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Mississippi County Community College -- A Photovoltaic Demonstration Project

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MISSISSIPPI COUNTY COMMUNITY COLLEGE
A PHOTOVOLTAIC DEMONSTRATION PROJECT

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Abstract

An overall view of the integration of all systems involved in the world's largest photovoltaic demonstration project.

Mississippi County Community College in Blytheville is presently being planned using a 240 KW $\pm$ photovoltaic collection field for its energy source. Systems include the collectors, thermal, process control, storage (both thermal and electrical) power conditioning, and the building itself.

1. INTRODUCTION

Mississippi County Community College is the first civilian institution designed to receive its total energy supply from solar cells. It is the largest photovoltaic project of its kind to date and the first comprehensive, practical alternate-energy package based on solar cells.

The energy portion of the project is a Large Scale Experiment undertaken in cooperation with the U. S. Department of Energy as part of the National Solar Total Energy Program.

In 1976, a technical/management proposal was prepared by the college, together with its architect/engineer and energy consultants. Final approval was announced on April 29, 1977, and completion is scheduled for the Fall of 1979.

Members of the management and design team include first of all the owner, Mississippi County Community College, Blytheville, Arkansas, under the direction of Dr. Harry Smith, President; Cromwell, Neyland, Truemper, Levy & Gatchell, Inc., Architect/Engineer, Little Rock, Arkansas, John J. Truemper, Jr., AIA, Principal-in-Charge; and TEAM, Inc., Springfield, Virginia, Energy Consultants, Dr. Daniel P. Ahearne, President.

2. SYSTEM DESCRIPTION AND OPERATION

The energy requirements of Mississippi County Community College will be met by a solar photovoltaic concentrating collector system which generates both electricity and hot water. Key features of the energy system are:

(1) Concentrating collectors, producing electricity and hot water

(2) Silicon photovoltaic cells

(3) Computerized process control of energy production, utilization and storage functions

(4) Power conditioning

(5) IRON-REDOX battery storage providing 24-hour standby capability

(6) Electric utility interface for standby power

(7) Energy conserving design

Figure 1 shows a simplified system schematic diagram. Solar energy is captured by the concentrating collectors where direct conversion of sunlight to electricity takes place. DC electric current is generated by the solar cells. These cells are connected in a series/parallel arrangement for the desired voltage/current characteristics.

This network is then tied to the power conditioning system in parallel to the battery system. The power conditioning system then converts DC current to the desired AC current while regulating the output. Should the cells produce more electrical energy than the school is using, the surplus will be used to charge the batteries for use during the night or on cloudy days. During extended periods of overcast the batteries will be charged at night with "off-peak" electrical rates.

Because the solar cells must be cooled to prevent damage, a ready-made source of heat is available to supply the thermal needs of the school. Excess heat will be stored in water in tanks for use during the night and on cloudy days. A standby electric boiler operating during "off-peak" rate hours will supplement the solar supply as required.

The utility interface is most important in this project. Without Arkansas-Missouri Power's complete cooperation the project would not be possible.

3. COLLECTORS

The collector procurement was a two-phase procedure. The first phase was a design and development contract to Honeywell, Inc. to design a concentrating collector utilizing a reflecting Fresnel lens. Figure 2 shows the faceted surface of the Fresnel lens.

Figure 3 shows the results of the Phase I contract to Honeywell. The collector has a concentration of 20 and tracks east to west. The polar mounting is manually adjustable to compensate for seasonal changes. The collector is capable of being stored during times of nonuse.

A prototype unit was built and tested. However, for the second phase of the collector procurement, the Honeywell collector proved to be too expensive.

With the Honeywell collector 288 units would be required to produce a minimum of 240 KW peak power. Figure 4 shows a layout of the field as proposed by Honeywell. The heat from the collectors marked by a cross would be used to provide the thermal requirements for the building. The heat from the other collectors would be rejected at all times.

Present status of the collector procurement is being negotiated with Acurex Corporation. The Acurex collector has a parabolic trough reflector and tracks east to west with the tracking axis horizontal.

4. SOLAR CELLS

Silicon cells were chosen over the more exotic types such as gallium arsenide because of the state of the art and the lower cost. The silicon cells are less efficient and require that they be operated at a lower temperature (55°C).

Competitive bids were taken for the manufacture of these cells shortly after the grant was awarded to the college. Solarex, Inc. was the successful low bidder. Before the bids were received, estimates were from \$6.00 to \$15.00 per watt based on the market. The bid cost was for \$2.75 per watt. This reduction was, in part, to advance technology, but for the most part, was due to the large order allowing the manufacturer to gear up for mass production.

