CEER-26

SOLAR THERMAL SYSTEM TEST FACILITY

FOR LOW AND MEDIUM TEMPERATURE RANGE

PROPOSAL TO THE DEPARTMENT OF ENERGY'S
NORTHEAST REGIONAL APPROPRIATE TECHNOLOGY PROGRAM

SOLAR TECHNOLOGY DIVISION
CENTER FOR ENERGY AND ENVIRONMENT RESEARCH
UNIVERSITY OF PUERTO RICO
MARCH 1979

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ENDORSEMENTS:

Ugur Ortabasi — 3/29/79
DR. UGUR ORTABASI, HEAD, SOLAR TECHNOLOGY DIV. — DATE

Juan A. Bonnet, Jr.
DR. JUAN A. BONNET, JR., DIRECTOR, CEER — DATE

SOLAR THERMAL SYSTEM TEST FACILITY FOR LOW AND MEDIUM TEMPERATURE RANGE

Prepared by: Solar Technology Division
Center for Energy and Environment Research
College Station
Mayaguez, Puerto Rico 00708

Project Site: Center for Energy and Environment Research
Carretera 108, Km. 1.3
Bo. Miradero
Mayaguez, Puerto Rico

Telephone: 809-832-1414

Total Funding Requested: $41888

This project is a development project in the area of solar process steam and solar hot water.

The Center for Energy and Environment Research is a part of the University of Puerto Rico, a public institution of higher learning.

Solar Division, CEER

I. PROJECT OVERVIEW

As part of its research and development program in medium temperature solar thermal energy systems, the Solar Division of the Center for Energy and Environment Research of the University of Puerto Rico (CEER), proposes to build a test facility for such systems. The main objective of this project is to achieve the capability of doing detailed and precise measurements of the efficiency of solar thermal systems in a tropical environment. This unique test facility in the Caribbean will offer the opportunity to study low to medium temperature (140°F-550°F) solar collector systems under operating conditions. The funding requested for this project will be utilized to install, test and operate the thermal loop designed previously at CEER.

The proposed test facility has been designed after studying the experience of other researchers with similar facilities in the United States. Many of the problems encountered by them have been eliminated in our design.

Fuel costs for the production of hot water and low pressure, medium temperature (350°F) steam for domestic and commercial use in Puerto Rico can be conservatively estimated at $150 M per year. The Solar Division of CEER is engaged in an active research program to develop cost effective systems which can fill this energy need with a renewable, local, non-polluting resource.

An experimental test facility is indispensable for the evaluation of prototype systems and for the eventual development of systems which are best suited to the climatic conditions prevalent in Puerto Rico.

II. BENEFITS FROM THE PROJECT

The Center for Energy and Environment Research of the University of Puerto Rico was established on July 1, 1976, under an agreement between the President of the University and the U.S. Energy Research and Development Administration, now a part of the U.S. Department of Energy. CEER has as its main goals: (1) to help Puerto Rico achieve energy independence by serving as the Island's focal point for energy research; (2) to help Puerto Rico develop scientific, engineering and other trained personnel in the energy and environmental fields.

The Solar Technology Division of CEER is engaged in an active, on going research program which includes, among others, measurement of solar insolation, computer simulation of thermal systems, and design and development of concentrating collectors. At this point in the program, a strong need is felt for an experimental test facility which will provide detailed, precise data on the performance of solar thermal systems in a tropical environment. This data is indispensable for the continuation of the research program in thermal systems.

The Solar Technology Division of CEER has identified thermal systems (in particular hot water and medium temperature steam systems) as one of its focal areas of research. The main reason for this decision is the potential for a substantial impact on fuel use within a relatively short development period. In Puerto Rico, fuel costs for such systems amount to at least

$150 M per year (15% of all fuel use). The technological feasibility of using solar systems for these applications has already been well established. The main challenge lies in developing efficient, low cost systems.

Besides providing basic efficiency data, the test facility will be used to test system materials and reliability. It will also provide long-term performance data which is a very important consideration in system appraisal.

