An Overview of SERI Solar Thermal Research Facilities

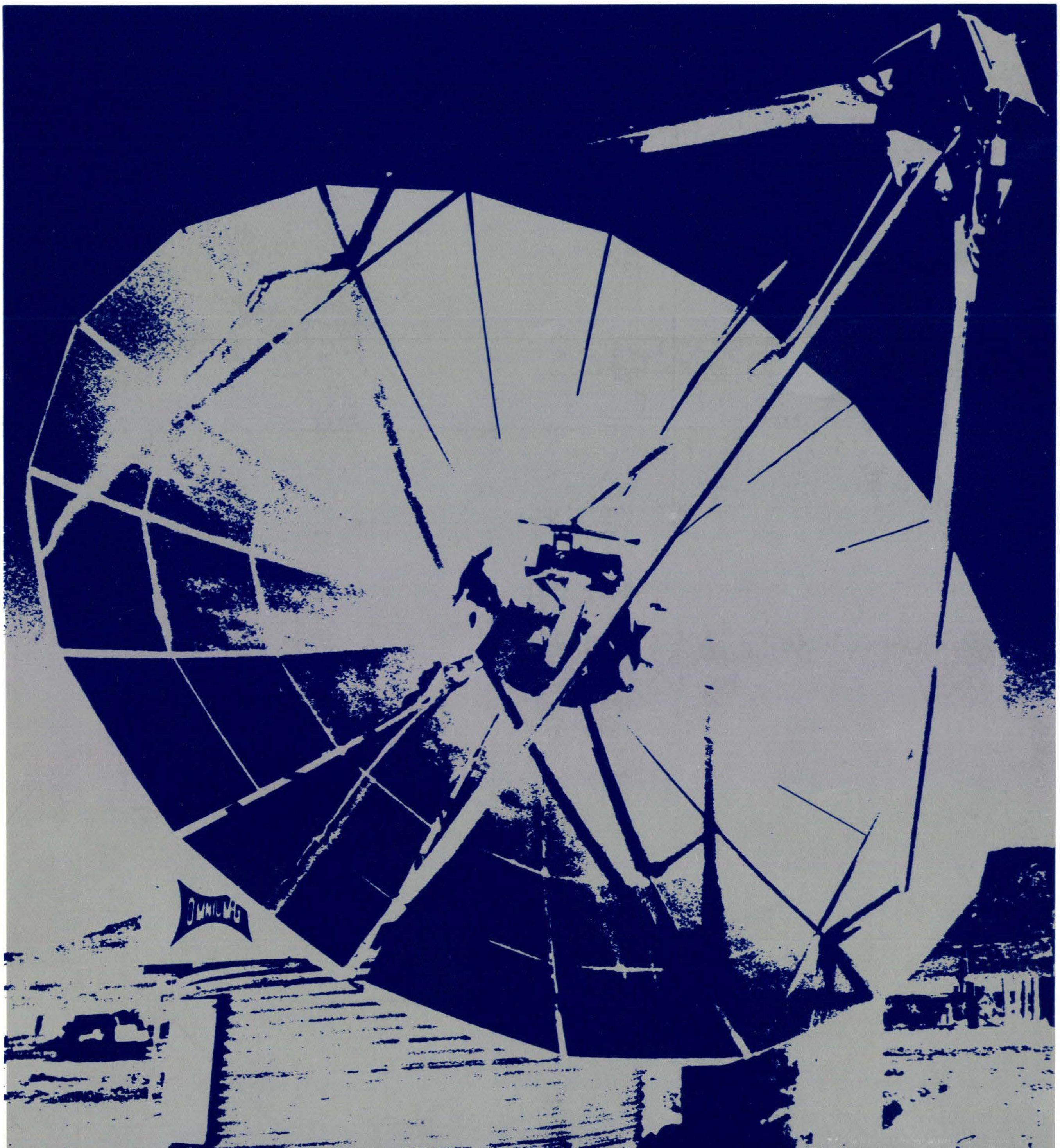
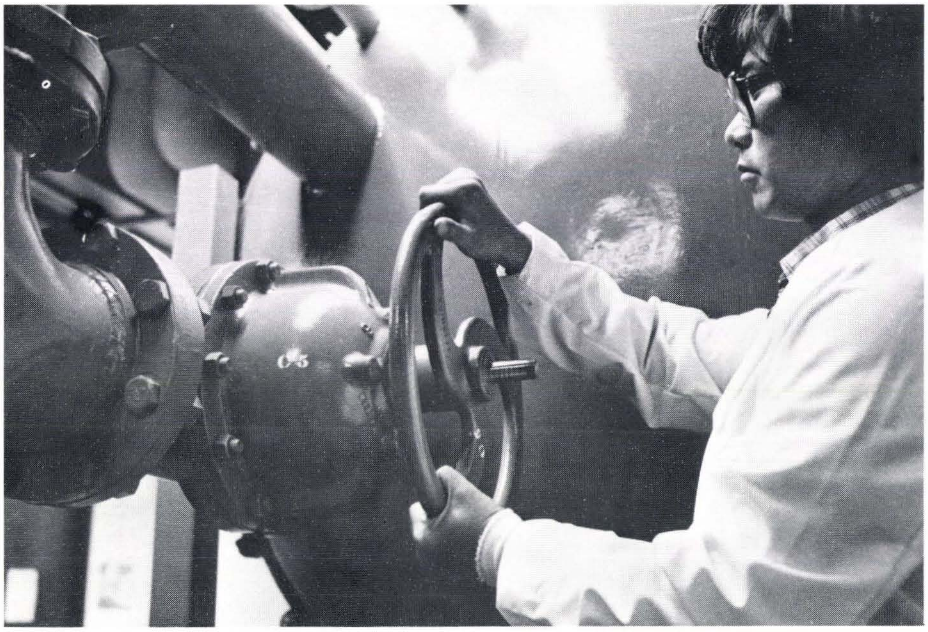


Table of Contents

Introduction



The Solar Thermal Research Branch grew out of the Thermal Conversion Branch which was formed on July 1, 1977, to conduct all solar thermal conversion research and development at the Solar Energy Research Institute (SERI). A part of this assignment was to design and build several laboratories and field stations dedicated to specific solar thermal technology thrusts. Four laboratories have been built at SERI and they are devoted to:

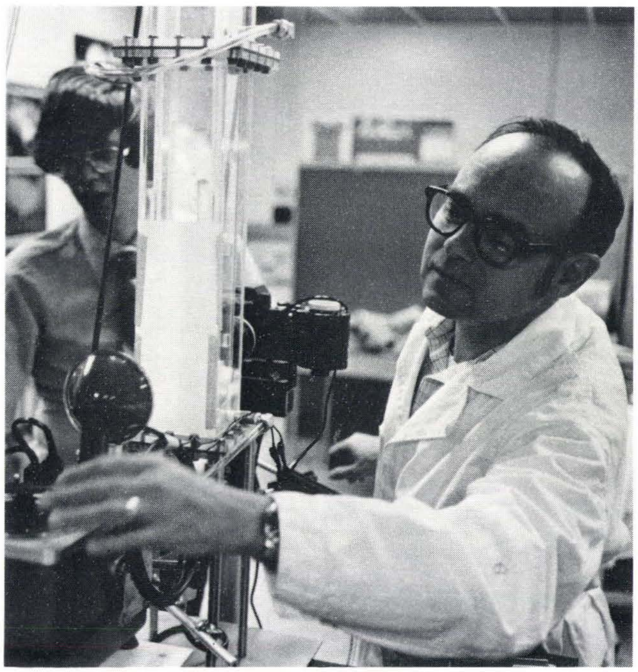
- solar thermal fuels and chemicals production research and development,
- direct contact heat and mass transfer research,
- solar cooling development, and
- thermal energy storage research.

The solar thermal conversion field station includes facilities for:

- advanced component research (ACRES),
- mid-temperature collector research (MTCRF), and
- solar energy research and applications in process heat (SERAPH).

During the SERI reorganization in 1980, the original Thermal Conversion Branch was split into a Solar Thermal Research Branch and a Solar Thermal Engineering Development Branch. Responsibility for SERAPH was transferred at that time to the newly formed Engineering Development Branch.

This report presents overviews of each of the four SERI in-house solar thermal research laboratories, as well as the ACRES and MTCRF field facilities which have been combined into a single unit called the Thermal Conversion Research Station. A brief description of the SERAPH facility, which has not yet been built, is also presented.



Solar Cooling Laboratory

Objective

Study various desiccant materials, grain sizes and bed geometries with regard to dynamic adsorption/desorption performance and required fan power. This will lead to a better understanding of which desiccant bed designs are best suited for solar regenerated cooling and dehumidification applications.

Capabilities

The Solar Cooling Laboratory contains a desiccant test loop designed to test a variety of full scale (1 to 1.5 ton range) desiccant beds. The test loop consists of a 12-inch diameter circular air duct section containing two 1-1/3 hp centrifugal fans, two electric duct heaters (6 kW and 35 kW), a 50-kW electric boiler, a test bed section and a variety of sensors. A schematic of the system is shown in figure 1. It is designed so that the air flow rate is in one direction for adsorption and the other direction for desorption.

Air can be supplied to the test section at the following conditions.

	Adsorption	Desorption
Flow Rate	0-600 SCFM	0-600 SCFM
Temperature (at max air flow)	70° F - 110° F	70° F - 250° F
Humidity (at max air flow)	ambient* -95%	9% - ambient*

*Humidity in the laboratory is typically below 30%.

The loop has been designed with maximum flexibility. Each fan has a two-speed motor and a stepped pully drive system which together allow for eight different fan speeds. The duct heaters are both SCR-controlled to permit any temperature setting within the range given above. Duct sections are connected by bolted flanges and are supported on moveable stands.