At the start of this project it was estimated that the efficiency of the silicon cells would be about 11%. Test on produced cells with glass cover has been falling in the range of 13 to 14 percent. This is at 20X and 55°C.

Figure 5 shows a typical voltage current characteristic of the solar cells. The cell maximum power output occurs at the knee of the V/I curve. Without some sort of regulation the output of the cell might be anywhere on the curve depending on the system requirements; but, by operating the cells in parallel to the batteries at all times the voltage is essentially locked and the cell becomes a variable current device.

5. IRON-REDOX STORAGE BATTERY

One of the problems in any solar project is the storage of energy collected during periods of low or no insolation. With the photovoltaic project this is more complicated and costly than in the case of thermal.

As with the collector the procurement is a two-phase procedure. The first phase was a research and design contract to GEL, Inc. for the development of an IRON-REDOX battery. The results of the R & D contract are still being reviewed.

Figure 6 generally illustrates the structure and plumbing arrangements for a single cell stack. Electrolytes are separately circulated on each side of an ion exchange membrane and between the membrane and the electrodes. In the discharged state, both electrolytes are $FeCl_2$. As charging proceeds the positive electrolyte (catholyte) becomes concentrated in Fe^{+3} ions and energy in the form of $FeCl_3$ is stored in the catholyte tank. Metallic iron is electro-deposited on the negative electrode at the same time. The negative electrolyte (anolyte) remains essentially $FeCl_2$ and provides ionic transport between plates.

During the discharge process, the catholyte returns to the $FeCl_2$ state and the metallic iron on the negative plate returns to the catholyte electrolyte. This reaction provides an operating voltage of approximately 1.0 volt depending on state of charge, plate surface, current density and the molarity of the electrolyte.

The overall reversible chemical reaction is

$3FeCl_2 \underset{D}{\overset{C}{\rightleftharpoons}} 2FeCl_3 + Fe$, which produces an overall cycle efficiency of approximately 70% depending on charge, discharge rate and state of charge.

The battery system is required to provide 2 megawatt-hours during a 24-hour period after being fully charged.

6. POWER CONDITIONING

The functions of the power conditioning system are:

(1) Convert DC from the battery/array to usable AC.

(2) Charge the batteries from utility AC.

(3) Provide an automatic changeover from battery/array to utility.

Figure 7 is a schematic of the power conditioning system. The arrays, batteries and power conditioning equipment have been divided into two parallel systems. DC current is supplied from either the array or the battery depending on which is the stronger at the time. The inverter converts and regulates the DC into AC with solid state devices.

The output from the two inverters is then fed to the main bus to the load. The characteristics of the inverter are such that each will supply exactly the same power regardless of the input.

The inverters are rated at 180 KW each and can produce 480-volt, 3-phase, alternating current while being supplied with 295 to 440 volts direct current. Inverter efficiency is 92% at full load. A static switch will provide instant changeover from inverter to utility in case of inverter failure.

Each of the two systems will have a rectifier with proper regulation to charge the batteries during "off-peak" hours.

7. COMPUTERIZED PROCESS CONTROL

Process control consists of a comprehensive energy management system designed to reduce energy demand and to monitor and coordinate all phases of energy production, conversion, storage and utilization. The central computer coordinates all functions, such as collector pointing and tracking, power conditioning and switching, maintaining battery charge status, programming of using devices, checking all subsystems, and maintaining the data base.

8. THERMAL SYSTEM

Because of the requirement for cell cooling a photovoltaic project has the benefit of having a ready-made source of heat for heating structures, etc. On the other hand, this characteristic becomes a liability when the heat cannot be used.

The thermal system must be able to perform the following tasks:

(1) Provide cooling for the cells.

(2) Provide heat for structure.

(3) Provide storage for the heat.

(4) Provide a backup for the solar heat.

Figure 8 illustrates the thermal system. The cells are mounted on an aluminum extrusion with channels arranged so a 30% glycol solution can be circulated to pick up excess heat from the cells. This solution is circulated through a heat exchanger and if still too hot, through a closed-circuit cooling tower.

The heat exchanger is required to separate the glycol solution from the clear water solution. Because of the low grade heat available from the cell cooling (131°F) a plate heat exchanger was selected because of its ability to provide a close approach.