Another benefit from this project will be the educational opportunities it will provide to students at the U.P.R.'s School of Engineering. In the last two years 10 undergraduate students have worked or done projects in the Solar Division. The plans are to use students to help in the testing of solar collectors and systems. This represents for them an invaluable, hands-on experience in solar. For Puerto Rico it represents a growing number of professionals trained in the solar field.

In summary, this project deals with a renewable, locally-available, non-polluting resource, solar energy. The application involved represents a substantial percentage of the total energy needs of Puerto Rico and has a large potential impact on both the domestic and commercial markets. The proposed test facility will be an indispensable part of the research program of the Solar Division of CEER and will allow it to continue to meet its commitment as a research and educational institution working on behalf of the Commonwealth of Puerto Rico.

III. TECHNICAL DESCRIPTION OF PROJECT

The proposed solar collector test facility can be used for collectors having an aperture area of up to 5 m^2 (54 ft^2) at temperatures between ambient and 288°C (550°F). It will be a low pressure closed loop system using a liquid phase heat transfer fluid. The system will have a pumping station; heaters; flow, pressure, temperature, insolation, wind speed and direction monitors; cooler; filter; temperature controls; expansion tank and associated piping system. All data will be monitored and written on paper by means of a data logger.

The test station will be built on top of the machine shop at CEER's Mayaguez site. The monitoring station will be in a room at the machine shop directly under the loop where the test station will be constructed.

The testing loop configuration is shown in Figures 1 and 2.

A. Instrumentation

1. Solar radiation measurements will be made by a pyranometer and a pyrheliometer.
2. Temperature measurements will be made by platinum resistance thermometers (RTD) and J type iron-constantan thermocouples (TC).
3. Liquid flow rate measurements will be done by two different types of flowmeters and will be checked against each other. A turbine type and a strain gage type flowmeter will be used.