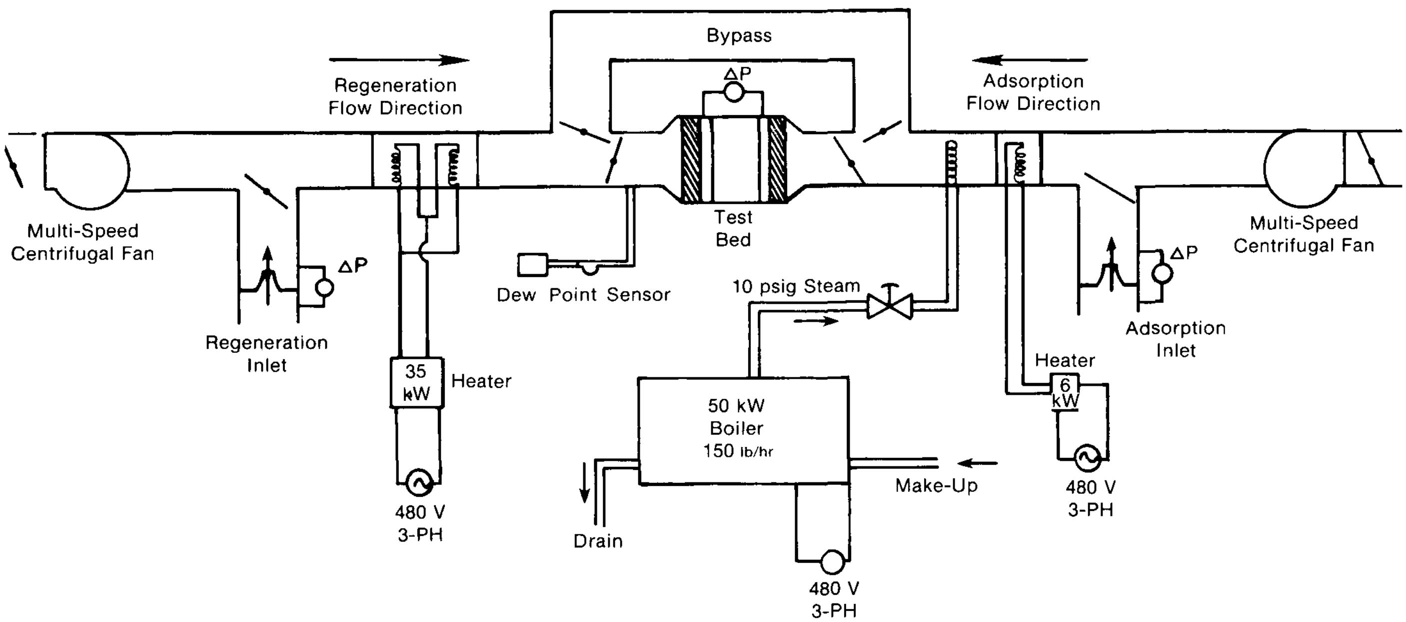


Figure 1. SERI Desiccant Laboratory

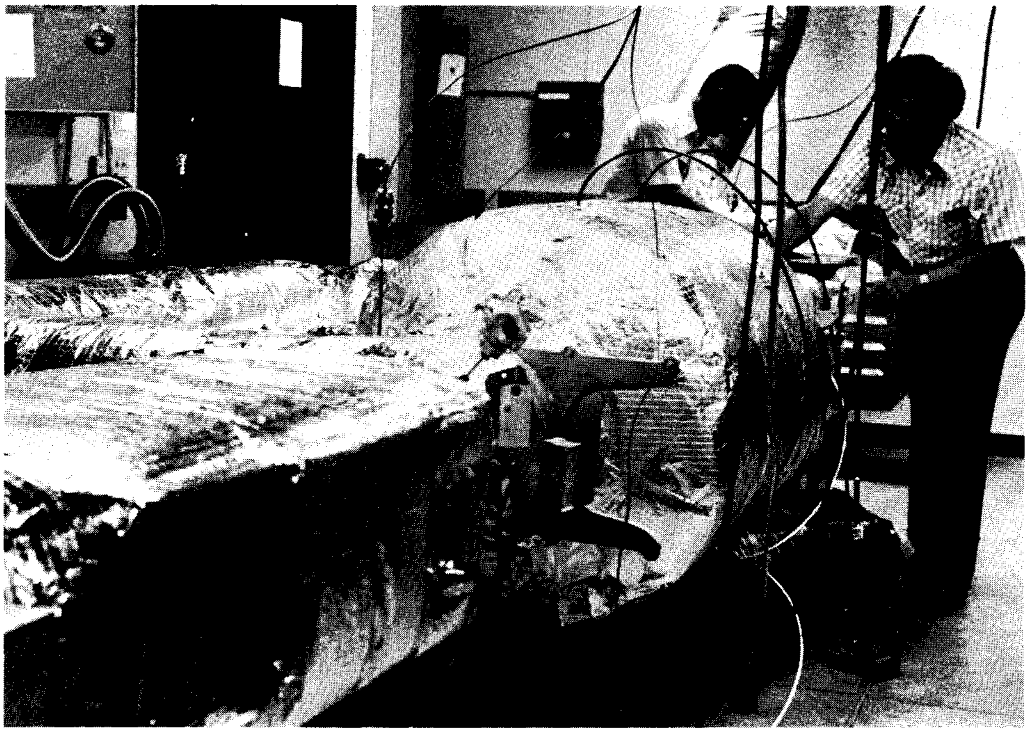


Figure 2.
The desiccant test loop is used to validate the results of various analytical models currently in use and to test new solar cooling concepts.

Instrumentation

Total flow rate through the loop is measured by capacitance type pressure transducers which monitor changes in pressure across five-inch ASME flow nozzles. Point velocity measurements are made with a hot wire anemometer. Temperatures are measured with T-type (copper-constantan) thermocouples. Humidity is determined with an optical condensation-type dew point hygrometer. Absolute pressure is measured with a sealed capacitance pressure transducer.

All sensor outputs are fed into a Kaye Digistrip-II data logger. This performs basic calculations (such as converting flow nozzle change in pressure measurements to flow rates) and outputs data in engineering units on a built-in, full page line printer. A number of digital panel meters are also used to provide visual data on temperatures, flow rates, and power supplied to the duct heaters.

Applications and Future Plans

The desiccant test loop, photographed in figure 2, became operational in April 1980. It has been operating since that time in a shakedown phase. A 1.25-inch thick, 29-inch diameter desiccant bed containing 8-10 mesh silica gel is currently being tested. This bed matches closely the desiccant portions of a chiller being developed by Airesearch Corporation. The heat and mass transfer results from this experiment will be used to check the validity and applicability of various analytical models currently in use. Furthermore, these tests results can be used to determine the applicability of chiller models when Airesearch will have test results from their complete chiller. The hardware is designed so that various bed depths and desiccant types and sizes can be tested. The result is a complete tool capable of validating models as well as evaluating new concepts.

Work will continue in the area of model validation. It is hoped that the basic physical models will be developed to the point where they can be expanded to include such things as laminar flow channels and composite beds. The viable future of desiccant cooling will definitely be tied to new desiccant materials in new and unusual geometries. It is felt that the apparatus described herein represents an important tool that allows researchers to optimize new materials and new configurations for solar desiccant cooling machines of the future.

Thermal Energy Storage Laboratory: Thermochemical Energy Storage

Objective

Define optimal thermochemical energy storage and transport systems for various temperature ranges, with emphasis on system efficiency and performance—particularly as a function of the chemical reactor design and operating conditions.

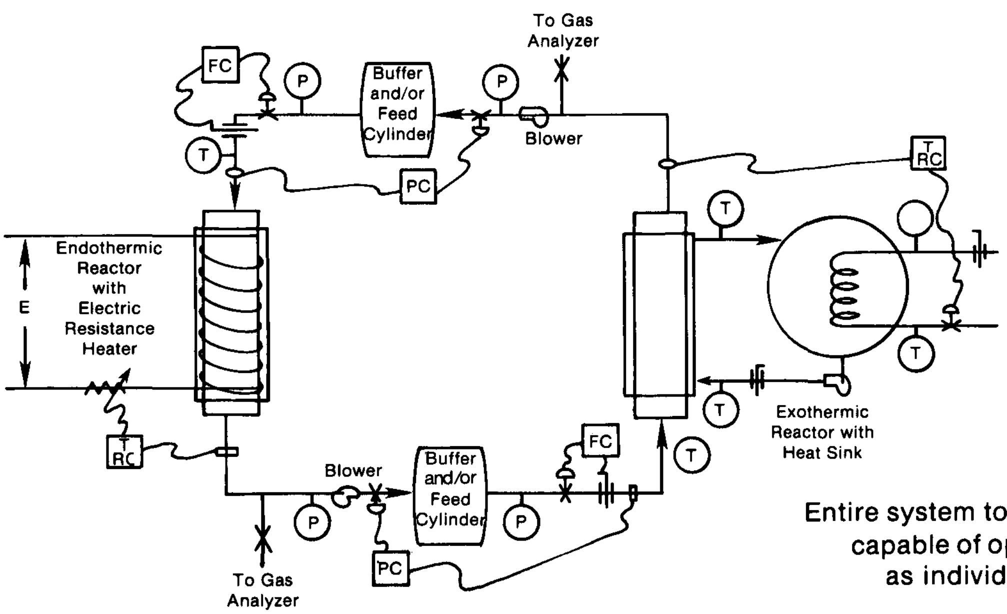
Capabilities

The laboratory facility will consist of equipment to study systems ranging from gaseous catalytic reactions, most useful for pipeline energy transport, to solid-gas reactions for direct thermochemical energy storage. Temperatures for these types of systems range from 350 to 650° C.

Catalytic gaseous reactions will be studied in a test loop, similar to that shown in figure 1, with the capability of operating endothermic and exothermic reactors as a system or individually.

The research facility will be used mainly to determine reaction rates and the extent of extraneous reactions. The results will be used to evaluate rate constants in fundamental kinetic models. This work includes measurement of the effects of diffusion, heat transfer, and reactor geometry on the reaction rates. Degradation of reacting species, catalyst, and reactor construction materials will also be investigated since they may affect the reaction rate. Facilities are being constructed to gather the information necessary to evaluate the economic potential of reversible reactions.

Figure 1(a).
Preliminary Schematic for Thermochemical Test Loop



Entire system to be well insulated. System to be capable of operation as an integrated unit or as individual reactors fed from cylinders.

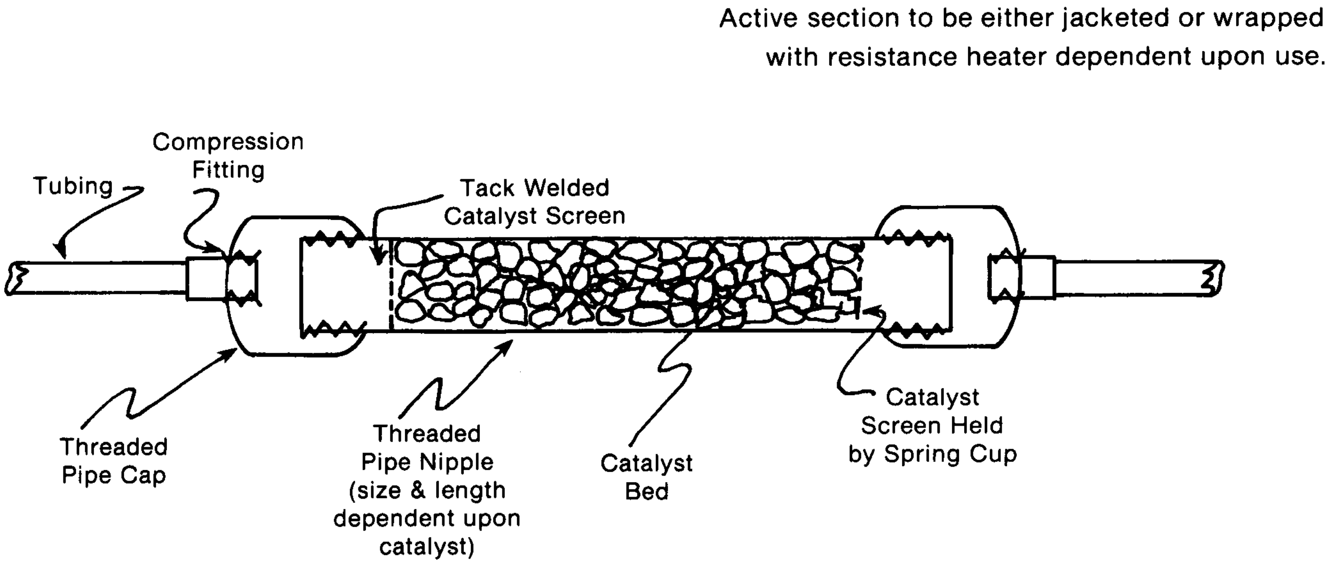


Figure 1(b).
Typical Catalytic Reactor

Instrumentation

Non-catalytic, solid-gas reactions will be studied through use of both a Sartorius model 4433 electronic vacuum microbalance and a DuPont model 990 Thermal Analysis System. Both systems are capable of extreme accuracy when working with small amounts of materials, i.e., micrograms to milligrams. The Sartorius microbalance is useful for reactions involving weight changes, and the DuPont system has the same capabilities and can determine a range of thermal properties including latent and specific heats. The thermochemical energy storage research facility will be fully instrumented with typical thermocouples, pressure indicators, flow indicators, temperature controllers, pressure controllers and flow controllers. A data collecting system is available with automatic calculation and control using the analogic Hewlett-Packard 9845 computer.

