated DC Option for any Recorder | | | $75.00 |
| Regulated DC Option for any Recorder | | | 225.00 |

NOTE: Each Recorder is shipped with three rolls of chart paper

| | | | |
|---|---|---|---|
| A21 | Wind Data Accumulator, indoor model | | $180.00 |
| A22 | " " " | w/outdoor box/lithium batteries | 230.00 |
| A23 | Wind Data Kit; includes A22, A76-040, guys and anchors | | 300.00 |
| A25 | Wind Energy Monitor | | $425.00 |
| A30-101 | Wind Speed Compilator; one anemometer input | | $950.00 |
| -202 | " " " | two " " | 1325.00 |
| -203 | " " " | three " " | 1400.00 |
| -204 | " " " | four " " | 1475.00 |
| -205 | " " " | five " " | 1550.00 |
| -206 | " " " | six " " | 1625.00 |
| -208 | " " " | eight " " | 1750.00 |
| -301 | " " " | wind speed/direction, one anemometer/one direction input | 1650.00 |
| -401 | " " " | wind speed/octurnal, one anemometer | 1950.00 |
| -95 | Special Weather Housing Option | | 175.00 |

NOTE: Recorder outputs are provided on single anemometer Compilators

| | | |
|---|---|---|
| A35-1XX | DC Ampere-Hour Meter | $320.00 |
| A40-1XX | DC Watt-Hour Meter | $410.00 |
| A50-101 | RPM Transducer and 6 inch diameter Standard Split Gear | $400.00 |
| | Separate Components: | |
| | Transducer (tachometer pickup) | $145.00 |
| | Split Gear Standard (6 inch diameter, 1 inch bore) | 255.00 |
| | Split Gear Special | 355.00 |
| | Regular, one-piece Gear | 80.00 |
| | Special, one-piece Gear | 180.00 |
| A51-101 | Power Trandsucer, AC | Contact NPI |
| -102 | " " DC | " " |
| A60 | Data Logger | $3500.00 |
| A62 | Cassette Tape Reader | $3100.00 |
| A65 | Environmental Monitoring System | $7500.00 |
| A70-104 | Sensor w/Interface, Speed | $150.00 |
| -204 | " " Run | 185.00 |
| -301 | " " Direction | 225.00 |
| A71 | Signal Conditioner (magnetic tape interface) | $280.00 |
| A72-801 | Wind Speed Indicator, "Vigilant," Brass | $215.00 |
| -803 | Wind Direction Indicator, "Radiant," Brass | 198.00 |
| -804 | Wind Speed/Temperature Indicator, "Chillmeter," Brass | 340.00 |
| -807 | Wind Direction/Barometric Pressure, "Forecaster," Brass | 330.00 |
| -811 | Wind Speed/Direction Indicator, "Maestro," Brass | 315.00 |
| -8XX | Complete Weather Station by Maximum, mounted on attractive mahogany panel | Contact NPI |

NOTE: Add $10 for chrome finish on any A72- instrument

## WIND INSTRUMENT ASSESSORIES

| | | |
|---|---|---|
| A75-104 | Anemometer Head, 4-pole | $55.00 |
| -301 | Wind Direction Head | 90.00 |
| A76-020 | Instrument Mast, 20 feet | $35.00 |
| -030 | " " 30 feet | 50.00 |
| -040 | " " 40 feet | 65.00 |
| -050 | " " 50 feet | 80.00 |
| -900 | Guy Wire and Anchors for Instrument Mast | 25.00 |
| A85-XXX | Gill Precision Wind Sensor | Contact NPI |
| A90-003 | Battery, Lithium, 3V, for A22, A60 | $15.00 |
| -012 | Battery, 12V DC, Gel-Cell | 100.00 |
| -A95 | Special Weather Housing, A90 Battery | 30.00 |