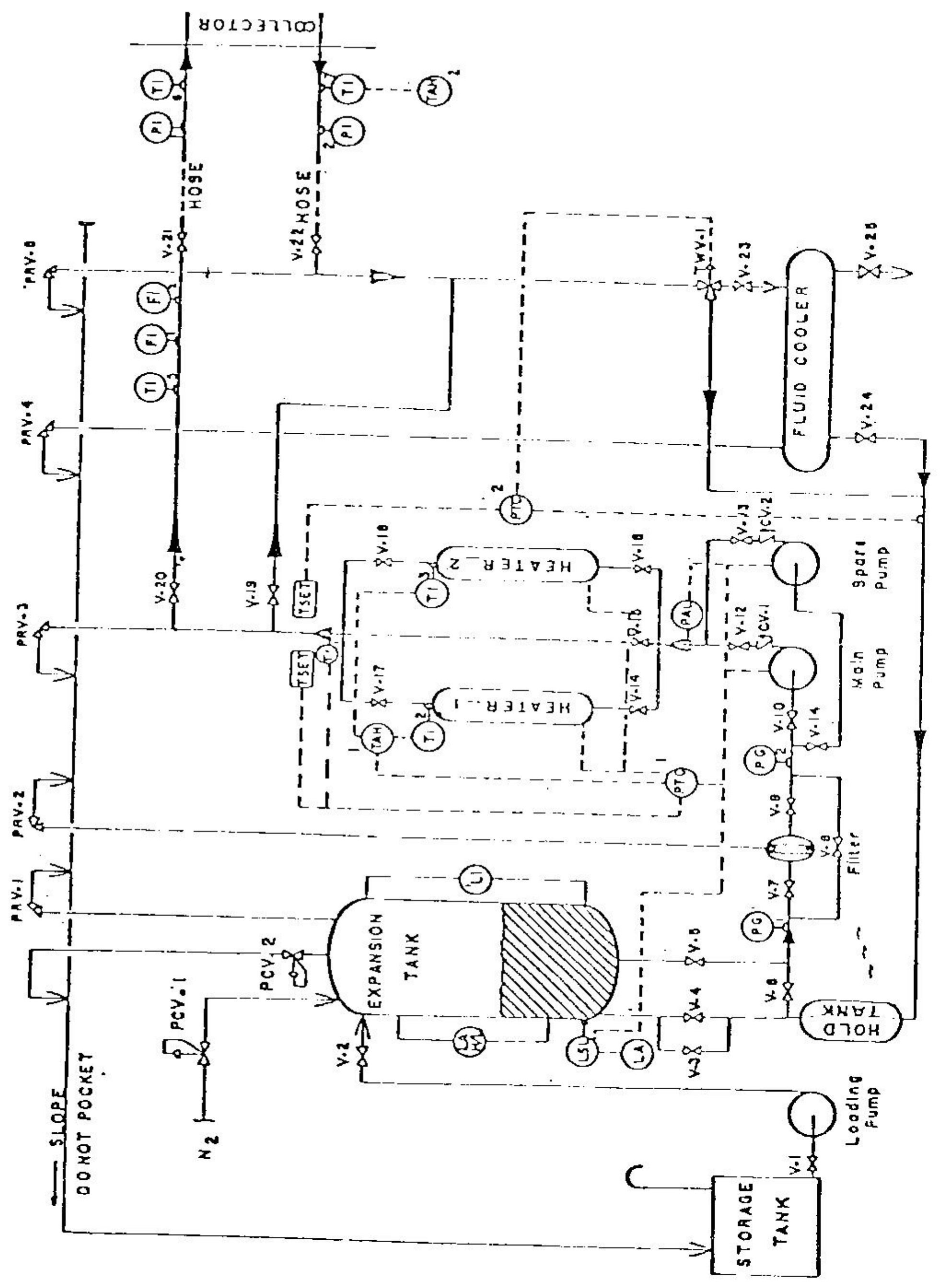

STORAGE TANK
Loading Pump
EXPANSION TANK
HOLD TANK
HEATER 1
HEATER 2
Main Pump
Spare Pump
Filter
FLUID COOLER
COLLECTOR
HOSE
HOSE
SLOPE
DO NOT POCKET
N2
PCV-1
PCV-2
PRV-1
PRV-2
PRV-3
PRV-4
PRV-8
TSET
TSET