Gaseous composition will be measured by gas chromotagraphy. The DuPont Thermal Analysis System includes a microcomputer for detailed, automatic calculations to aid interpretation of results. Various experimental items are in either the planning or procurement stage, but several experiments will be conducted in FY80.

Fiscal Year 1980 Experiments

The primary emphasis of FY80 experiments will be on solid-gas reactions using the Sartorius microbalance and the DuPont Thermal Analysis System. A reactor system will be constructed to study catalytic gaseous reactions.

The following systems will be studied during FY80, with emphasis being placed on the first system.

$$Ca(OH)_2 \rightleftarrows CaO + H_2O$$

$$CH_4 + CO_2 \rightleftarrows 2CO + 2H_2$$

$$SO_3 \rightleftarrows SO_2 + 1/2\ O_2$$

Publications

- **A Review of Collector and Energy Storage Technology for Intermediate Temperature Applications;** Solar Energy, 1980; C. E. Wyman, J. N. Castle, F. Kreith
- **Thermal Energy Storage for Solar Applications: An Overview,** March 1979, C.E. Wyman, SERI/TR-34-089

Thermal Energy Storage Laboratory: Direct Contact Heat Exchange

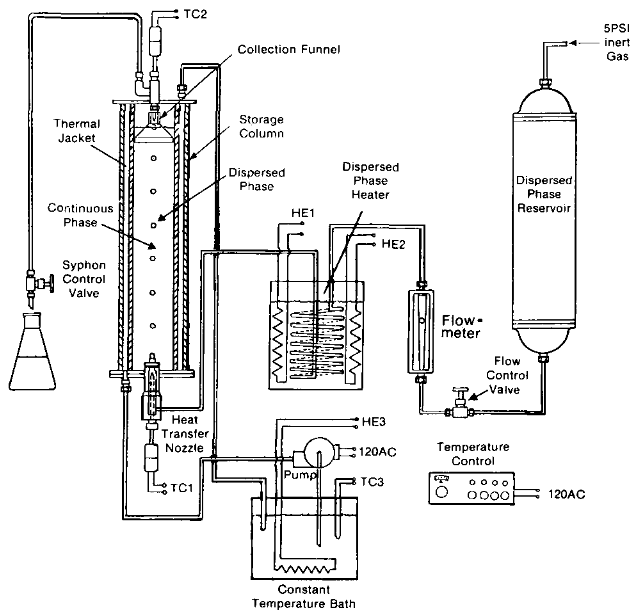
Objectives

Achieve a quantitative understanding, based on fundamental physical principles, and examine the operational problems of direct contact storage systems. Such knowledge will lead to better designed and more efficient storage systems for a variety of solar applications.

Capabilities

Experiments in the Thermal Energy Storage Laboratory are capable of independently measuring the three parameters controlling heat transfer in direct contact heat exchange: drop size, heat transfer mechanism, and dispersed phase holdup. The single-drop experiment injects a heat transfer oil through a single nozzle into an aqueous continuous phase (water or salt hydrate). Flow rates are on the order of 1 cm^3/sec. The multi-drop experiment is essentially a pilot scale storage unit. Oil is injected into the continuous phase at any desired temperature. The dispersed phase flow rate ranges from 0 to 2.5 kg/min. Both experiments are capable of working over a temperature range of 0 to 90° C, and are constructed of glass to allow the experimenter to view the processes. Schematic diagrams of both the single-drop and multi-drop experiments are shown in figures 1 and 2. The multi-drop experiment is photographed in figure 3. Figure 4 shows the single-drop column.

Figure 1.
Single-Drop Heat Transfer Column



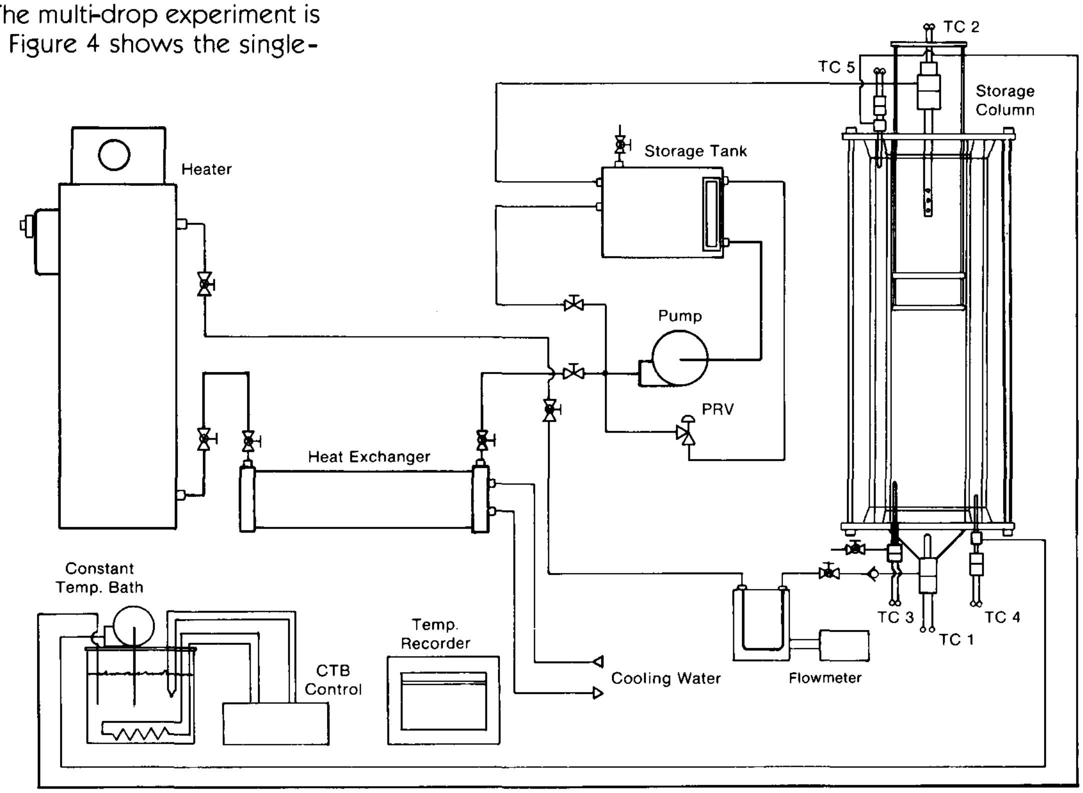
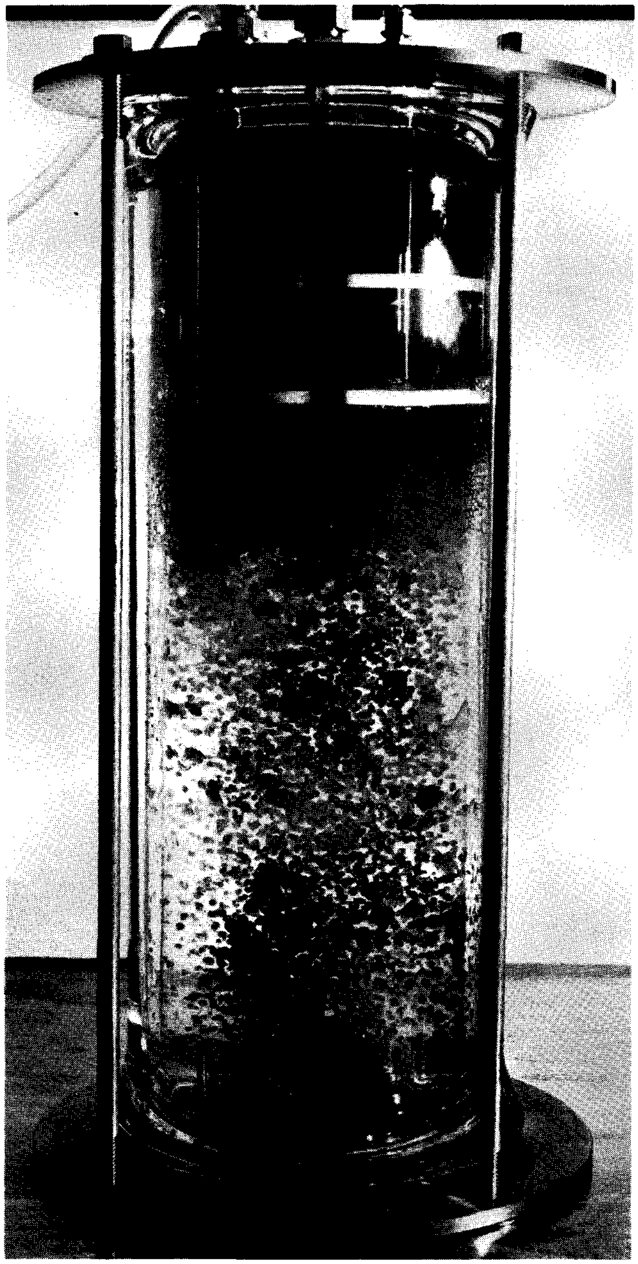


Figure 2.
Multi-Drop Heat Transfer Column

Instrumentation

Both heat storage columns are equipped with T-type thermocouples to measure the inlet and outlet temperatures of the dispersed phase and continuous phase. In the single-drop experiment, flow rate is measured with precision rotometers. Dispersed phase flow rate in the multi-drop apparatus is measured with a Micro-Motion mass flowmeter. Provision exists to monitor temperature with precision thermistors and to record data with a Hewlett-Packard 9845 minicomputer and an analogic interface.

Figure 3.
The multi-drop column is used to study flow patterns, droplet interactions, and practical operating phenomena of direct contact heat transfer.



Fiscal Year 1980 Experiments

The single-drop experiment is being used to determine the mechanism limiting the heat transfer rate between the dispersed and continuous phases and to measure dispersed phase drop diameter as a function of drop nozzle diameter, flow rate, and fluid physical properties. The multi-drop experiment will be used to gather information on dispersed phase holdup and on operating problems common to direct contact systems.

Publications

- **A Model of Direct Contact Heat Transfer for Latent Heat Energy Storage,** to be presented at the 15th IECEC Conference; Seattle, Washington; August 1980; M.E. Cease
- **The SERI Solar Energy Storage Program, Fourth Annual Thermal Storage Contractors Information Exchange Meeting,** Tysons Corner, Virginia, December 1979; R.J. Copeland, J.D. Wright, C.E. Wyman

Figure 4.
The single-drop column is used to define the transfer mechanism and determine the drop size as a function of the physical properties.

Thermal Fuels and Chemicals Laboratory

Objectives

Study high temperature thermo-chemical processes in which heat is added to various feedstocks to produce fuels and useful industrial chemicals. Data from these studies will be used to design and develop solar thermal receiver/reactors in which concentrated solar energy replaces the heat source used in the laboratory.