## WIND GENERATION and CONTROL

| | | |
|---|---|---|
| C20-012 | Dynamic Loading Switch, 12V DC | $170.00 |
| -024 | " " " 24V DC | 170.00 |
| -032 | " " " 32V DC | 170.00 |
| -110 | " " " 110V DC | 180.00 |
| C25-110 | Alternator, 110V DC | $600.00 |
| C26-012 | Regulator, 12V DC | 95.00 |
| -024 | " 24V DC | 95.00 |
| -032 | " 32V DC | 95.00 |
| -110 | " 110V DC | 95.00 |

NOTE: C26-110 price is $50 when purchased with C25-110 Alternator

| | | |
|---|---|---|
| C46-100 | Wind Trigger, single set point | $600.00 |
| -200 | " " dual set point | 780.00 |

## RECORDERS

| | | |
|---|---|---|
| R10 | Recorder, Single Channel, AC | $235.00 |
| R20 | Recorder, Dual Channel, AC | $500.00 |
| Unregulated DC option for any Recorder | | $75.00 |
| Regulated DC option for any Recorder | | 225.00 |
| A70-200 | Automatic Sampling Switch (multiplexer) | $110.00 |
| R90-100 | Chart Paper, Single Channel, 6 rolls minimum @ $5.50 ea. | $33.00 |
| -200 | " " Dual Channel, 4 rolls minimum @ $11.00 ea. | 44.00 |
| -300 | " " Triple Channel, 2 rolls mimimum @ $22.00 ea. | 44.00 |

## SOLAR SYSTEM CONTROLS and MONITORS

Note: All prices include Sensors and Recorder outputs

| | | |
|---|---|---|
| S25-125 | Differential Thermostat, 2 sensors | $284.00 |
| -225 | 2 sensors w/secondary relay on S1 (collector) | 330.00 |
| -425 | 2 sensors w/secondary relay on S2 (storage) | 330.00 |
| -525 | 2 sensors w/secondary relays on S1 and S2 | 330.00 |
| S26-125 | Differential Thermostat, 3 sensors | $330.00 |
| -225 | 3 sensors w/secondary relay on S1 (collector) | 358.00 |
| -425 | 3 sensors w/secondary relay on S3 (third sensor) | 358.00 |
| -525 | 3 sensors w/secondary relays on both S1 and S3 | 358.00 |
| -725 | 3 sensors w/secondary relays on S2 and S3 | 358.00 |
| S27-125 | Proportional Differential Thermostat, 2 sensors | $325.00 |
| -225 | 2 sensors w/secondary relay on S1 (collector) | 352.00 |
| -425 | 2 sensors w/secondary relay on S2 (storage) | 352.00 |
| -525 | 2 sensors w/secondary relays on S1 and S2 | 352.00 |

(Solar System Controls and Monitors, continued)

| | | |
|---|---|---|
| S28-125 | Proportional Differential Thermostat, 3 sensors | $358.00 |
| -225 | 3 sensors, w/secondary relay on S1 (collector) | 385.00 |
| -425 | 3 sensors, w/secondary relay on S3 (third sensor) | 385.00 |
| -525 | 3 sensors, w/secondary relays on both S1 and S3 | 385.00 |
| -725 | 3 sensors, w/secondary relays on S2 and S3 | 385.00 |
| S35-100 | Temperature Monitor, 2 inputs | $225.00 |
| -200 | " " 3 to 12 inputs | $300 + $30/input over 3 |
| -300 | " " 13 to 24 inputs | $550 + $30/input over 13 |
| S40 | Pyranometer Head (only) | $240.00 |
| S42 | Recording Pyranometer w/Integrator (for replacement chart paper, specify N or WN) | 1050.00 |
| S43 | Integrating Pyranometer w/Digital Display | 950.00 |
| S45 | BTU Meter w/2 temperature sensors, flow sensor, PVC tee (up to 1½ inch diameter,) instantaneous display | $1425.00 |
| S46-100 | BTU Meter: Pipe Mount w/meter, flow sensor, temperature sensor, tee assembly (bronze, up to 1 inch diameter,) battery | 450.00 |
| -200 | BTU Meter: Wall Mount w/separate meter, temperature sensors, flow sensor, tee assembly (bonrze, up to 1 inch diameter,) battery | 480.00 |