Figure 1

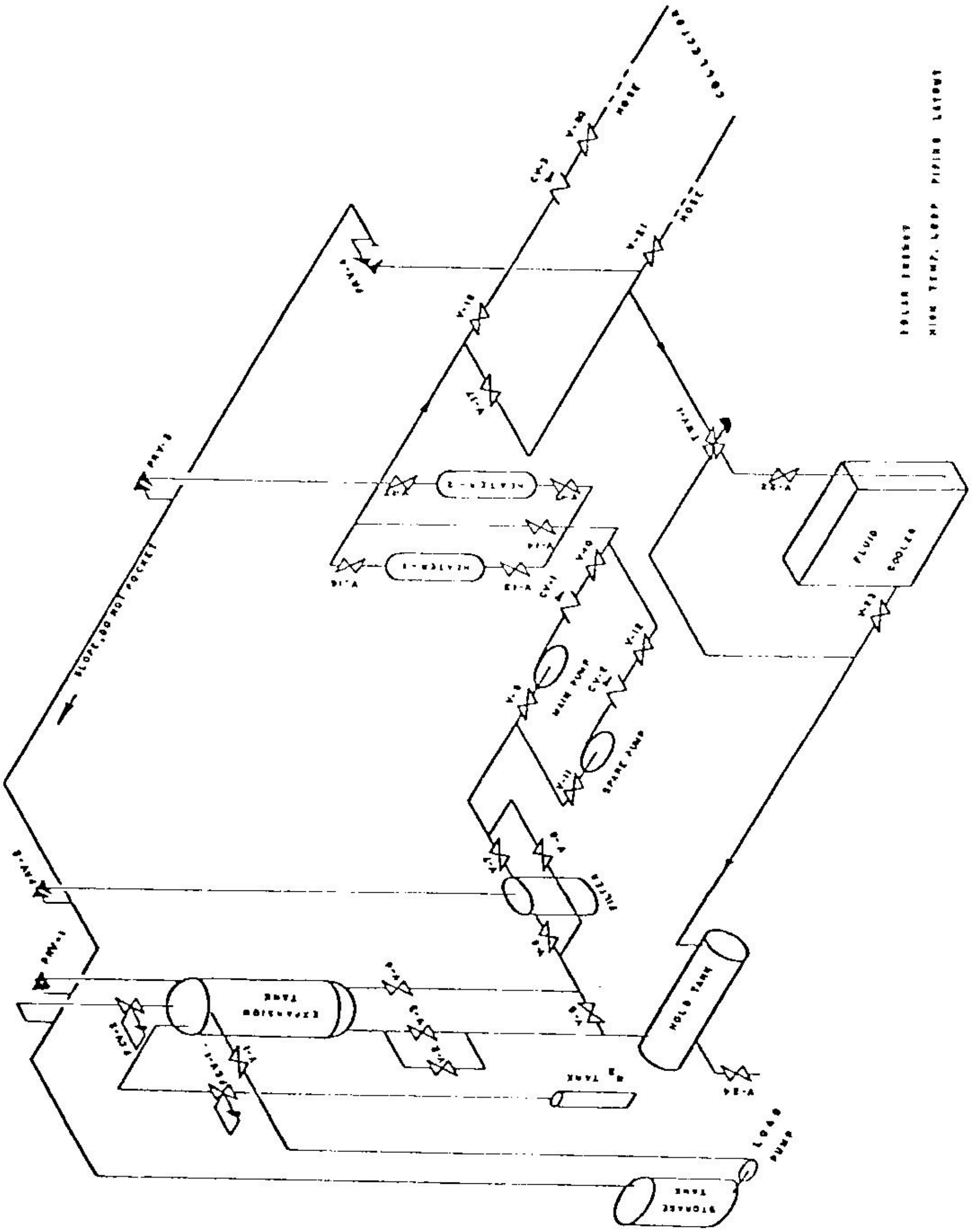

SOLAR ENERGY
HIGH TEMP. LOOP PIPING LAYOUT
COLLECTOR
HOSE
HEATER-1
HEATER-2
MAIN PUMP
SPARE PUMP
FILTER
EXPANSION TANK
HOLD TANK
STORAGE TANK
LOAD PUMP
FLUID COOLER

Figure 2

4. The pressure measurements will be made by bonded strain gage transducers.
5. The wind velocity and direction measurement will be made by electro-mechanical anemometers.
6. All data will be monitored by a data logger which is built around a microprocessor and printed on papertape. Individual monitoring equipment will also be used for flow, pressure and wind measurements.

B. Apparatus

The main function of the collector test loop is to feed the solar collectors under test with constant flow rate, constant temperature fluid. For a complete efficiency test, this loop supplies an input temperature between ambient and 288°C with a wide variety of flow rates from 0.025 to 2.5 liters per minute per square meter of collector.

The system will utilize Dowtherm A as a heat transfer fluid which is a composition of 73.5% diphenyl oxide, 26.5% biphenyl.

To avoid oxidation of Dowtherm A at elevated temperatures, the system will be kept under nitrogen gas blanket at 50 psi.

A 50 micron size wire mesh strainer filter will be put in the system to ensure contamination free liquid and elongate pump life. Two pressure gauges will serve for the filter cleanliness indication.

The pumps will circulate the liquid in the system and through collectors. They will be selected as stainless steel gear pumps with high temperature packings.

Four 500 watt, on-line heaters will be used to heat the liquid to desired temperatures. Due to thermal shocking limitations, they are specially selected as low watt density ($20W/in^2$) firerod immersible heaters. The heating elements will be controlled by a solid state digital proportional controller in order to keep the inlet temperature to the collector within a very narrow deviation range.

The two flowrate measuring devices will be on the final line to the solar collector and a temperature measuring RTD will be supplied at this point in order to make necessary corrections due to physical property changes of the fluid with temperature.

To supply flexibility to the system, the connections to collectors will be made by teflon lined, stainless steel, braided hoses. Inlet and outlet temperatures and pressure measurements across the collector will be done as close as possible to the collector. Two platinum RTD's and two pressure transducers will be located at inlet and outlet of the collector.

To simulate a load, a 2.5 KW heat rejection capacity, air-cooled, fluid cooler will be used. The amount of temperature drop, i.e. heat removal, will be controlled by a proportional temperature controller where the final element will be a three way valve.