The short term objective is to study rapid pyrolysis of farm-related biomass feedstocks, such as wheat straw, and the related synthesis of the pyrolysis gases to diesel fuel. Data from the pyrolysis experiment will be used at the SERI Advanced Component Research Facility to design a solar receiver/reactor for testing.

Capabilities

The laboratory apparatus is a variable length tubular reactor through which feedstock entrained in a carrier gas is pumped. Heat is added by electrical resistance heating under controlled and measurable conditions. Gases generated in the reactor are sampled at several points along the reactor and analyzed by a gas chromatograph. The temperature of the reactor wall as well as the reacting flow is measured at several points. The mass flow rate and molecular weight of the gas are measured in real-time. Also, the feedstock mass flow rate and the temperature and mass flow rate of the carrier gas can be controlled and measured. These measurements can be used to determine the mass fraction of feedstock converted to gas, the gas composition as a function of reactor length and temperature, and feedstock to carrier gas flow rate ratio. In addition, the energy required to drive the reaction can be obtained from the heat input. The range of experimental parameters are:

Reactor length	15 to 150 cm (in 15-cm steps)
Reactor wall temperature	up to 1000° C
Reactor power input	up to 67 W/cm
Feedstock flow	0.5 to 3.0 kg/hr
Carrier gas flow	0.5 to 3.0 kg/hr
Carrier gas temperature	up to 800° C

Figure 1 shows schematically the layout of the laboratory apparatus. Superheated steam entrains the biomass particles falling off the screw feeder and the mixture flows through the reactor. A cold water spray quenches the reaction and the gases, solids, and liquids are separated for disposal or analysis. Figure 2 is a photograph taken during some recent experiments on rapid biomass pyrolysis.

Instrumentation

The Thermal Fuels and Chemicals Laboratory is equipped with thermocouples to measure reactor wall and reaction gas temperatures, solid-state power transducers to measure reactor power input, a digital balance to measure feedstock feed rate, pressure transducers, flowmeters, and a gas chromatograph.

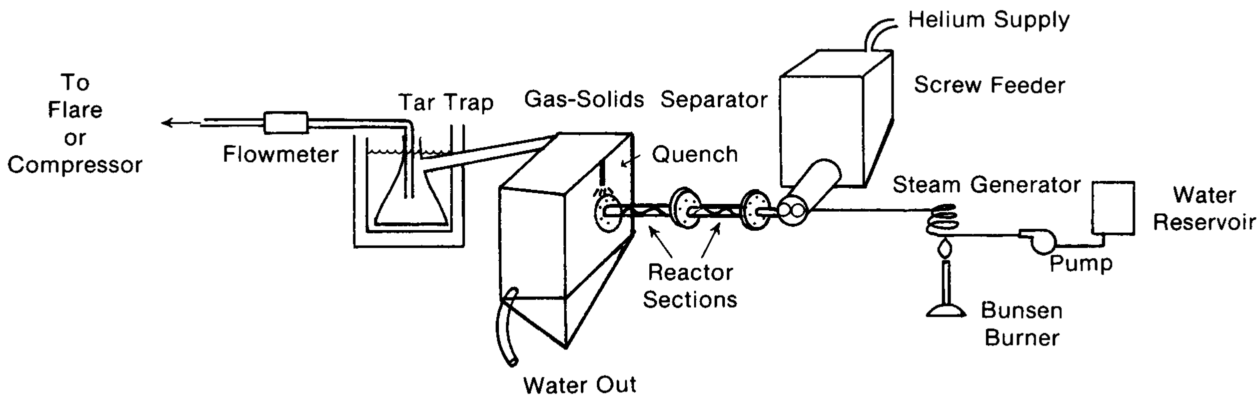


Figure 1. Biomass Pyrolysis Experiment

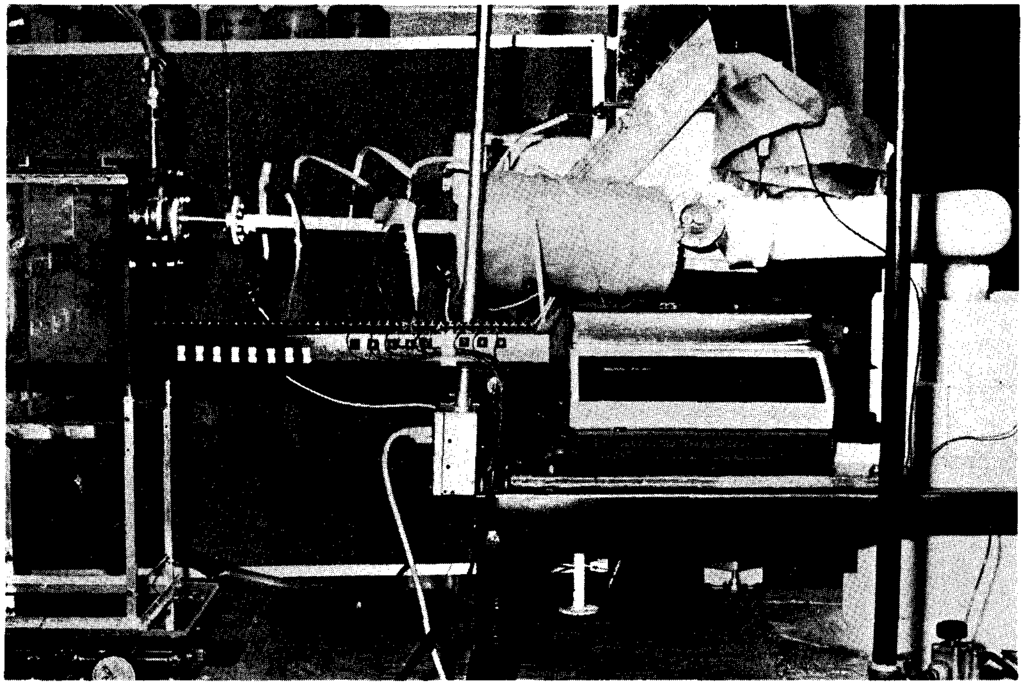


Figure 2. Pyrolysis equipment is used to study the conversion of biomass into liquid fuels and industrial chemicals.

Data acquisition and experimental control is provided by a microcomputer-controlled data logger. Capabilities of this computer include 30 thermocouple inputs, 30 voltage inputs, eight resistance measurement inputs, eight frequency inputs, 12 analog voltage or current outputs and 64 channels of digital input or output. Five RS-232 ports are used to interface the computer with a cathode-ray tube (CRT), teletype, digital plotter, feedstock digital balance, and gas chromatograph. Computer output can also be sent to several panel meters and a multipoint recorder.

Fiscal Year 1980 Experiments

During FY80 the facility will be used to pyrolyze wheat straw and to catalytically convert the pyrolysis gases into diesel fuel. Conversion efficiency and pyrolysis gas composition will be measured as functions of reactor length and wall temperature, and ratio of biomass feed rate to carrier gas (steam) flow rate. These data will serve two purposes. First, the data will be used to design a receiver/reactor which will be tested with concentrated solar energy heat input replacing the electrical heat in the laboratory reactor. This experiment will be conducted at the Advanced Component Research Facility and will help identify and solve problems associated with solar input, e.g., transients. Second, the data will be used to develop an energy balance/economic analysis of the process. This analysis will be useful in predicting economically feasible conditions for the process.

Applications and Future Plans

The long-term goal of the Thermal Fuels and Chemicals Laboratory is to develop a procedure to determine the best path from a given feedstock to a desired hydrocarbon fuel. This will require basic heat transfer measurements on solid-gaseous, two-phase flows at low Reynolds Numbers as well as systematic studies of the pyrolysis mechanism of feedstocks and the catalysis of pyrolysis gases to produce the desired fuels. Once such a procedure is available, it will provide the information necessary to design and construct an optimum solar receiver/reactor and catalytic reactor using economically available feedstocks to produce a liquid fuel suitable for specific end uses.

Publications

- **Development of a Solar Thermal Receiver for High Temperature Applications;** November 1979; M. Bohn, G. Bessler; SERI/TP-333-485
- **Integrated Solar Receiver/Biomass, Gasifier Research;** November 1979; C. Benham. P. Bergerson, G. Bessler, M. Bohn; SERI/TP-333-507

Heat and Mass Transfer Research Laboratory

Objectives

Study and improve methods of transferring heat and mass under the small driving forces which often exist when the sun is the energy source for the process. The driving force can be a small temperature difference or a small difference in some other intensive thermodynamic quantity, e.g., concentration gradient in a dilute solution. Unless the heat and mass transfer are very efficient, the transfer surface becomes very large. The primary method under consideration is direct contact between the working fluid and the reservoirs, but other methods such as enhanced contact area may be studied.

The near-term objective of laboratory research is to investigate the heat and mass transfer phenomena relevant to various open-cycle ocean thermal energy conversion (OTEC) systems. The first experiment will be to measure the heat and mass transferred between a falling liquid and the surrounding vapor, as in a falling jet evaporator or condenser, under conditions present in a Claude-cycle OTEC power plant.

Capabilities

The laboratory has the capability to supply one million Btu/hr to a warm water loop with a gas-fired boiler, and remove one million Btu/hr from a cold water loop with a chiller (table 1). The warm and cold water loops can exchange heat (and mass) through a variety of exchangers. The present set up uses an evacuated test cell with the warm water flowing through one end and the cold water through the other end. Heat and mass are exchanged by evaporation of the warm water and direct contact condensation of the vapor on the cold water. The evaporator and condensor are set up so that falling jet and film configurations may be tested.

Both the warm and cold water loops can supply water at rates up to 750 gpm. The vacuum system has a leak rate of less than 0.01 lb of air/hr. The vacuum is maintained by a liquid ring vacuum pump augmented by an air ejector. The pump with ejector has a capacity of about 100 cubic feet per minute at 0.1 psia (the vapor pressure of water at 35° F).

Next year, the capability to inject controlled amounts of non-condensible gas into either loop will be added. The ability to sample the vapor in the test cell and measure the concentration of non-condensibles will also be added.