NOTE: Contact NPI for price on tee assembly larger size or other type material

## TEMPERATURE SENSORS

| | | |
|---|---|---|
| S91 | Temperature Sensor, Liquid (screw type) | $12.00 |
| S92 | " " Air | 7.00 |
| S93 | " " Surface (lug end) | 6.00 |
| S94 | " " Radiation (anodized black) | 12.00 |
| S95 | " " Extended Temperature Range | 15.00 |

## MISCELLANEOUS

| | | |
|---|---|---|
| A96-1 | Sensor Lightning Protector, 2 lead protection | $17.00 |
| -2 | " " " 4 lead protection | 27.00 |
| -3 | " " " line surge protection | 47.00 |
| Full Product Catalog | | $2.00 |

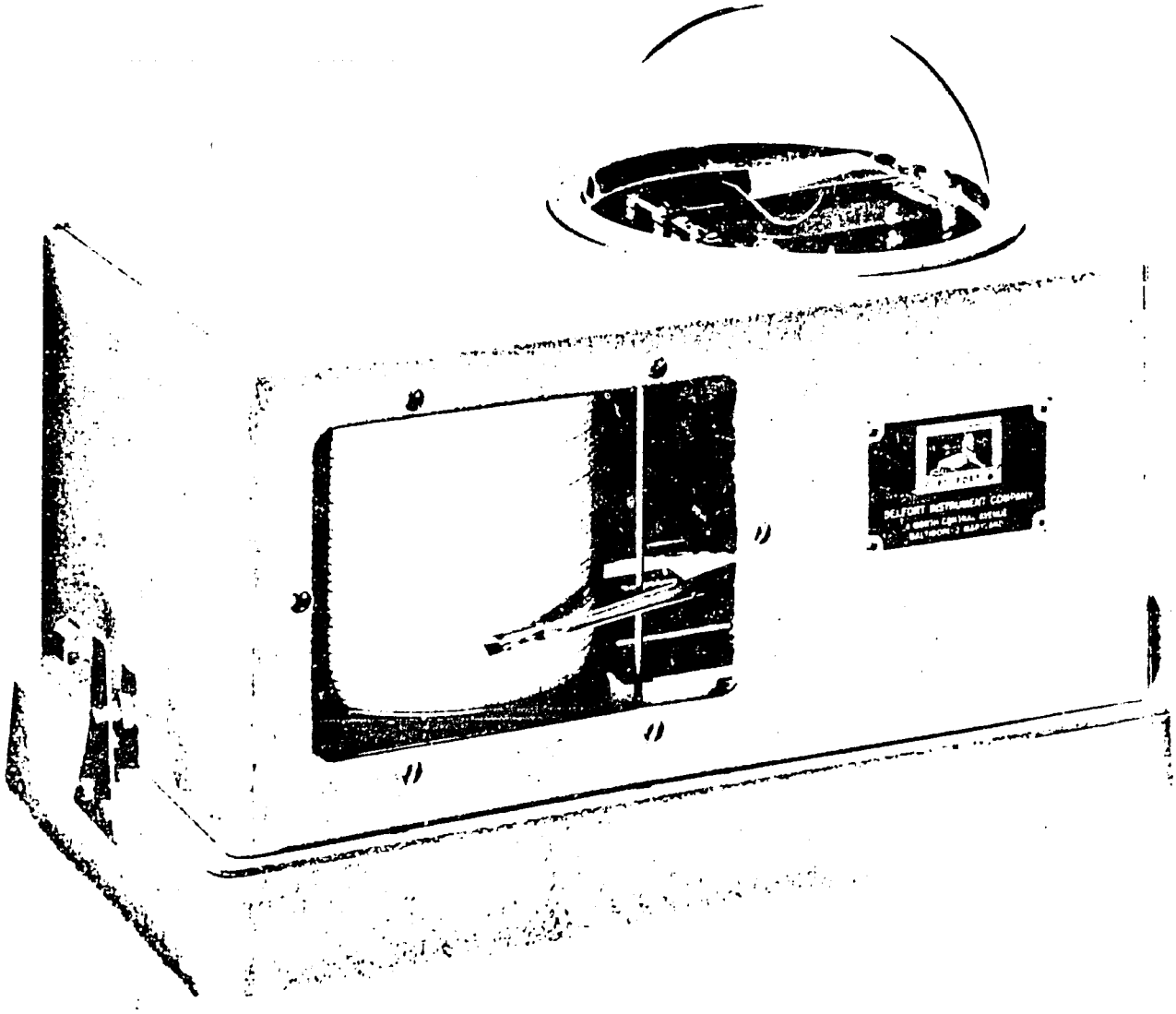
Most models listed above can be furnished for operation from 240V, 50 hz power sources. Contact NPI.