Assuming 120°F water is available from the heat exchanger and the HVAC system can use down to 100°F water for heating, only 20°F temperature differential is available for storage. The 24-hour heating design requires approximately 13 million BTU's. In order to store this amount at a 20°F temperature differential, 80,000 gallons are required.

The primary hot water pump circulates water through either the heat exchanger or the boiler depending on the mode being used. While circulating through the heat exchanger an automatic valve limits the flow to assure at least 120°F temperature off the exchanger.

From the primary pump the hot water is directed either to the storage tanks or the structures depending on the requirements of the secondary pumps.

9. ENERGY BACKUP

The source of standby power for the college is the local utility company. The college is supplied with an energy storage system, so electricity may be drawn from Arkansas-Missouri Power Company, when it is needed, during "off-peak" hours at a special "off-peak" rate.

10. ENERGY CONSERVATION

The need for energy efficient design played a significant role in the architectural design of the college. The result represents a return to what were once accepted practices before the era of cheap energy made brute force mechanical and lighting systems possible. The college is designed to work with nature, using building shape and orientation, natural ventilation, shading devices, daylighting, insulation, thermal mass, and an overall energy management system, to achieve energy savings greater than the energy efficient design standards recently published by the American Society of Heating, Refrigeration, and Air-Conditioning Engineers.