To stabilize the flow rate and to prevent oscillations, a 40 liter hold tank will be used.

The expansion tank will serve as a main ventilation point for the system. It will be sized such that it is one-quarter full at ambient temperature and three-quarters full at 260°C.

Loading of the system will be accomplished from the storage tank by a small load tank where this tank also acts as a catchpot for the system.

Valves, check valves, and pressure relief valves will be all selected for high temperature usage and located as shown in Fig. 1. All relief valve exits will be collected at a common pipe to avoid spilling of fluid to the working area which can be hazardous to workers.

C. Controls

The level control of the expansion tank will serve as a level gauge and a low level alarm switch. Any leakage from the system can be detected by this control.

A low level alarm will automatically turn off the pumps and electric heaters and an audio alarm system is triggered.

A pressure alarm switch which will detect a loss of flow will be put after the pumps. This condition will turn on the spare pump and turn off the main pump.

The first proportional temperature will control the heaters as mentioned in the previous section. Two thermocouples located at the exit of the heaters will be used as high alarms to avoid boiling of the heat transfer fluid. In such a case, power to the heaters will be shut off.

Another high temperature alarm will become effective if the collector outlet fluid temperature exceeds the preset limits. This alarm will result in an audio alarm which necessitates shading of the collector.

A proportional temperature controller will control the temperature of the fluid which goes to the hold tank. The amount of cooling is adjusted by the three way valve which diverts the fluid proportionally to cooler and by pass.

D. Data Collection

Monitor Lab. Model 9300 Data Logger will be used to monitor and record system outputs.

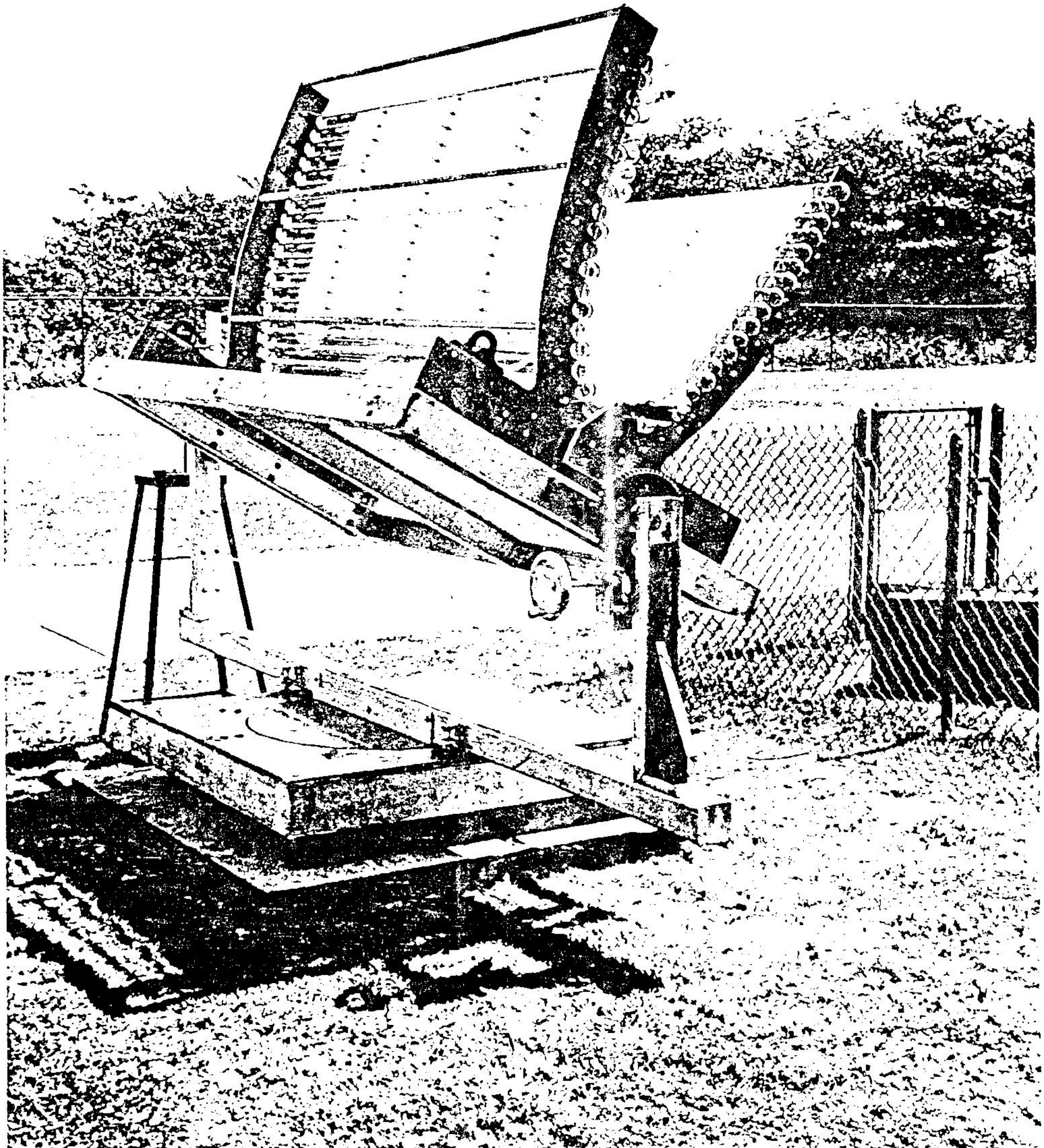
This data logger has the capabilities of scaling, averaging, converting TC and RTD outputs to °C or °F, alarming, scanning etc. With its 60 channels it can handle all the data to be recorded or monitored.