All prices are based on FOB Factory, New Boston, NH and are subject to change without notice.

Terms of payment are cash with order, except for organizations with established credit; then 2% within ten days, NET thirty days.

# Pyranograph

Bulletin 79-8




## Cat. No. 5-3850A
## Radiation Recorder

## measuring direct solar and diffuse sky radiation

BELFORT INSTRUMENT COMPANY
1600 SOUTH CLINTON STREET
BALTIMORE, MARYLAND 21224

BELFORT

# Pyranograph

Bulletin 79-8

The Cat. No. 5-3850A Pyranograph accurately measures and records variations in solar radiation, completely independent of any external power source. This together with compactness, portability, and sturdiness make it ideal for field exploration and remote installation.

The measuring element of the instrument consists of two plated bimetallic strips, one of which is blackened and the other given a highly reflective plating. The blackened strip is exposed to both the ambient temperature and the radiant energy of the sun while the polished strip is exposed to the ambient temperature but shielded from the radiant energy of the sun. These two strips are mounted in tandem through a long thermal path, convector fin coupling which prevents heat flow between the two strips. Mounting is such that only differential temperature produces motion of the pen arm, while ambient temperature changes result in no motion. Thus, only the motion of the blackened strip which is caused by radiant energy is recorded, while that resulting from ambient temperature is compensated and has no effect. The elements are housed under a dome made of Borosilicate glass. A table of transmission coefficients for this type of glass is included below.

The time constant of the instrument is five minutes. Sensitivity is 0.1 gram calorie per square centimeter per minute for 3/32" of chart width. The total range of the instrument is 3 gram calories per square centimeter per minute. This provides adequate margin over the maximum solar radiation encountered and brings the most usually recorded values at mid-scale where the highest instrument accuracy exists. From this, it is clear that speed of response, accuracy and precision of recording are entirely adequate for all practical use where extensive area measurements are required and where convenience, simplicity, and sturdy construction are important factors. No outside source of power is required.

## SPECIFICATIONS

ACCURACY: within ±5% of value recorded or ±0.05 gm-cal/sq cm/minute, whichever is greater
SIZE: 13½" lg x 7" wd x 9" hg (34.5 cm x 18 cm x 23 cm)
NET WEIGHT: 10 lbs (4.5 kg)
GROSS WEIGHT: 15 lbs (6.8 kg)

| WAVELENGTH MICRONS | TRANSMISSION COEFFICIENT |
|---|---|
| 0.36 - 2.0 | 0.9 |
| 3.3 | 0.5 |
| 4 | 0.2 |
| 0.28 | UV Cutoff |

## ORDERING INFORMATION

| EQUIPMENT DESCRIPTION | SPECIFY |
|---|---|
| Pyranograph As Described Above with 8-day Spring-powered Chart Drive, A Set Of Charts Selected From Table Below, And Ink | Cat. No. 5-3850A |
| Pyranograph Same As Above, But With Battery-powered Chart Drive And A Set of Charts Selected From Table | Add "with Chart Drive PL-15605" |

## CHART SETS AVAILABLE

| CHART NUMBER | CHART PERIOD HRS/REV | | CHARTS PER SET |
|---|---|---|---|
| 5-1050AD | 24 | −0.3 to +3.0 gm-cal/sq cm/min (Langleys/min) | 100 |
| 5-1050AW | 192 | | |
| 15667 | 861* | | 25 |