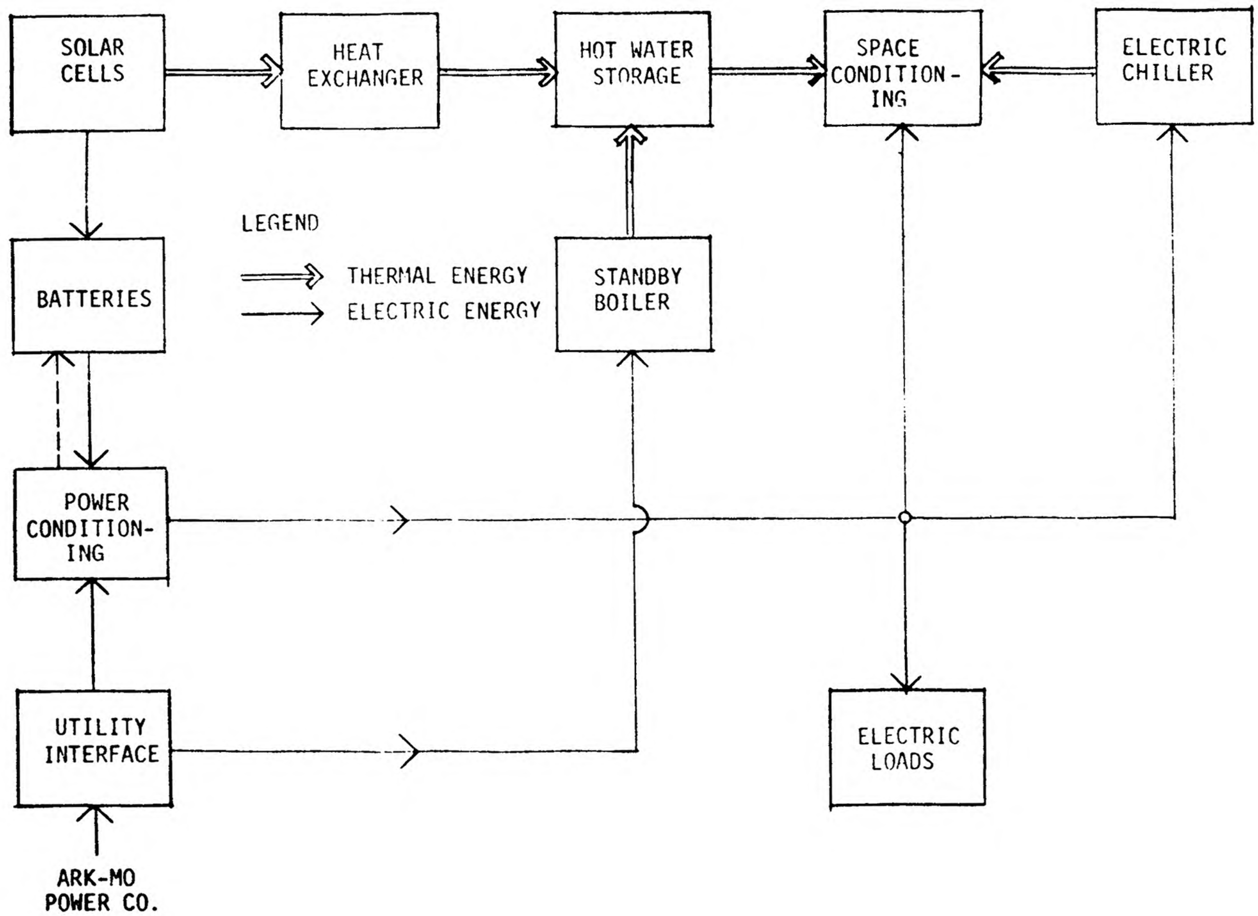

FIGURE 1. SIMPLIFIED SYSTEM SCHEMATIC DIAGRAM

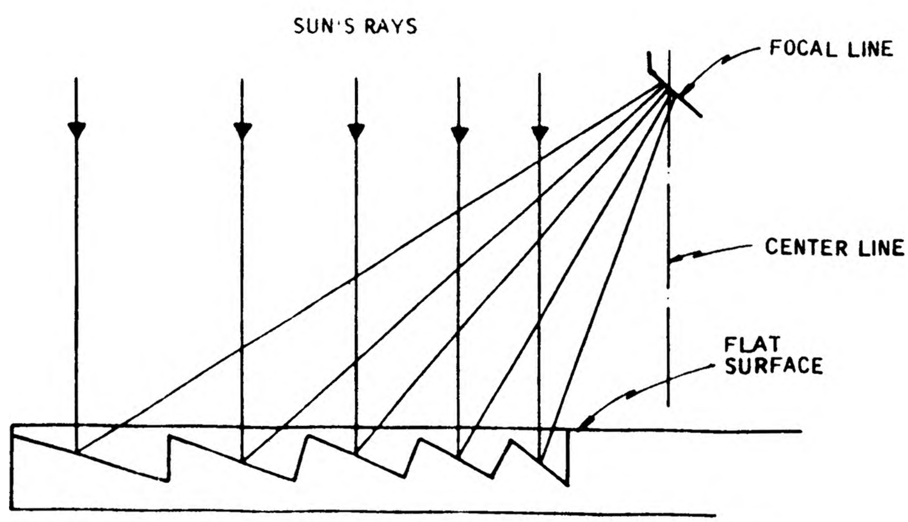

FIGURE 2. SECTION OF FACETED SECOND SURFACE REFLECTOR

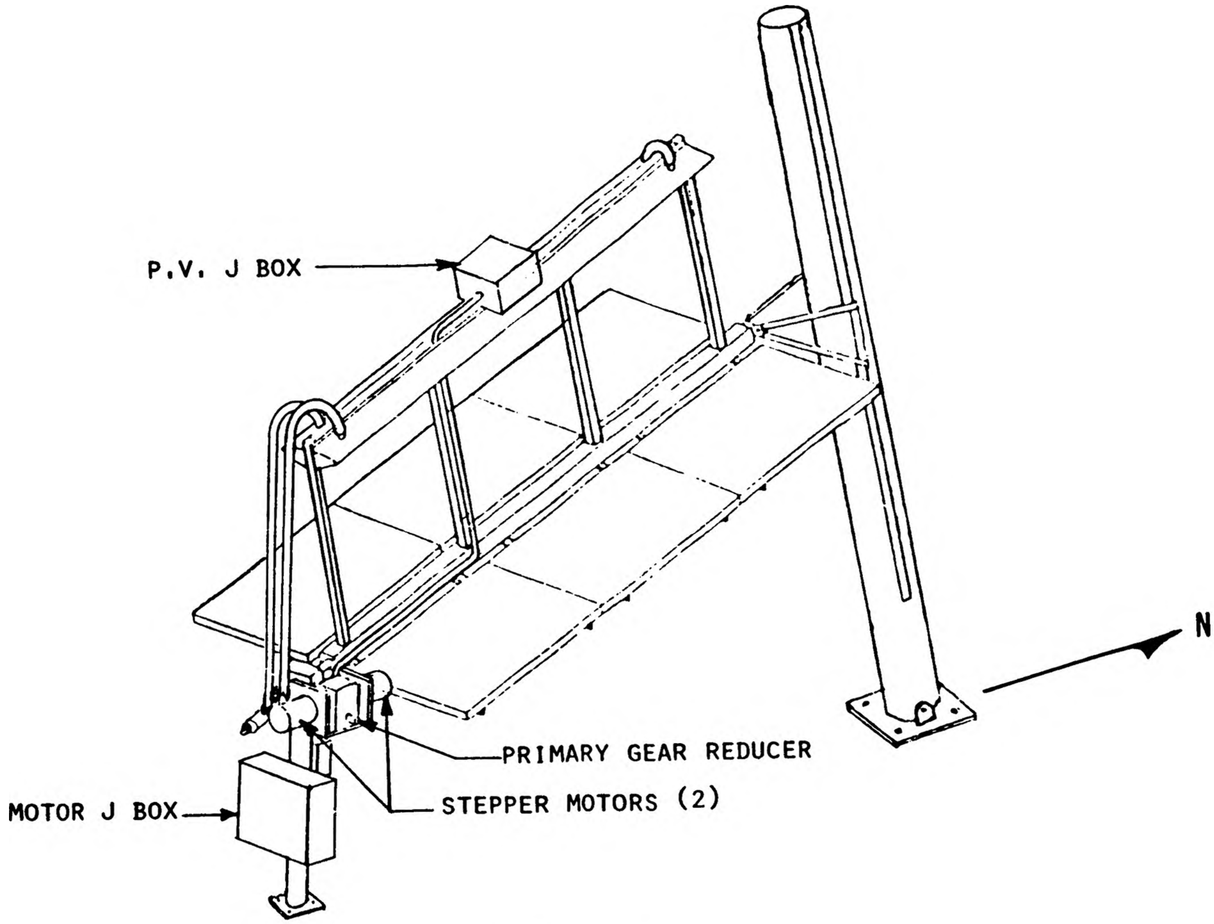

FIGURE 3. COLLECTOR