All instrumentation will fullfil the requirements of ASHRAE STANDARDS No. 93-77, No. 41.8-78, No. 41.1-74.

Future Plans

The proposed system will constitute an unique opportunity to test and evaluate low to medium temperature solar collector systems in Puerto Rico and the Caribbean.

Although the system is suitable to test solar water heaters, its main purpose is to evaluate solar process heat collectors. As a part of its program, the Solar Division is now developing a series of prototypes suitable for operation in the tropical environment. The photograph on the next page shows one of the prototypes recently developed by CEER. Plans call for testing of other collectors developed in the U.S.A. and elsewhere. Comparative testing of these collectors will supply the data to determine the most cost effective type that can be applied to Puerto Rico's needs.



Solar Division, CEER

IV. QUALIFICATIONS OF KEY PERSONNEL

A. Dr. Angel Mario López Berríos, Project Manager

Dr. López has a B.S. degree in Physics from the University of Puerto Rico and an M.S. and Ph.D. in Physics from the University of Massachusetts. His doctoral thesis was in experimental particle physics. He has been working in the solar energy field for the last two years and was appointed as a Scientist at CEER in September, 1978.

B. Mr. Levent Ozakçay, Graduate Student

Mr. Ozakçay obtained a B.S. in Chemical Engineering from the Middle East Technical University in Ankara, Turkey. He has been working in the Solar Energy Division of the Mineral Research and Exploration Institute of Turkey for the last 3 1/2 years. During 1977, Mr. Ozakçay worked with the Solar Energy Group at Argonne National Laboratory, Chicago, Illinois on an United Nations Fellowship.

C. Dr. Ugur Ortabaşi, Consultant

Dr. Ortabaşi did undergraduate and graduate studies in Physics at the Universities of Gottingen and Hamburg, Germany. He received his Ph.D. from the University of Florida in the area of Nuclear Physics. His work in the solar field dates to 1973 when he became Senior Physicist at Corning Glass Works and served as Technical Leader of the Solar Energy Program there. His work has included the theory, design and experimental testing of evacuated collectors and he is recognized internationally as an expert in this field. Presently, he is a Senior Visiting Research Scientist and Head of the Solar Technology Division at CEER.