Figure 1 is a schematic diagram of the laboratory layout. Both pumps are located in a pit 10 feet below the floor line to maintain a static head which prevents cavitation. After leaving the pumps, part of the cold water may be directed through the chiller (which is located outside of the laboratory building) and part of the warm water may be directed through a heat exchanger fed with hot water from the boiler. The chilled or heated water recombines with the direct streams in the static mixers. The temperature of either loop is regulated by controlling the ratio between the amount of water flowing through the chiller or heater to the amount of water which bypasses them. The water flow rate in either loop is controlled by throttling the flow. The flow rate is measured by turbine flowmeters. Water temperatures at the inlets and outlets of the test cell are measured with platinum resistance temperature transducers. The test cell (see figures 2 and 3) is a vacuum chamber four feet in diameter and six feet long. This cylinder is mounted with its axis parallel to the floor. Hemispherical end caps seal the cylinder. These are mounted on trolleys which roll on rails easily away from the cell. The evaporator and condenser to be tested mount on the end caps so that they are exposed and easy to work on when the end caps are

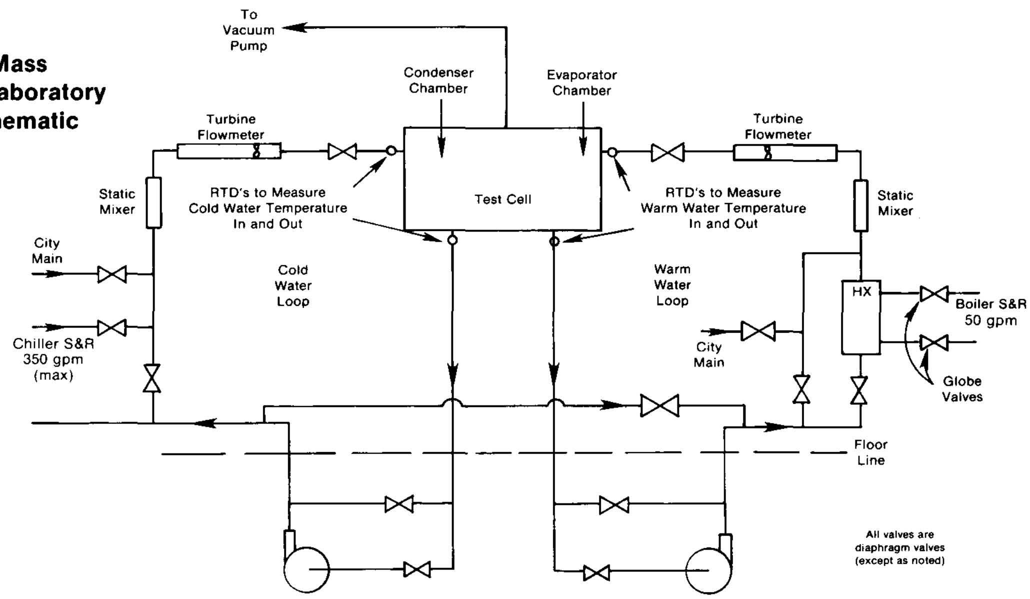
Table 1. Laboratory Capabilities

	Warm Water Loop	Cold Water Loop
Heat Input	1×10^6 Btu/hr	
Heat Rejection		1×10^6 Btu/hr
Temperature	38° to 8° F	38° to 85° F
Flow Rate	750 gpm	750 gpm
Vacuum	0.1 psia minimum	

rolled back from the cell. The system is filled with water from the city main. This water is deaerated as it passes through the test cell. After several passes through the test cell, enough oxygen has been removed to prevent rusting of the carbon steel pipes.

Figure 2 is an artist's sketch and figures 3(a) and 3(b) are photographs of the test cell. Figure 3(a) shows the condenser, and figure 3(b) shows the evaporator end. The evaporator consists of four pipes whose axes are horizontal and perpendicular to the axis of the test cell. There is a slot along the bottom of each pipe. Water falls from the slots in flat, parallel, vertical sheets. Water evaporates from these sheets and the vapor is directed by baffles upward between the sheets in countercurrent flow, and then axially along the test cell to the condenser. The condenser geometry is similar, except that there are two sets of four slotted pipes and the vapor flows down between them in cocurrent flow to condense on the sheets.

Figure 1.
Heat and Mass Transfer Laboratory Piping Schematic



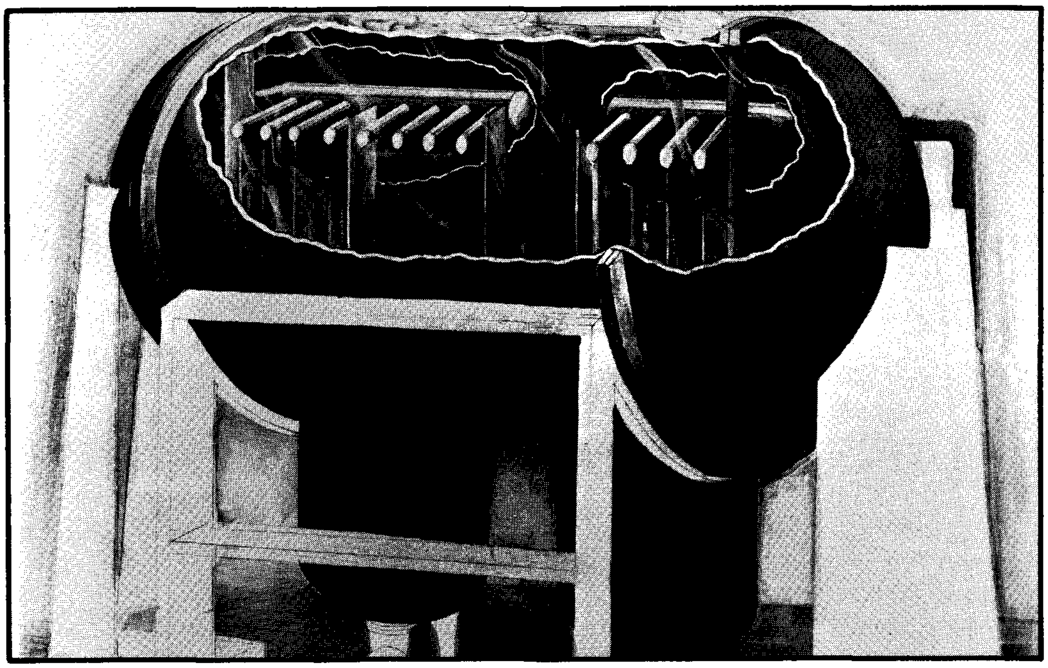


Figure 2.
Artist's sketch of the cell shows a cutaway of the evaporator (right) and condenser (left).

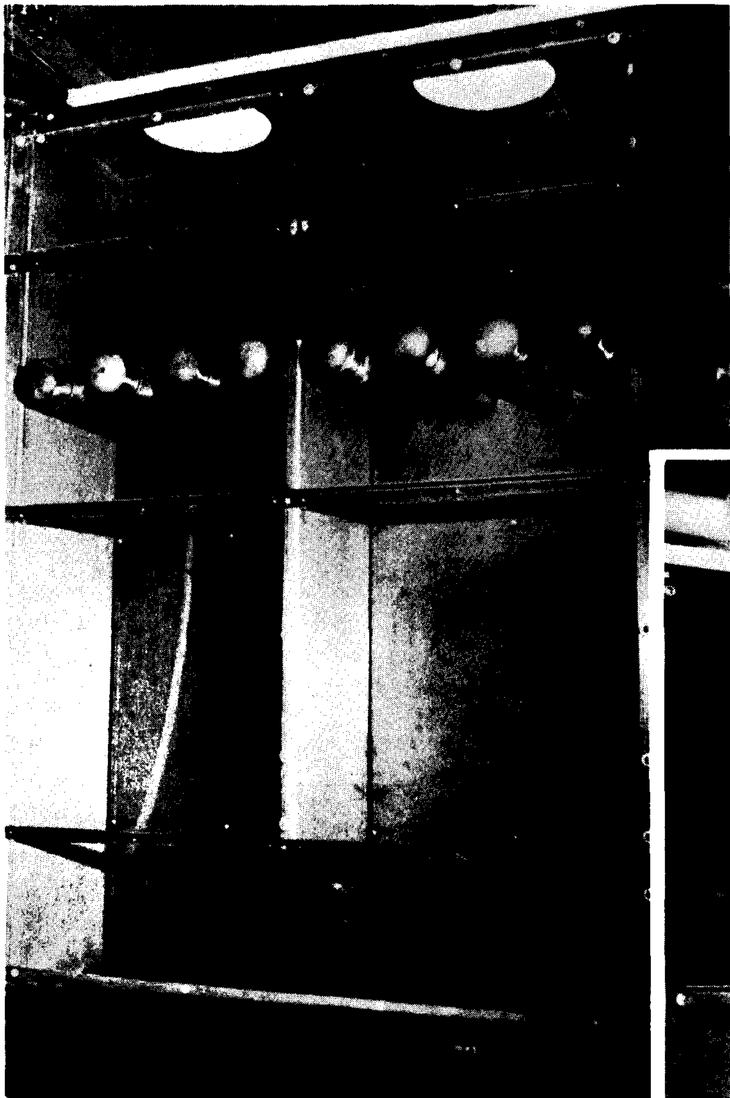


Figure 3(a).
OTEC Condenser

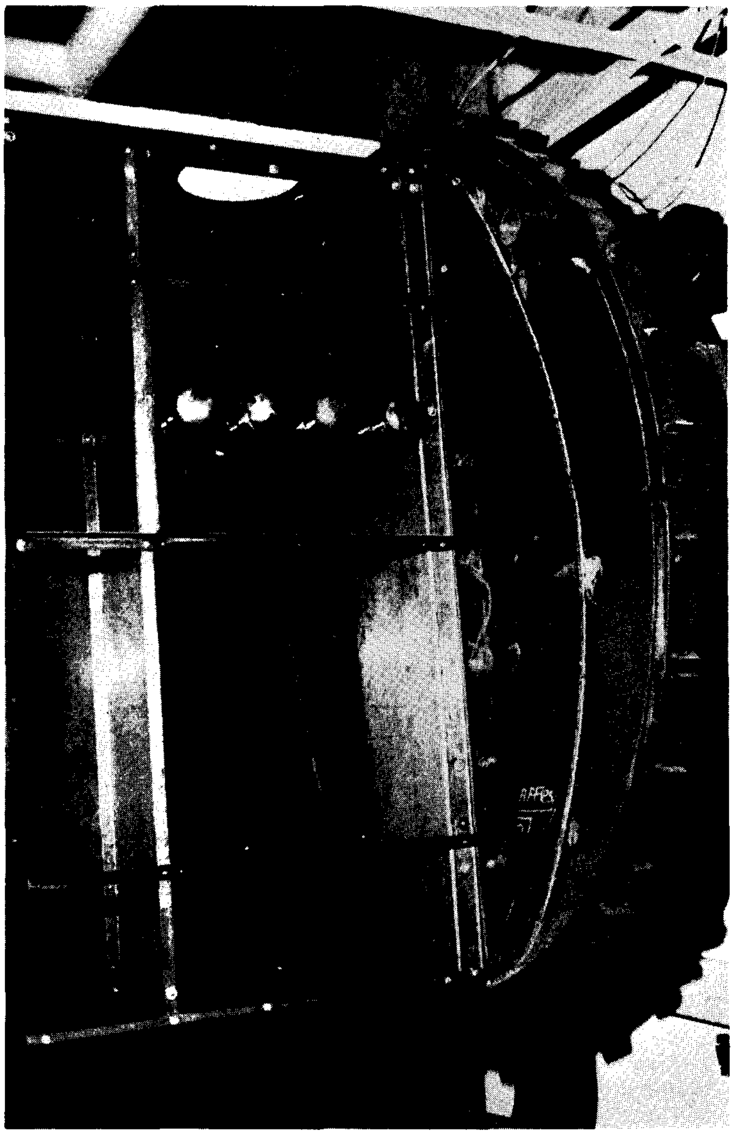


Figure 3(b).
OTEC Evaporator

	Transducer	Range	Accuracy
Temperature	Platinum RTD	32°-85°F	+0.02°F
Flow Rate	Turbine Flowmeter	300-750-gpm	+0.4 gpm
Pressure	Variable Capacitance Diaphragm Type	0 - 1 psia	+0.0015 psia
Dissolved Oxygen	Amperometric Oxygen Sensor	0-200 p/10^9 Dissolved O_2	+2.0 p/10^9 Dissolved O_2
Mass Transfer	Sight Glass	0-7 ft^3	+0.05 ft^3

Table 2. Instrumentation

Instrumentation

Table 2 lists the transducers presently installed in the laboratory. Temperature is measured at the cold and warm water inlets and outlets, at the evaporator vapor outlet, condenser vapor inlet, and at several points within the evaporator and condenser. The evaporator and condenser vapor pressures are measured as well as the warm and cold water flow rates. Oxygen dissolved in either the warm or cold water is measured by withdrawing a sample. Mass transferred from the evaporator to the condenser is measured with sight glasses in reservoirs below the condenser and evaporator.