* 35.9-day chart for use with Electric Chart Drive Only

BELFORT INSTRUMENT COMPANY
1600 SOUTH CLINTON STREET
BALTIMORE, MARYLAND 21224

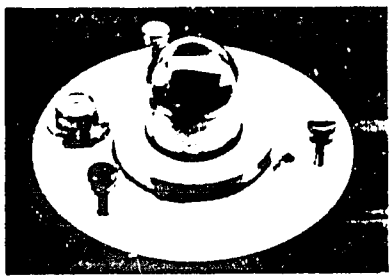
BELFORT

69

MATRIX, INC. • 537 SOUTH 31st STREET • MESA, ARIZONA 85204 • 602 • 832-1380

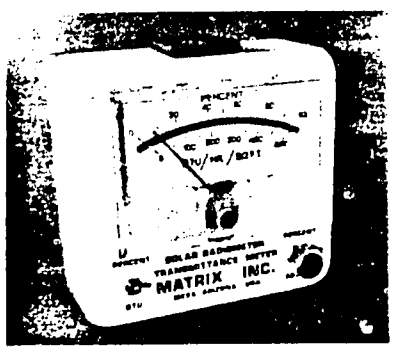
# PRODUCT BULLETIN
# SOLAR RADIOMETERS AND ACCESSORIES

Sol-A-Meters are low cost, rugged, weatherproof solar radiometers intended for use under the most severe field conditions.* They are completely self contained and do not require any external power supply. All models incorporate the silicon photovoltaic cell as a sensor. Spectral response is from 0.35 to 1.15 microns. One hundred percent response to a change in signal takes less than one millisecond. All Sol-A-Meters are calibrated for the entire solar spectrum by comparison with thermopile type radiometers in bright sunshine on clear days. Cosine effect and air-mass effect corrections are made during calibration. Standard temperature compensation is from 40 to 140 degrees F. Each instrument is furnished with a certificate of calibration showing radiation in both English and Metric units.



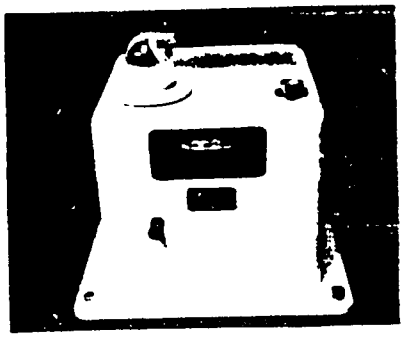
The Mk 1-G Sol-A-Meter is a weatherproof pyranometer (for total radiation from both sun and sky). Standard sensitivity is 50 mV per cal./cm$^2$. min. (2.5 or 5 mV per cal./cm$^2$. min. on request). Impedence is 1.0 ohm (0.05 and 0.10 ohm for 2.5 and 5.0 mV respectively). Accuracy is ± 5%. When the Mk 1-G is ordered with either the optional meter or recorder they are calibrated as a system for best accuracy. Special filters and other modifications are available on special order. Base is 5" in diameter. Shipping weight is 1½ lbs.

The Mk 3 Sol-A-Meter is a pyrheliometer which measures direct solar radiation at normal incidence. The Mk 3 is constructed with an internally baffled and blackened (3 M Black Velvet) 10-inch collimating tube with a 5.7° aperture. This complies with W.M.O. recommendation for measuring solar radiation. Sensitivity is 25 mV per cal./cm$^2$. min. Impedance is 1.75 ohms. Accuracy is ± 5%. Spectral filters can be furnished on special order. A mounting hole (¼ x 20) is provided in the base. (Stand not included.) Overall length is 11 inches. Shipping weight is 4 lbs.




The Mk 6 Sol-A-Meter is a compact, rugged and highly portable instrument for the quick measurement of solar insolation falling on horizontal, vertical or other surfaces directly in Btu./hr./sq. ft. (read on the lower scale). The transmittance and reflectance of drapes, screens, glass and other materials may be determined directly in percent on the upper scale with a ± 2% accuracy. This convenient instrument will enable the user to measure the heat load falling upon any surface and to determine the effectiveness of shading materials in reducing the solar input. This instrument is extremely useful to designers and users of sun control devices, architects, heating and air conditioning engineers, and those involved with the development and installations of solar collectors. Also, an extremely effective sales tool. Approximately 5½ x 5½ x 2½ inches. Shipping weight 2 lbs.