D. Dr. Kenneth G. Soderstrom, Consultant

Dr. Soderstrom received BSME, MSE and Ph.D. degrees from the University of Florida. He has been a member of the Mechanical Engineering Faculty of the University of Puerto Rico since 1961. During the last five years, Dr. Soderstrom has been engaged in research in the measurement of solar insolation, in the computer simulation of solar thermal systems and in the testing of solar collectors. He has also served as a consultant to government and private industries in energy related problems. Presently, he is Associate Director of CEER's Mayaguez site and has an appointment as Senior Scientist and Project Director in Solar Technology.

V. SCHEDULE

Months after adjudication date

Activity	1	2	3	4	5	6	7	8	9	10	11	12
Order Materials	S/*	* *	* *	*/E								
Receive Materials		S/*	* *	* *	*/E	-						
Construction					S/*	* *	* *	* *	* *	*/E		
Testing											S/E	
Report												S/E

S = Starting date of activity

E = Ending date of activity

* = Continuation of activity

- = 15 days noncritical path

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BUDGET

Total Funding Requested $41888.00

		Hrs/week	Total weeks	$/hr.	Total
1.	Salaries & Wages				
	Dr. A. López - Project Manager	8	48	$11.00	$ 4224.00
	L. Ozakçay - Grad. Student	35	48	3.93	6600.00
	Technician	20	24	5.20	2496.00
	Dr. U. Ortabaşi - Consultant	1	48	22.00	1056.00
	Dr. K. Soderstrom - Consultant	1	48	22.00	1056.00
					$15432.00
2.	Marginal Benefits				904.41
3.	Equipment				42177.00
4.	Materials				
5.	Rent				
6.	Supplies				
7.	Trips				
8.	Subcontractors				
9.	Other direct costs (400 hours of shop charges at $12/hr.)				4800.00
	Total direct costs				63313.41
10.	Indirect costs				5463.59
	Total cost of project				68777.00
	CEER/UPR Contribution to the project				26889.00
	Funding requested from DOE				41888.00

Solar Division, CEER

MARGINAL BENEFITS
(Budget Item # 2)

Benefit	Amount
Social Security (FICA)	$ 411.93
Retirement	295.68
Workmen's Compensation	100.80
Medical Insurance	96.00
Total	$ 904.41

Note: These were calculated following the usual CEER formulas.

COST BREAK-DOWN FOR EQUIPMENT

(Budget Item #3)

#	ITEM	Qty.	UNIT PRICE	COMPANY	SPECIFICATIONS	AMOUNT	CONTRIBUTION OF CEER
1	Data Logger	1	$8675.	Monitor Labs. Inc.	Model 9300, 60 channel	$	$8675.
2	Pyranometer	1	990.	Eppley Lab.	Model PSP Precision Spectral Pyranometer		990.
3	Recorder & Anemograph	1	10714.	Kahlsico Intl. Co.	02AM290 electro-mechanical anemograph & recorder		10714.
4	TC exten.wire		798.	Omega Eng. Inc.	NN-J30 Iron constantan extension wire (6000 ft.)		798.
5	Platinum RTD	5	67.	Omega Eng. Inc.	PR-12-2-100-1/4-2-E RTD Thermowells	335.	
6	J Type TC'S	6	37.50	Omega Eng. Inc.	NBI-ICSS-14V-2 J type TC wells	225.	
7	Probes for #6	6	32.50	Omega Eng. Inc.	As in item # 6	195.	
8	Flowmeter	1	756.	Flow Tech. Inc.	Omniflo turbine flowmeter	756.	
9	Readout meter	1	700.	Flow Tech. Inc.	PRI-102D readout meter for item 8	700.	
10	Amplifier	1	186.	Flow Tech. Inc.	LFA-307 range extending amplifier for item 8	186.	
11	Flowmeter	1	639.	Ramapo Intl. Co.	Mark V Strain gage linear flowmeter	639.	
12	Reaout meter	1	897.	Ramapo Intl. Co.	SGA350 RMD Digital readout meter for item 11	897.	
13	Pressure transducer	2	525.	Teledyne Taber	Model 254 0-100 psi strain gage transducer	1050.	
14	Electrical plugs	2	15	Teledyne Taber	Model 10-281165-2S for item 13	30.	
15	Readout meter	1	195.	Statham Inc.	Model BCR 1-0 readout meter for item 13	195.	
16	Level meter	1	800.	Inventron Ind.	Model PC15 Ultrasonic level controller 3 alarms	800.	
17	Flow switch	1	142.	Gems Sensor Div.	Series FS 10798 P/N 25364 flow detector switch	142.	
18	Prop. Temp Cont.	1	330.	Barber Colman Co.	Model 526Z Proportional Temperature Controller	330.	
19	Prop. Temp Cont.	1	439	Barber Colman Co.	Model 576X with digital setpoint & readout	439.	