The electrical outputs from the temperature, flow rate, and pressure transducers are displayed with digital panel meters on a control and display rack. These displays are used to control the experimental parameters.

Fiscal Year 1980 Experiments

The test cell currently installed in the laboratory (figure 2) is designed to simulate, in full-scale, the operating conditions expected in a segment of an open-cycle OTEC evaporator and condenser. The experiments planned for FY80 will provide data on heat and mass transfer between a falling jet evaporator and a falling jet condenser. The experimental parameters to be varied include the cold and warm water flow rates and inlet temperatures, the jet widths and heights, the configuration of the condenser non-condensible gas exhaust, and the amounts of non-condensible gas present.

Applications and Future Plans

The Heat and Mass Transfer Laboratory can be used to study the exchange of heat and mass between many different open cycle OTEC evaporators and condensers. Besides the Claude-cycle concepts presently under study, the laboratory has the capability to study hydraulic cycles such as the Beck, Mist Lift, or Foam. The laboratory can also be used to test evaporators and condensers that can be used to extract power from a solar pond or other collector/storage combinations that provide only a small driving force.

Publications

- **Mist Lift Analysis Summary Report,** May 1980, R. Davenport, SERI/TR-631-627
- **Open–Cycle OTEC System Performance Analysis;** June 1980; A. Lewandowski, D. Olson, D. Johnson; SERI/TR-631-692
- **Open-Cycle OTEC Systems with Falling Jet Evaporator and Condenser,** presented at the 7th Ocean Energy Conference; June 2-5, 1980; A. Kogan, D. Johnson, H. Green, D. Olson

Advanced Component Research Facility (ACRES)

Objectives

Development and evaluation of innovative concepts to improve high-temperature solar energy collection and conversion devices. In the near term the ACRES facility will be used to evaluate receiver concepts and heat transfer methods appropriate for industrial process heat, solar thermal fuels, and chemical applications.

Capabilities

Currently, the ACRES facility has two, six-meter diameter parabolic dish solar collectors. A schematic of the North Dish plumbing loop is shown in figure 1. The working fluid is water which can be supplied to the receiver within the following range of parameters:

Mass Flow Rate	0 to 225 kg/hr	(0 to 1 gpm)
Pressure	0 to 10 MPa	(0 to 1500 psi)
Temperature	0 to 400° C	(32° F to 750° F)

The South Dish is designed to perform optical experiments. It can operate at low temperatures and high flow rates, but with proper valving this collector may also operate at high temperatures to test receiver coating stability and other material problems.

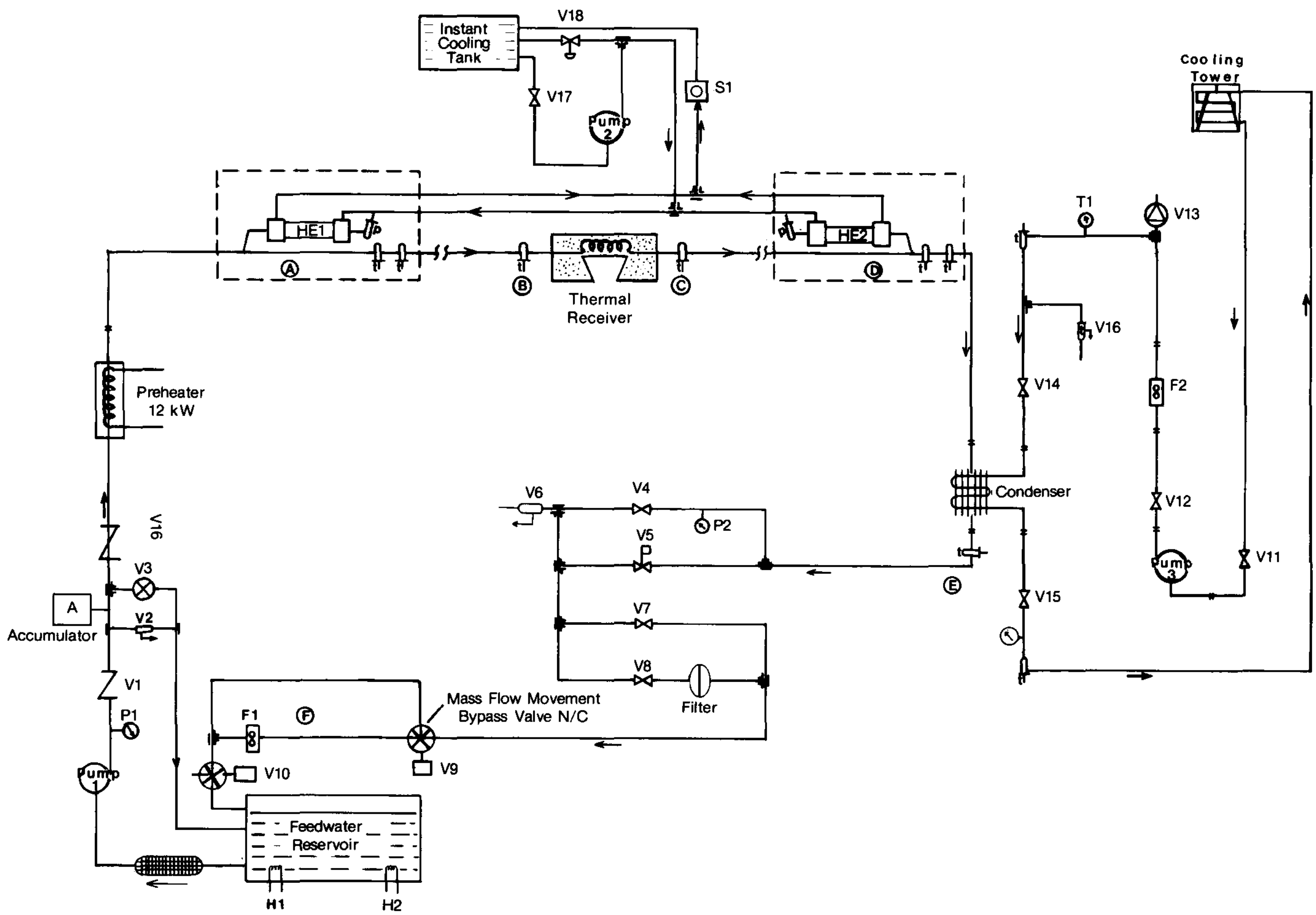


Figure 1. Omnium-G: North Dish Schematic Flow Diagram

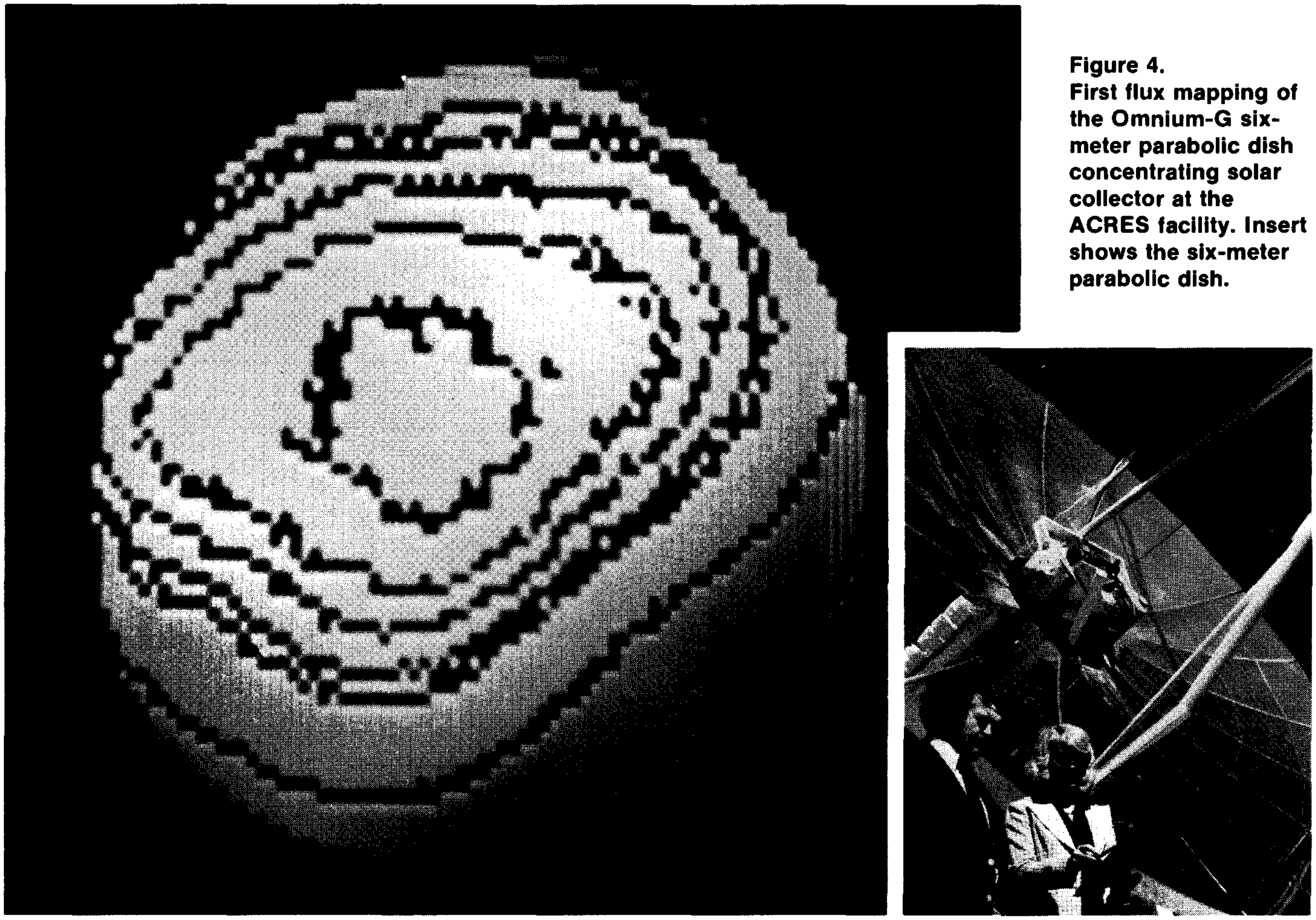


Figure 4.
First flux mapping of the Omnium-G six-meter parabolic dish concentrating solar collector at the ACRES facility. Insert shows the six-meter parabolic dish.