*except the Mk 6.

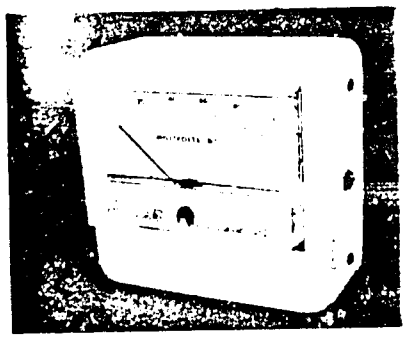


The Mk 14E Sol-A-Meter incorporates the Mk 1-G (described above) into a completely self contained solar radiometer (pyanometer). The Mk 14E is designed with low power C/MOS circuits that provides a readout of total integrated insolation on a digital display with an accuracy of ± 3% over periods of a day or more. A meter provides a readout of instantaneous insolation in cal./cm$^2$. min. with an accuracy of ± 5%. A replaceable desiciant assembly with a visible humidity indicator provides easy monitoring of humidity within the instrument.

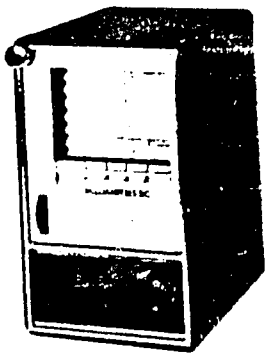
The Mk 14E is battery operated but never requires a battery change under normal operating conditions. A small solar battery charger is built into the Mk 14E which keeps the Nickel-Cadmium batteries charged. Because of its small power requirements, the batteries will allow the Mk 14E to operate up to 20 days with no sun available for recharging. Integration values represent total radiation between readings; analog values are instantaneous on the meter or they can be recorder as a signal of approximately 0-100 mV on the optional recorder listed below. Remote sensors and readouts are available. Base is 9 x 9 inches, height 9 inches maximum. Shipping weight is 8 lbs.

The Mk 18E is a net radiometer version of the Mk 14E. All Mk 14E systems and options are available with Mk 18E. Shipping weight 12 lbs. (Not pictured.)

The pyranometer Shadow Band is designed to shield the sensing elements of a pyranometer from direct solar radiation. This allows measurement of diffuse sky radiation directly and continuously. Designed for use at 0-60$^{\circ}$ North or South latitudes, the unit is constructed of black anodized aluminum, engraved with latitude and solar declination markings. The band is 3 inches wide and 25 inches in diameter and may be used with any manufacturer's pyranometer as well as the Mk 1-G described above. Shipping weight approximately 25 lbs.



The meters furnished with Sol-A-Meter models designated -M are taut-band, 100 millivolt meters having an overall accuracy of ± 2% and a repeatability of ± 1%. The Sol-A-Meter is calibrated with the meter to assure the highest possible accuracy. Height 5½". Shipping wt. 1½ lbs.



The recorders furnished with Sol-A-Meter models designated -R are of the galvanometric, inkless type. The stylus is clamped against pressure sensitive paper by a striker bar activated by a cammed assembly on the drive motor. The standard recorder, 0-100 mV, has a 2½ inch wide chart which provides a 750 hour record at 1 in. per hour. Standard -R model Sol-A-Meters have a 115 volt 60 Hz AC motor. Models designated -RD have a DC motor for 6 or 12 volts as required (24/28 volts extra charge). DC motor speed depends on supply voltage. A solid-state regulator is available for more accurate DC motor control. Models designated -RDS have a 12 volt DC motor and a photocell operated relay which turns the recorder on just before sunrise and off just after sunset. This feature increases the average time between paper changes to 60 days, and saves power. the Sol-A-Meter is calibrated with the recorder to insure the highest possible accuracy. Height 6". Shipping wt. 3 lbs.