COST BREAK DOWN FOR EQUIPMENT
(Budget Item #3)

#	ITEM	QTY.	UNIT PRICE	COMPANY	SPECIFICATIONS	AMOUNT	CONTRIBUTIO OF CEER
20	Pyrheliometer	1	$ 890.	Eppley Lab. Inc.	Model NIP Normal Incidence Pyrheliometer	$ 890.	
21	Equatorial Mount	1	1275.	Eppley Lab. Inc.	Equatorial Mount for item 20	1275.	
22	Pressure gauge	2	74.46	McMaster Carr.	Bourdon Type 316 SS case 100 psi No. 3904-K43	148.92	
23	Heat Exchanger	1	76.19	McMaster Carr.	No. 3525 N 12 Finned air cooled heat exchanger	76.19	
24	Hold tank	1	299.64	McMaster Carr.	No. 4146Y23 SS.316 15 gal. tank	299.64	
25	Expansion tank	1	261.45	McMaster Carr.	No. 4146Y22 SS 316 10 gal. tank	261.45	
26	Valves	30	63.93	McMaster Carr.	No. 4737 K 13 Forged steel ball valves	1917.90	
27	Relief valves	5	158.13	McMaster Carr.	No. 6871R11 SS 316 Factory set pressure	790.65	
28	Piping	100 ft	0.33	McMaster Carr.	1/2" SN 40 Seamless stainless steel piping	33.00	
29	Fittings			McMaster Carr.	Various SS fittings	500.00	
30	Load pump	1	143.33	McMaster Carr.	1/3 HP 1.62 GPM Gear pump No. 4272K1	143.33	
31	Electric heaters	4	114.80	Thermal Corp.	4 X 500 W firerod electric heater	459.20	
32	Dowtherm A	100gal	9.12	DowChem Co.	Dowtherm A heat transfer fluid	912.00	
33	Filter	1	200.00	AMF Cuno	50 micron size wire mesh strainer	200.00	
34	Hose	2	75.00	Comoco Tools Inc.	10 ft. 1/2" teflon lined SS. braided hose	150.00	
35	Pump	2	906.00	Lobee Pump Co.	4LOES, 3/4 HP SS High temp gear pump	1812.00	
36	Three way valve	1	1249.00	Foxboro Co.	V5310 High temp 3 way valve complete	1249.00	
37	Positioner	1	234.00	Foxboro Co.	E69PA-1 current to air positioner	234.00	
38	Check valve	3	30.00	J.P.& C. Incorp.	220 S-4PP spring loaded high temp	90.00	
39	Pressure Cont. Valve	2	86.00	Western Gas Co.	Two stage N_2 gas controller valve	172.00	

COST BREAK DOWN FOR EQUIPMENT

(Budget Item #3)

#	ITEM	QTY.	UNIT PRICE	COMPANY	SPECIFICATIONS	AMOUNT	CONTRIBUTION OF CEER
40	N_2 tank	2	$ 138.9	Western Gas Co.	100 lb. type H industrial liquid N_2 tank	$ 277.80	
41	Insulation	100ft	3./ft.	Owens Corning Co.	Kaylo 1/2" X 2" thick pipe insulation	300.00	
42	Insulation	$20ft^2$	$1.25/ft^2$	West Ref. Co.	1" thick Kaowool sheet insulation	25.00	
4[illegible]	Materials			Cesaní Hardware	wires, welding electrodes, bolts, nuts, tapes, etc.	863.92	
					Total equipment costs to be provided by DOE	$20,000	
					Total equipment costs to be provided by CEER	21,177	
					Estimated postage and handling	1,000	
					TOTAL equipment costs	$42,177	