Instrumentation

The ACRES equipment consists of an LSI-11 Computer Data Acquisition System (DAS) with a capability of measuring the output of 100 different sensors. These sensors include types T, J, K, and S thermocouples; 4-wire resistance temperature detectors (RTDs); low-level and high-level voltage sensors; and frequency output devices such as turbine flowmeters and pressure transducers. The following electrical power is available for experiments: 120 VAC, 230 VAC-3 phase, 24 VDC, and 12 VDC. In addition, there exists a nominal 1 mA power supply for RTD measurements. The specific instrumentation for the North Dish consists of a normal incidence pyrheliometer, inlet and outlet pressure transducers, tachometer and turbine-type flowmeters, and many thermocouples and RTDs. Besides the typical heat-transfer and mass flow instrumentation, there is also an optical measurement system which can map the flux from a single reflector or an entire parabolic dish. This system has a video camera, lenses, filters, scatter plate (target), binary frame storer and monitor. This "flux-mapper" is controlled by the LSI-11 computer which can perform subsequent analysis of the video data. The first flux-mapping of the Omnium-G six-meter parabolic dish concentrating solar collector at the ACRES facility was performed during February 1980. Figure 4 shows the flux map. The insert is the six-meter dish which provided the flux that was characterized. The purpose of the flux map is to determine the two-dimensional distribution of reflected solar flux near the focus of a concentrating solar collector. It is anticipated that a heliostat test facility will be built during FY81. This facility will consist of a small tower and telescope and use the "flux mapper" system from the dish system to measure optical performance of various heliostats, including inexpensive designs.

Figure 5(b).
Cross section of the copper cast shell.

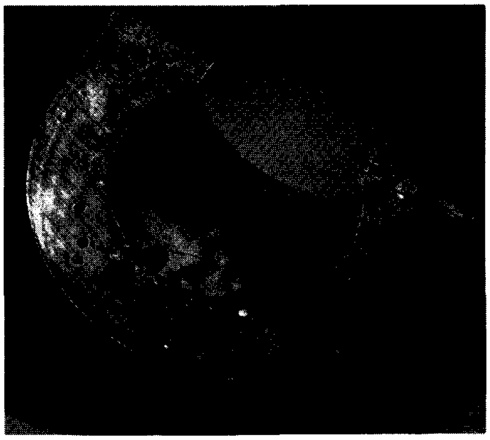
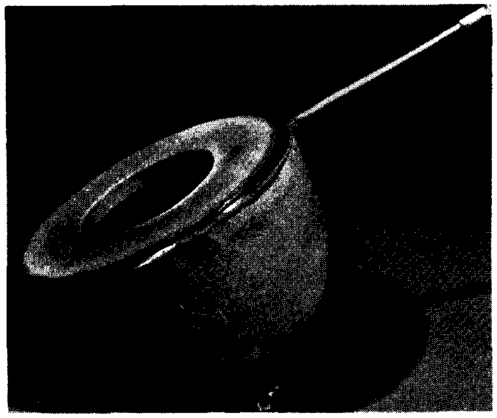


Figure 5(c).
The complete copper mass which acts as buffer storage for the receiver.



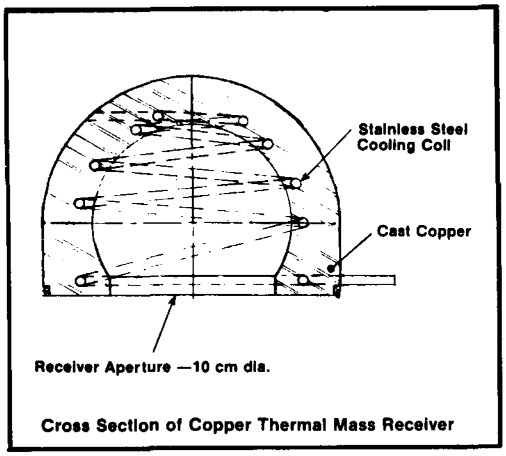


Figure 5(a).
Schematic cross-section of copper receiver used for biomass conversions.

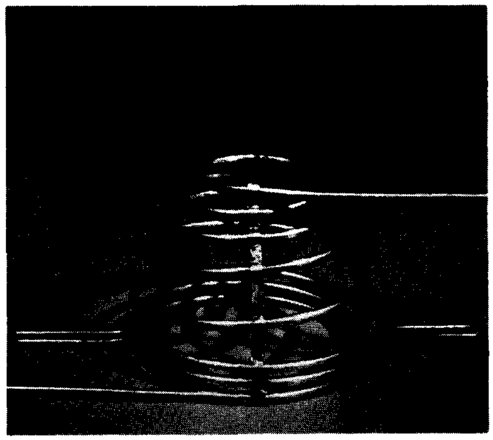


Figure 5(d).
The stainless steel cooling coil which is cast into the copper mass.

Fiscal Year 1980 Experiments

The North and South Dishes will be operated during FY80 to determine their optical and thermal performance, and a SERI-designed copper receiver will be tested. The copper receiver, shown in figure 5(a), has a stainless steel coil to circulate the working fluid. The copper mass acts as a buffer storage and the receiver can be used as a reactor for biomass conversion. A description of the solar thermal biomass conversion process is presented in the Thermal Fuels and Chemicals Laboratory section. The results of these tests will be used to design, fabricate, and test a biomass reactor/receiver. This biomass receiver will be used to pyrolyze biomass materials into gases which can be converted into diesel fuel and other hydrocarbon fuels. Several experiments will be conducted to support the SERI Materials Branch research in the stability of high-temperature receiver coatings.

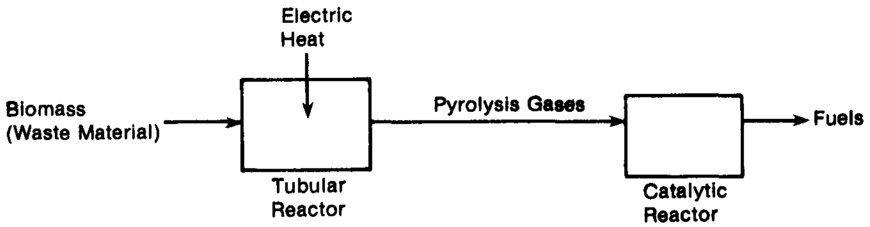


Figure 2.
Laboratory Apparatus

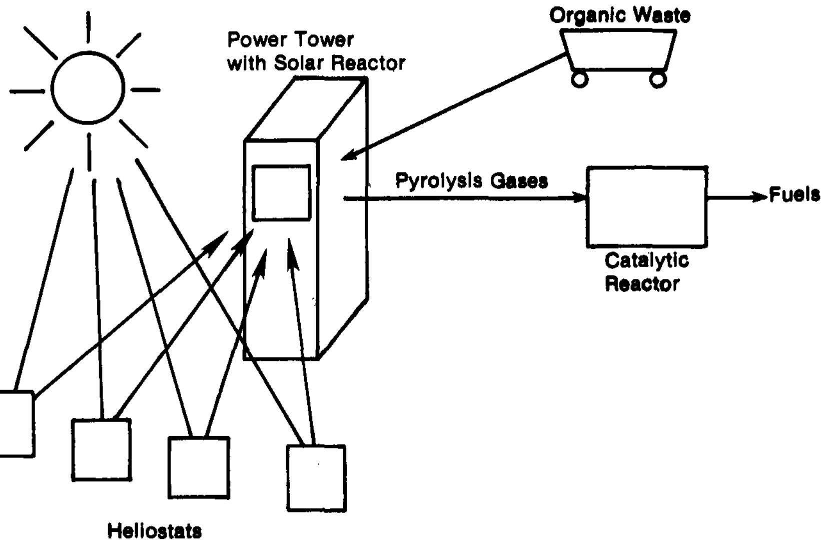


Figure 3.
Full-Scale Field Demonstration

Applications and Future Plans

ACRES will play an important role in the large-scale demonstration of biomass pyrolysis. Figure 2 illustrates the intermediate step in this process. Information obtained in the laboratory will be used to design a reactor using high-temperature heat derived from concentrated solar energy. This step will identify problems associated with using solar input to pyrolyze biomass. This intermediate step will provide experience before going to step 3, which is a large-scale plant such as shown in figure 3. The laboratory scale study and the large scale demonstration are shown schematically in figure 3. The large scale demonstration will involve a central receiver and heliostat field and a plant of several tons per day capacity. ACRES will provide the bridge from the lab scale study to the final step—a large-scale demonstration and commercialization.

Publications

- **Advanced Component Research Facility,** M. Bohn, in review
- **Omnium-G Parabolic Dish Optical Efficiency - A Comparison of Two Independent Measurement Techniques;** M. Bohn, H.W. Gaul; in review
- **Performance Characteristics of a Commercially Available Point-Focus Solar Power System,** April 1979, M. Bohn, SERI/TP-34-169 (Also in Proceedings, ASME/AIChe Heat Transfer Conference, August 1979)

Mid-Temperature Collector Research Facility (MTCRF)

Objectives

Establish and operate a versatile test facility dedicated to the investigation of a variety of research issues relating to the thermal performance of concentrating solar collectors. Various research areas can be addressed by the MTCRF, including advanced component development for collectors operating in the mid- and low-temperature range; materials and fluid evaluations; measurement and testing techniques; component and system reliability; long-term performance measurements; and hybrid systems. The short-term (FY80) objectives are to complete fabrication, installation and testing of the MTCRF test loop and to conduct research in support of the development of a thermal performance test method for concentrators.

Capabilities

The MTCRF in its present configuration is a single collector module test loop with the ability to make state-of-the-art thermal performance measurements on a variety of generic collector types over the mid- and low-temperature range. The basic features are outlined below:

• Number of collector work stations	3
• Number of collectors active at any time	1 (FY80), 2 (FY81)
• Maximum collector area serviceable (based on peak performance of two collectors)	400 ft²
• Fluid flowrate	0.2-10 gpm/ collector
• Operating temperature range	
Water	150-450° F
Heat Transfer Fluid	150-650° F

All performance parameters are measured with the most accurate and precise sensors available. Data is acquired with an LSI-11 minicomputer.

Figure 1 shows a simplified schematic of the test loop. The basic functions of the test loop are divided onto two equipment skids. The storage tank, circulating pump, warm-up heater, and heat exchanger are located on the main equipment skid. The flow control valve, flow meters, controllers, and conditioning heater are located on the flow metering skid. The arrangement of the skids is shown diagrammatically in figure 2, and a photograph of the MTCRF is shown in figure 3.

Instrumentation

The sensors, signal conditioning units and data acquisition equipment were selected to give state-of-the-art measurements of thermal performance. An estimate of experimental error has been made at 1-2 absolute percentage points in efficiency depending on flow, temperature levels and working fluid. An outline of the measurements and their accuracy is presented in table 1.