MATRIX, INC. • 537 SOUTH 31st STREET • MESA, ARIZONA 85204 • 602 •832-1380

# PRICE LIST

## SOL-A-METERS AND ACCESSORIES

| Model | Delivery | Price | Model | Delivery | Price | Model | Delivery | Price |
|---|---|---|---|---|---|---|---|---|
| Mk 1-G | 30 | $195.00 | Mk 3-M | 30 | $395.00 | Mk 14E-RDS | 60 | $1255.00 |
| Mk 1-GM | 30 | 265.00 | Mk 3-R | 60 | 610.00 | Mk 18E | 60 | 1130.00 |
| Mk 1-GR | 60 | 470.00 | Mk 6 | 30 | 195.00 | Mk 18E-R | 60 | 1490.00 |
| Mk 1-GRD | 60 | 555.00 | Mk 14E | 30 | 695.00 | Mk 18E-RD | 60 | 1570.00 |
| Mk 3 | 30 | 345.00 | Mk 14E-R | 60 | 1050.00 | Mk 18E-RDS | 60 | 1695.00 |
| | | | Mk 14E-RD | 60 | 1130.00 | | | |

Shadow Band for the measurement of diffuse sky radiation, 0-60° north or south latitudes. To be used with 180° solar radiometers. (Not described in literature. Apply to factory for details.) $ 655.00

Dehydrator assembly for Mk 14 and Mk 18 models 8.75

Battery, 6 volt lead-acid, replacement for Mk 14 & 18 models 17.00

Meter in case, -M, 0-10mv, ordered separately 75.00

Recorder, standard, -R, 0-100mv, 115 volts 60Hz AC motor ordered separately 275.00
For recorders with 240 volts 60 Hz AC motor add $25.00 to above prices.

Chart paper (style A or WA) for recorders, 6 rolls 30.00

Cable, extra instrument cable per foot 0.44

Prices for special items and requirements, quoted on request.

Prices: F.O.B. Mesa, Arizona, U.S.A. Prices subject to change without notice. No order will be processed without notifying customer of price increase. Prices in U.S. dollars.

Warranty: All Sol-A-Meters are warrantied against defects in materials and workmanship for a period of one year. Batteries for only 60 days.

Terms: WARRANTY IS CANCELED IF TERMS ARE NOT MET. Net 30 days to firms with open accounts. All other shipments, C.O.D. Past due accounts ARE charged 1½% per month service charge. For export sales, we require a guaranteed Irrevocable Letter of Credit, established with a United States bank, for a minimum period of nine months from the date of issue, negotiable upon receipt of the merchandise by the carrier. For all export shipments, (except Canada & Mexico), add 10%, ($20.00 minimum).

Minimum Billing: $15.00

Effective April 1, 1981

SOLAR AMERICA, INC.

DATE RECEIVED

# APPENDIX C

## RECOMMENDED SOLAR RADIATION EQUIPMENT, BUDGET

APPENDIX C-1

SOLAR DATA EQUIPMENT AND INSTRUMENTATION RECOMMENDED
FOR CATEGORY A, B, AND C STATIONS

| | Sept 1981 (U.S. $) |
|---|---|
| **Category A** | |
| Pyrheliometer (Eppley NIP with Tracker) | $ 2,100 |
| Pyranometer (Eppley PSP) | 1,200 |
| Temperature and Humidity Sensors | 1,800 |
| Wind Velocity Sensor | 1,200 |
| Digital Data Logging System with Integrating Capability | 13,000 |
| 2 Strip Chart Readers for Backup | 7,000 |
| Equipment & Instrument Racks, Mountings | 3,000 |
| TOTAL COST | $ 29,300 |
| **Category B** | |
| Pyranometer (Eppley PSP) | $ 1,200 |
| 1 Strip Chart Recorder | 3,500 |
| Equipment & Instrument Racks, Mountings | 700 |
| TOTAL COST | $ 5,400 |
| **Category C** | |
| Integrating Sol-A-Meter (Heliografo that requires no external power) | $ 1,250 |
| Max/Min Thermometer with Standard Instrument Shelter | 650 |
| Instrument Mountings, etc. | 700 |
| TOTAL COST | $ 2,600 |

The above equipment lists assume that regulated 115V or 230V AC power is available and that the equipment will be housed in an appropriate controlled enclosure. Where such facilities are not presently available, the costs for providing such should be added to the above costs.

