Solar Energy Research
at Georgia Tech

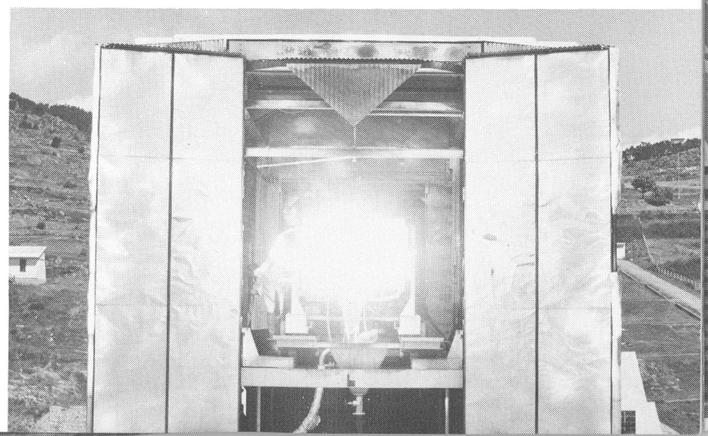
First International Solar Research

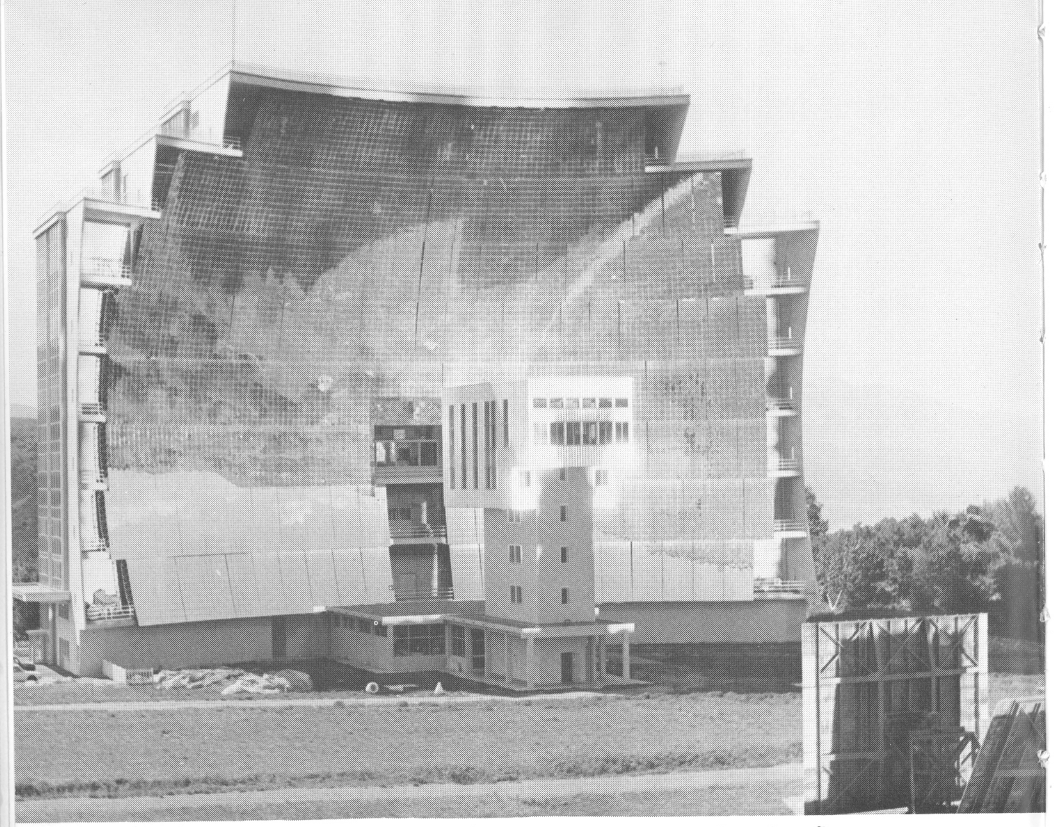
Since 1971 Georgia Tech's Engineering Experiment Station (EES) has conducted materials research programs in collaboration with the Centre National de la Recherche Scientifique (CNRS) in France. CNRS owns and operates the 1000 KW Solar Furnace in southern France, currently the world's largest high-temperature solar test facility.

During the initial materials development activities, Georgia Tech engineers identified a military need which called for measurement of the radar transmission properties of materials while they were subjected to high heat fluxes. Conventional heating methods, such as the use of flames or electrical radiant heaters, either interfered with the radar measurements or were incapable of reaching the desired heat fluxes. The CNRS Solar Furnace offered the possibility of attaining very high heat fluxes using pure radiant energy which did not interfere with radar.