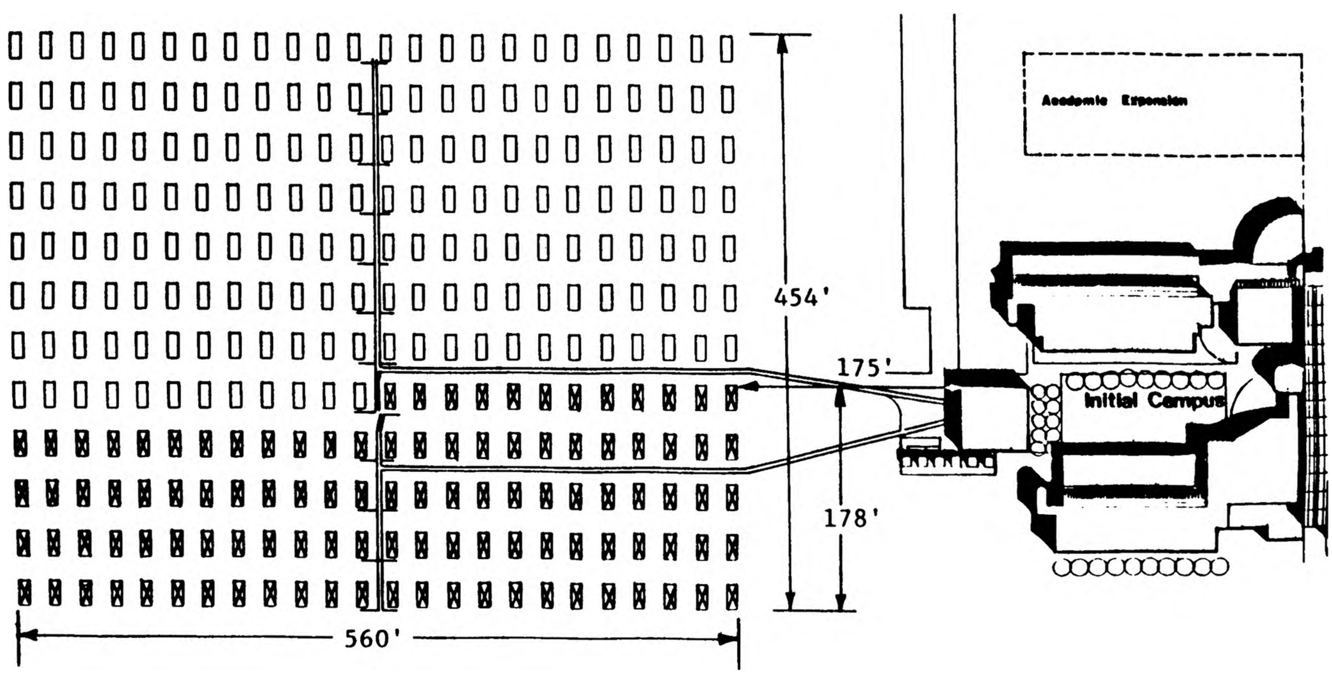

FIGURE 4. SITE ARRANGEMENT

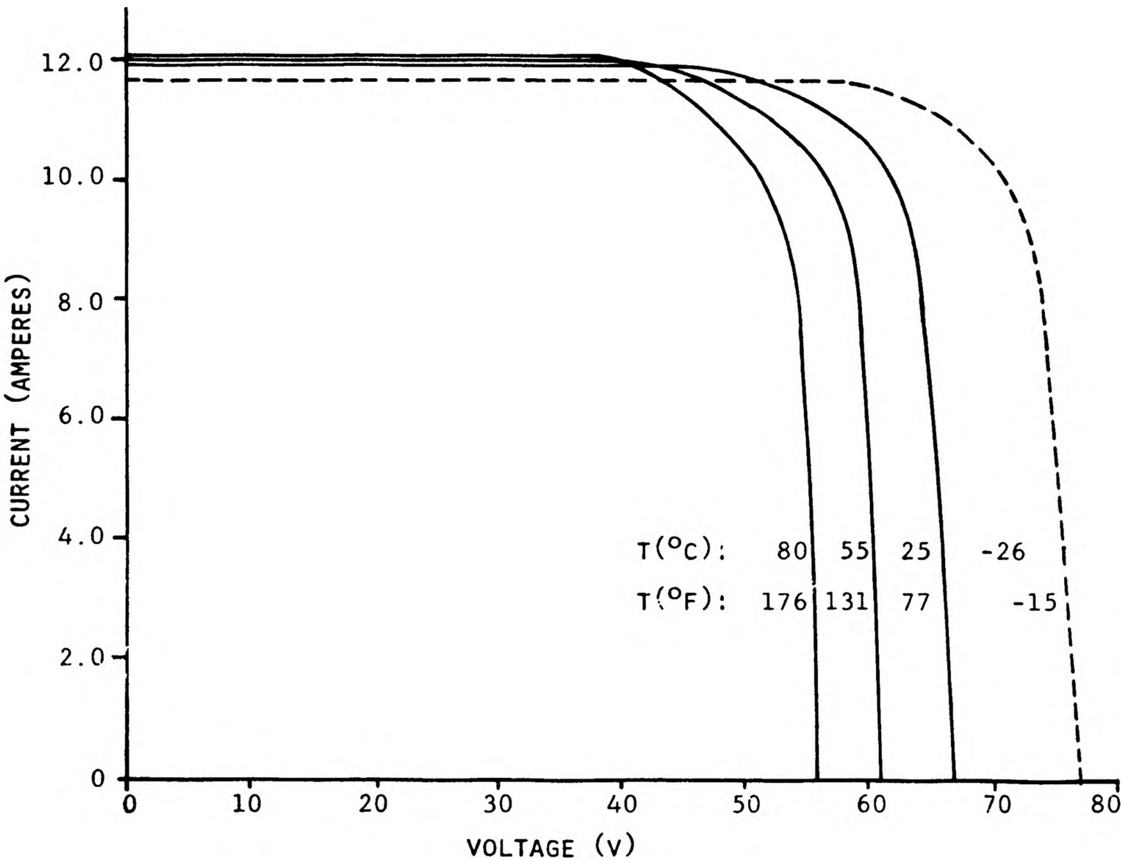

FIGURE 5. CELL PERFORMANCE

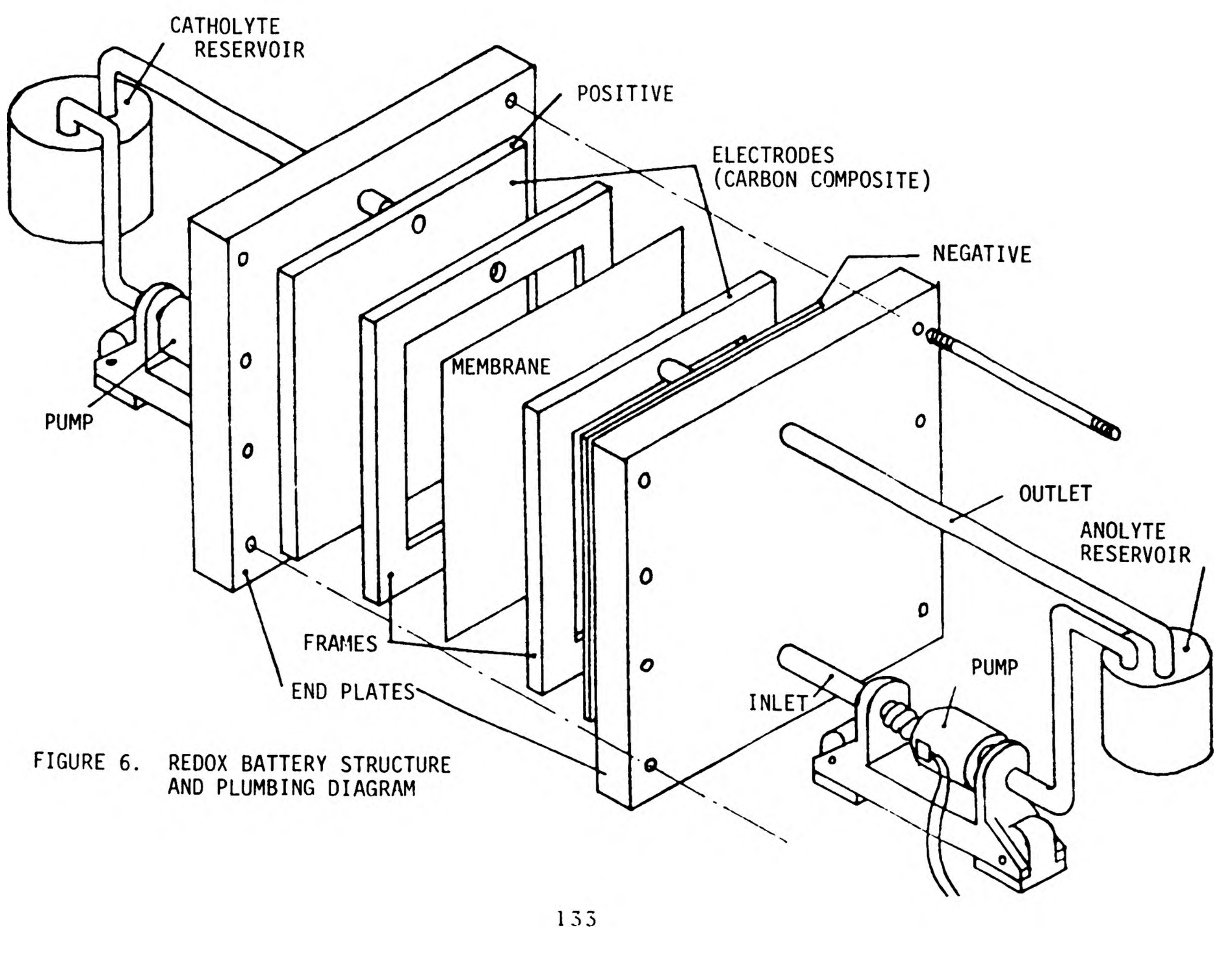

FIGURE 6. REDOX BATTERY STRUCTURE AND PLUMBING DIAGRAM