APPENDIX C-2

INSTRUMENT COSTS PROJECTION FOR EACH COUNTRY,
PHASED BY YEAR

| YEAR | CATEGORY A | CATEGORY B | CATEGORY C | TOTAL |
|---|---|---|---|---|
| 1 | $ 30,000 | $ | $ | $ 30,000 |
| 2 | 30,000 | 6,000 | 3,000 | 39,000 |
| 3 | 30,000 | 6,000 | 3,000 | 39,000 |
| SUBTOTAL | $ 90,000 | $ 12,000 | $ 6,000 | $108,000 |
| 4 | 30,000 | 6,000 | 3,000 | 39,000 |
| 5 | 30,000 | 6,000 | 3,000 | 39,000 |
| SUBTOTAL | $150,000 | $24,000 | $12,000 | $186,000 |

APPENDIX C-3

REGIONAL CALIBRATION FACILITY COSTS PROJECTION

| YEAR | T/A BY U.S. PERSONNEL | TRAINING OF C.A. PERSONNEL IN U.S. | TOTAL |
|---|---|---|---|
| 1 | 12 wk X $2,000 = $ 24,000 | 12 mo X $1,500 = $ 18,000 | $ 42,000 |
| 2 | 12 wk X $2,000 = $ 24,000 | 12 mo X $1,500 = $ 18,000<br>12 mo X $1,000 = $ 12,000<br>12 mo X $ 500 = $ 6,000<br>$ 36,000 | $ 60,000 |
| 3 | 12 wk X $2,000 = $ 24,000 | 12 mo X $1,500 = $ 18,000<br>12 mo X $1,000 = $ 12,000<br>12 mo X $ 500 = $ 6,000<br>$ 36,000 | $ 60,000 |
| SUBTOTAL | $ 72,000 | $ 90,000 | $162,000 |
| 4 | 12 wk X $2,500 = $ 30,000 | 12 mo X $1,500 = $ 18,000<br>12 mo X $1,200 = $ 14,400<br>12 mo X $ 800 = $ 9,600<br>$ 42,000 | $ 72,000 |
| 5 | 12 wk X $2,000 = $ 24,000 | 12 mo X $1,500 = $ 18,000<br>12 mo X $1,200 = $ 14,400<br>12 mo X $ 800 = $ 9,600<br>$ 42,000 | $ 66,000 |
| SUBTOTAL | $126,000 | $174,000 | $300,000 |

APPENDIX C-4

TRAINING OF PERSONNEL

| YEAR | IN U.S. | IN C.A. | T/A BY U.S. PERSONNEL | TOTAL |
|---|---|---|---|---|
| 1 | 6 mo X $1,500 = $ 9,000 | 6 mo X $ 1,500 = $ 9,000 | 24 wk X $2,000 = $ 48,000 | $ 66,000 |
| 2 | 6 mo X $1,500 = $ 9,000 | 6 mo X $ 1,500 = $ 9,000 | 24 wk X $2,000 = $ 48,000 | $ 66,000 |
| 3 | 6 mo X $1,500 = $ 9,000 | 12 mo X $ 1,500 = $18,000 | 15 wk X $2,000 = $ 30,000 | $ 57,000 |
| SUBTOTAL | $27,000 | $36,000 | $126,000 | $189,000 |
| 4 | 6 mo X $2,000 = $12,000 | 6 mo X $ 2,000 = $12,000 | 15 wk X $2,400 = $ 36,000 | $ 60,000 |
| 5 | 6 mo X $2,000 = $12,000 | 6 mo X $ 2,000 = $12,000 | 15 wk X $2,400 = $ 36,000 | $ 60,000 |
| SUBTOTAL | $51,000 | $60,000 | $198,000 | $309,000 |