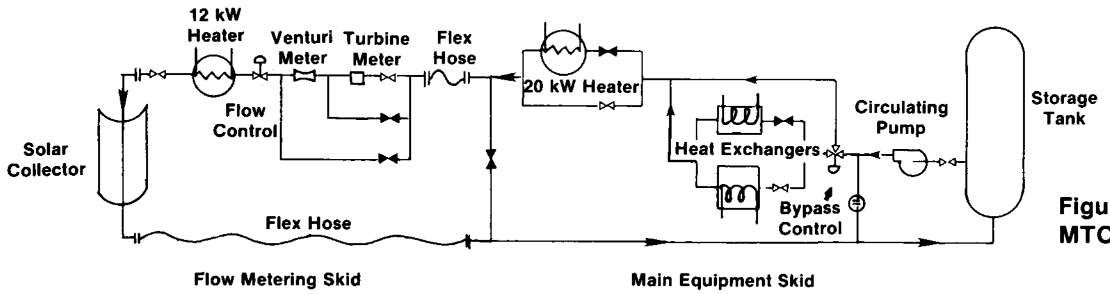


Figure 1. MTCRF Test Loop Schematic

Measurement	Sensor	Calibrated Accuracy	Data Acquisition
Flow	Venturi	0.25% F.S.	P Cell/LSI-11
Flow	Turbine	0.5%	Counter/LSI-11
Temperature	RTD	0.1°C	Autodata 9/LSI-11
Power	KWH Meter	0.25%	LSI-11
Irradiance, Direct	Pyrheliometer	2%	LSI-11
Irradiance, Total	Total Pyranometer	3%	LSI-11
Pressure, Change	Bourdon Tube	0.08%	LSI-11
Pressure, Absolute	Bourdon Tube	0.12%	LSI-11
Wind Speed	Anemometer	1%	Linearizer/LSI-11

Table 1. Measurement Accuracy

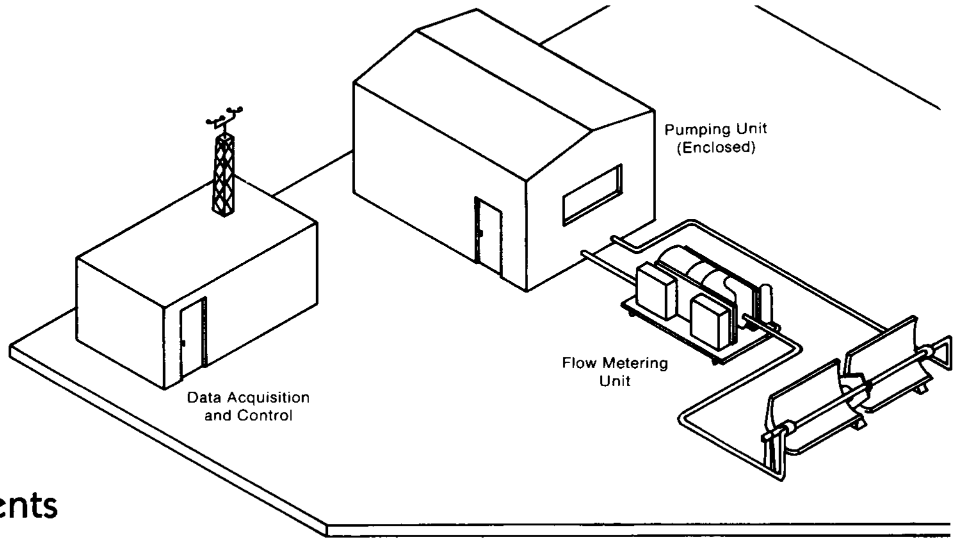


Figure 2.
SERI Mid-Temperature Collector Research Facility (MTCRF)

Fiscal Year 1980 Experiments

Much of FY80 will be spent constructing, installing and testing the MTCRF test loop. The FY80 test activities at the MTCRF will be coordinated with the standards development work in the area of thermal performance of concentrating solar collectors. A number of issues have surfaced in the standards discussions which can only be resolved by additional research, much of which will be done at the MTCRF.

Research areas at the MTCRF related to the standards work cover the broad categories of testing techniques, instrumentation and data analysis. Some specific issues include:

- Alternate methods of collector efficiency measurement, namely the calorimetric ratio technique.
- Off-peak performance of both tracking and non-tracking concentrators, including the effects of and compensation for end effects.
- "Time constant" measurement and its role in evaluating performance.
- Tracking accuracy evaluation and the related issue of system verses component testing.
- Definable limits for acceptable data established by statistical techniques or by setting individual parameter variation limits.
- Accuracy and precision specifications for instrumentation which by the nature of mid-temperature operation are more severe than for flat-plate collectors.

The calorimetric ratio technique is of special interest because the MTCRF has the first such equipment

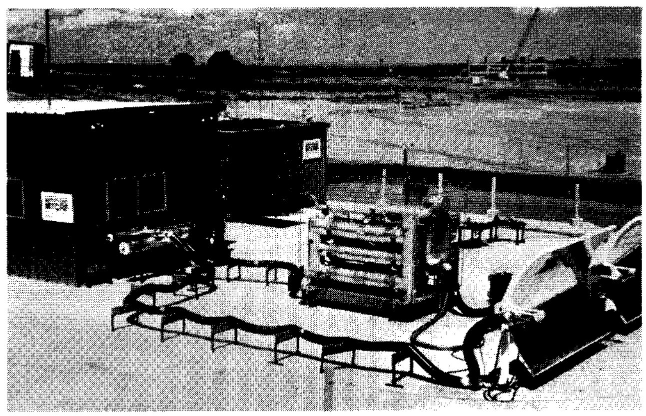


Figure 3.
The MTCRF test loop is designed to determine the thermal performance of concentrating solar collectors.

designed to operate over the mid-temperature range. This technique offers a potentially attractive alternate to the traditional $mc_p\Delta T$ method for measuring collector useful energy gain. These issues are of importance to not only the standards development process, but to other research areas within the solar thermal arena. For example, the accurate determination of peak and off-peak performance is crucial to the prediction of long-term performance, as are the effects of tracker performance. The development of accurate, reliable measurement techniques has impact throughout an industry beset with instrumentation problems.

Publications

- **STAM-SERI Standard Module for Collector Evaluation,** August 1978, Jim Castle, SERI/TR-52-043

Solar Energy Research and Applications in Process Heat (SERAPH) Facility

Objective

Investigate technical issues pertaining to the application of solar systems to mid-temperature (less than 300° C) industrial process heat requirements.

Discussion

Industries in the United States consume a large portion of the nation's annual energy budget, and a significant fraction of this energy consumption is of low- and intermediate-temperature heat. Several existing solar technologies are readily available to meet these temperature needs, such as line-focus concentrators, seasonally adjusted concentrators, and flat-plate and evacuated tube collectors. However, a number of engineering questions still exist regarding which solar systems can be operated reliably to supply specific load demands over long periods. Such questions apply most often to the application of concentrating collectors.

The SERAPH facility, to be built at SERI's field test site near Golden, Colo., will be designed so that a variety of solar systems can be accurately monitored in a closely controlled environment. Emphasis will be on evaluating complete systems as they respond to simulated process loads. The facility will be designed so that the components can be easily combined or redesigned to test a wide variety of systems. Provision will exist for providing supplemental energy when necessary, as would be the case with a back-up system in industry.

Design, assembly, procurement, and operational procedures at SERAPH will be the same, as much as possible, as those used by industry. Interested industry representatives will be invited to observe and review SERAPH operations. Technical results will be widely disseminated through SERI reports and data base entries. Results obtained at the SERAPH facility will be used to verify computer analysis predictions.

The SERAPH facility will provide industry with useful information on solar technologies. SERAPH will serve to expand engineers' and designers' knowledge of system mechanics, and thereby enable solar technology to find acceptance within industry.

SERAPH Capabilities and Features

Auxiliary heat addition	106 Btu/hr
Heat rejection	100 tons
Electrical power	125 kW
Uninterruptible power supply	10 kva
Maximum fluid temperature	650° F
Maximum working pressure	450 psig
Energy flow paths (field/storage/load)	7
Collector fields	5 1000-3000 ft² each
Control	Analog/ Suppervisory/DDC
Data acquisition computer	LSI-11
Interior test bay	600 ft²
Start-up/shutdown	Programmable controller
Emergency shutdown	Relay logic
Data storage	Magnetic tape
Equipment building	1600 ft²
Control house	500 ft²
Applicable standards and codes	NFPA, UBC, ANSI B31.1, ASME
Total area	100,000 ft²
Working fluids	Oil/water

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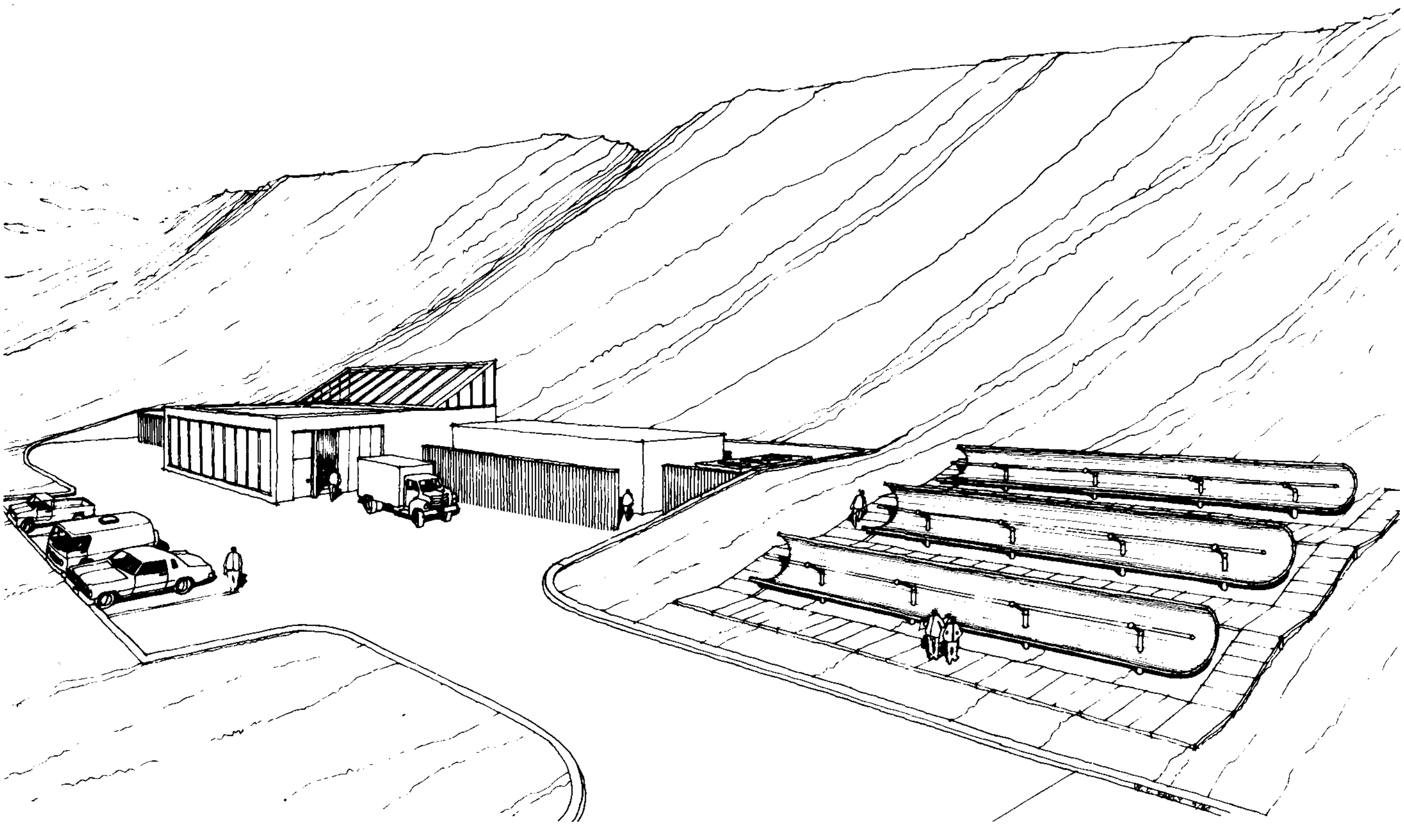

Proposed SERAPH Facility

Solar Energy Research Institute
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1617 Cole Boulevard
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