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SOLAR ENERGY - L-DIVISION MISCELLANEA

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May 27, 1976

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ABSTRACT

This report summarizes some of the capabilities that have been developed within L-Division related to the use of solar energy for heating of buildings, electrical generation and/or process heat. To date, these capabilities have been primarily directed towards studies related to the Sohio Process Heat Facility project. However, they would be applicable to a wide variety of solar energy projects, and therefore, are presented for information and review.

A stand-alone data acquisition system has been developed for the purpose of measuring instantaneous solar radiation and ambient air temperature. In addition, a compact, mobile calibration system is available to cross-calibrate solar instruments in-situ.

Solar radiation data has been collected and analyzed since January 1974. Data are available for total instantaneous insolation, total daily insolation and monthly-average total daily insolation.

Several computer codes are available for parametric performance studies of process heat facilities and calculating collection efficiency for a shallow solar pond.

Sources of information are listed including references to current LLL projects.

INTRODUCTION

Since calendar year 1973, L-Division personnel have been involved in the study of solar energy and its use for electrical power generation,¹ solar heating and cooling² and industrial process heat.³ In the fall of 1974 a no-funds-exchanged contract was signed by the AEC (now ERDA) and the Sohio Petroleum Company for a program to design and build a shallow solar pond water heating facility for a uranium mining and milling complex.^{4,5} In support of this project, a wide variety of solar energy related capabilities have been developed. These capabilities provide data and/or performance analysis information through the use of computer simulation that have proved useful to the designers of the shallow solar pond system.

The principal capabilities available include:

- A solar energy instrumentation system for instantaneous insolation and ambient air temperature measurements.
- A calibration system for cross-calibration of in-situ pyranometers.
- Computer program 'SOLAR'⁶ - A code used to calculate the long-term collection efficiency of a flat plate solar energy collector.
- Computer program 'SOHIO'⁷ - a code used to calculate the total solar heat collected daily by a shallow solar pond.

Insolation data base - since January 1974, instantaneous total insolation data have been collected, analyzed and stored on the OCTOPUS system. Daily and monthly-average daily data have been processed and tabulated.

The data base and the computer codes have been used extensively in performance analysis and system design for the process heat facility and an energy conversion system for electrical generation. In addition, these same capabilities have practical application to the design of solar heating and cooling systems.

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INSTRUMENTATION - SOLAR RADIATION MEASUREMENTS

We have designed and built an instrumentation system for measuring and recording instantaneous total solar radiation and ambient air temperature. The system consists of the following components:

- Eppley black and white pyranometer - a sensor for measuring the total solar radiation (direct + diffuse).
- Yellow Springs Instruments thermistor - a sensor for measuring ambient air temperature.
- An LLL control and calibrate sub-system - a master timer/calibration system to initiate 1) a calibration sequence and 2) data recording.
- A Leeds-Northrup strip-chart recorder - the insolation and temperature data are recorded on strip charts for later digitizing and data processing.

This data acquisition system is currently assembled in the L-Division Analog Data Center. The pyranometer and thermistor are located on the roof of Building 121.

INSTRUMENTATION - CALIBRATION SUB-SYSTEM

We have designed and built a compact, mobile instrumentation system that can be used to cross-calibrate in-situ solar radiation sensors. The system consists of the following components:

- A working standard Eppley black and white pyranometer mounted in a traveling case.
- A battery powered digital voltmeter to record the measurements also mounted in a traveling case.

To date we have used this system to verify the calibration of the various LLL instrumentation systems. Recently, we completed a cross-calibration check with the Lawrence Berkeley Laboratory. Our standard pyranometer agreed to better than 5% with the LBL Eppley Precision Spectral Pyranometer.

PROGRAM 'SOLAR'

In order to evaluate and predict the performance of solar energy collectors it is necessary to calculate the collection efficiency, defined as the useful heat collected divided by the solar radiation incident on the top surface. Techniques for this calculation have been described in the literature.^{8,9} Generally, these techniques have required an hour-by-hour analysis of each collector at each location of interest. We have chosen to use a simpler procedure based on readily available long-term average local solar and weather data.¹⁰ We have completed a first-order prediction code for calculating the long-term average performance of flat plate solar energy collectors. Provisions for various input parameters are available that allow collector performance to be evaluated for:

- Geographic location
- Collector tilt
- Number and type of cover surfaces
- Weather factors, such as wind speed, air temperature

The program allows users to calculate collector efficiency at specific locations and evaluate parameter effects specific to their needs.

The program has been used to compare results with those obtained with the more precise procedure requiring hourly data.¹¹ The intent was to study the feasibility of providing a performance handbook for solar heating systems using a simpler and easier to use design procedure. The program has also been used extensively to provide average-hourly solar radiation and collector transmittance-absorptivity input for design simulation of the process heat facility.

PROGRAM 'SOHIO'

Analysis of the use of solar energy in a specific application can be time consuming and expensive. Computer simulation and modeling codes can provide designers first-order design parameter information and means for studying the effects of specific parameters on system performance. As such, the codes could be used to identify the design variables which are most crucial to the application involved. Furthermore, the codes can be used in conjunction with and as a supplement to experimental techniques.

In this manner, we have designed and developed program SOHIO. This code is used to calculate the efficiency of a shallow-solar-pond heating facility in terms of the solar excitation function, the ambient air temperature, and the physical properties of the pond system. The analysis simulates a continuous flow mode in which water circulates through a shallow solar pond continuously until a final drain period or a batch mode where the pond is filled, allowed to heat and drained. A wide variety of input parameters can be varied to study their effects on the final system performance.

We have used the code in the design of the SOHIO Solar Process Heat Facility.^{3,4} In addition, we have compared code results with experimental measurements and found excellent agreement.⁴

SOLAR RADIATION DATA BASE

Effective use of solar energy in specific applications generally requires detailed records of such information as insolation, ambient air temperature, windspeed, etc., for the location of the collector. These records can provide the data input to precise simulation codes using instantaneous data or for the design procedure using long-term average information.

Solar radiation data has been collected, processed and stored on the Lawrence Livermore Laboratory OCTOPUS system since January 1974. Instantaneous measurements of the total radiation on a horizontal surface are

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available. In addition, the data has been processed to provide daily and monthly-average-daily information. Computer generated graphs and printouts can be made available from these data bases as required.

COMING ATTRACTIONS

Instrumentation -

We have recently purchased a CAMAC instrumentation system to interface to the pyranometer/thermistor and controlled by a DEC PDP-11 computer located in the Analog Data Center. We plan to provide a software system that will simplify our current method of data acquisition and processing. It is expected we can complete this effort by December 1976.

Recently, we met with Bay Area Pollution Control District personnel for the purpose of investigating calibration methods for ~ 15 Bay Area solar instrumentation locations. We would hope to participate with the BAPCD in their cross-calibration program using our mobile calibration facility.

We plan to continue our current procedure of cross-calibration of LLL solar instrumentation systems indefinitely.

Computer Programs -

We will continue to modify/update our current computer codes to provide further capabilities for simulation and modeling. In addition, we expect to develop new codes for modeling other solar energy systems. We have recently received from the University of Wisconsin their computer code TRNSYS. This code is a simulation program for transient thermal performance of solar heating and cooling systems. The code consists of a controller and a set of user specified modules that closely parallel an actual experimental system. The modules include collectors, controllers, storage tanks, heating exchangers, furnaces, building loads, etc. It is expected the code will be operation by September 1, 1976.

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Data Base -

We will continue to expand our insolation data base for the indefinite future. We plan to add an ambient air temperature data base beginning June 1, 1976.

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