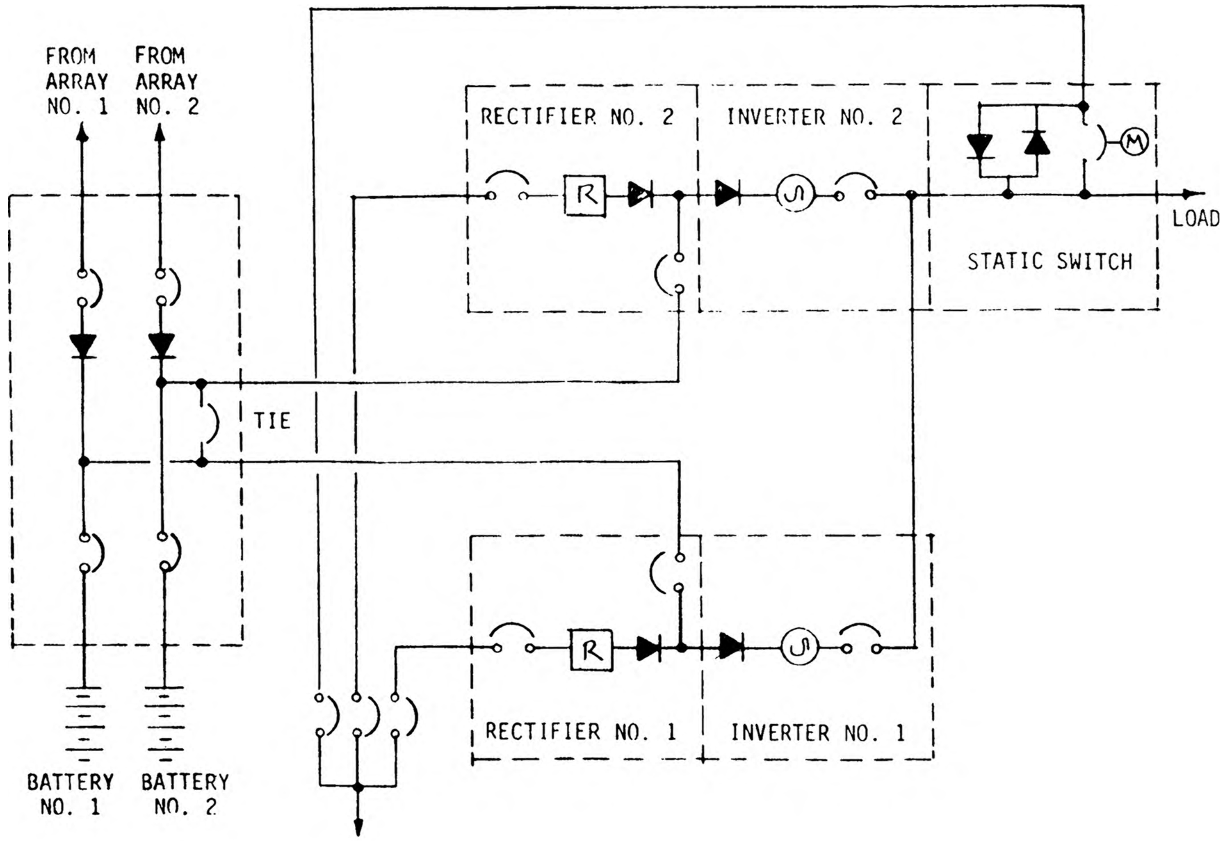

FIGURE 7. POWER CONDITIONING SYSTEM

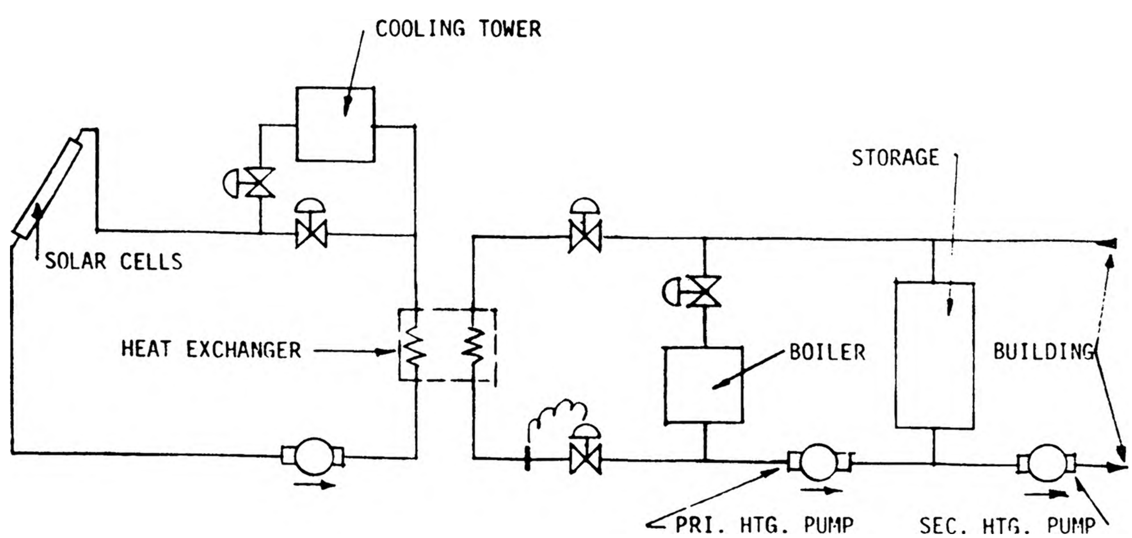

FIGURE 8. THERMAL SYSTEM

BIOGRAPHY

WILLIAM M. WOODSMALL, JR. earned his B. S. in Mechanical Engineering from the University of Arkansas, Fayetteville, in 1956. He is registered in the States of Arkansas, Alabama, Indiana and Tennessee; and is a member of the American Society of Heating, Refrigeration and Air-Conditioning Engineers.

He is presently Vice President in charge of Mechanical and Electrical Engineering for Cromwell, Neyland, Truemper, Levy & Gatchell, Inc., involved in extensive research for the use of energy saving heating and air-conditioning systems for buildings.