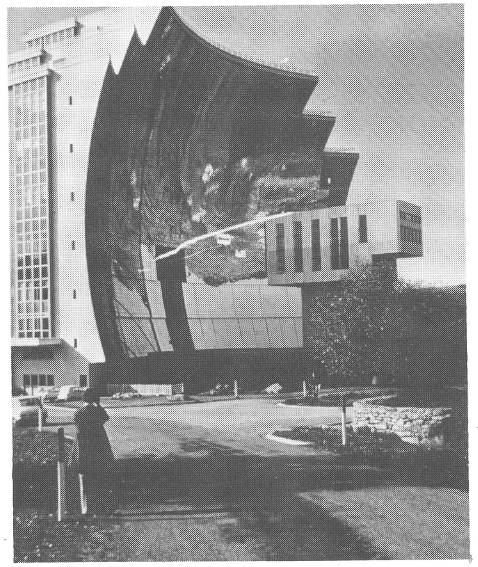
The initial research was a fundamental study on the behavior of ceramics and metals subjected to pulses of intense thermal radiation. Many of the specimens reacted differently than anticipated, and the resulting experimental data were useful to the U.S. Army for radar design purposes and to NASA for designing heat shields to be used on planetary entry probes for Venus and Jupiter. A subsequent research effort was an applied study intended to measure the radar transmission characteristics of radomes (nose cones) used on missiles during reentry into the earth's atmosphere.

Focal tower of the French Solar Furance showing furnace doors open.





The CNRS Solar Furnace in Odeillo-Font Romeu, France, produces heat fluxes up to 7000°F.



A Bench Model Solar Steam Generator

Another program using the French facility included designing, building and testing a bench model solar steam generator to acquire design information and operating data based on real experience. This is one of the early projects in solar thermal conversion begun under the National Science Foundation in 1974.

Martin Marietta Corporation and Georgia Tech have conducted the program as a team, with collaboration of the Centre National de la Recherche Scientifique (CNRS). The Energy Research and Development Administration (ERDA) assumed responsibility for the program when that agency was organized in 1975.

The boiler, or receiver design, as it is called, for the generator was based upon two primary considerations: It must model as

Bench Model Solar Steam Generator (boiler) under construction at Georgia Tech.

The completed Bench Model Solar Steam Generator ready for testing at the French furnace.

closely as possible the design expected to be used in a commercial solar electric power generation plant, and be scaled for solar testing in the CNRS Solar Furnace.

The solar receiver is designed to convert water to superheated steam at conditions acceptable for operation of conventional steam turbogenerating machinery; the output steam conditions will be 950° F. It thus performs the function of the boiler-superheater in a normal fuel-fired electrical generating plant. The receiver is built in the form of a 10′ × 10′ pyramid-shaped box with high-pressure steel tubing lining the interior walls. The tubing is illuminated by the concentrated solar radiation supplied by the solar furnace and water circulating inside the tubing is converted to steam.

The boiler has an output of approximately one megawatt of thermal energy with a steam flow rate of 2600-pounds per hour at a pressure of 1300 psi. This steam output is equivalent to 300 kilowatts of electrical energy output.

In July, 1976, steam was generated by the new boiler as planned, successfully proving the design and construction.

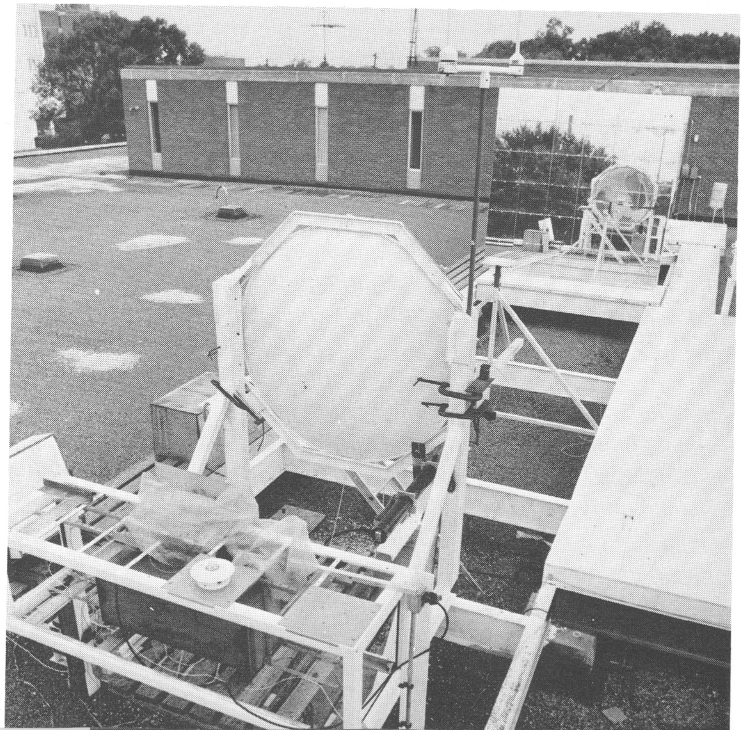
Tech's Model Solar Furnace

An experimental scale model of the French CNRS Solar Furnace located on the Georgia Tech campus has produced temperatures of 4000° F. Measuring 9½ by 9½ feet (a smaller equivalent of one of the CNRS's 63-heliostats), the flat mirror rotates with the sun as it reflects radiation into a 62-inch wide parabolic concentrator. Up to 2,000 watts of energy is available at the one-inch focal point of the concentrator.

An optical guidance system, designed by the School of Electrical Engineering, controls electric motors connected to the mirror's two axes, rotating the mirror to follow the sun. The unit also has an automatic gain control device which permits tracking over a much wider range of solar radiation intensity than have previously designed heliostat controls.

The furnace produces exceptionally clean and uncontaminated heat which has been extensively used in testing endurance levels of ceramics and crystals.

Model heliostat and 60-inch parabolic concentrator used to test high temperature materials at Georgia Tech.

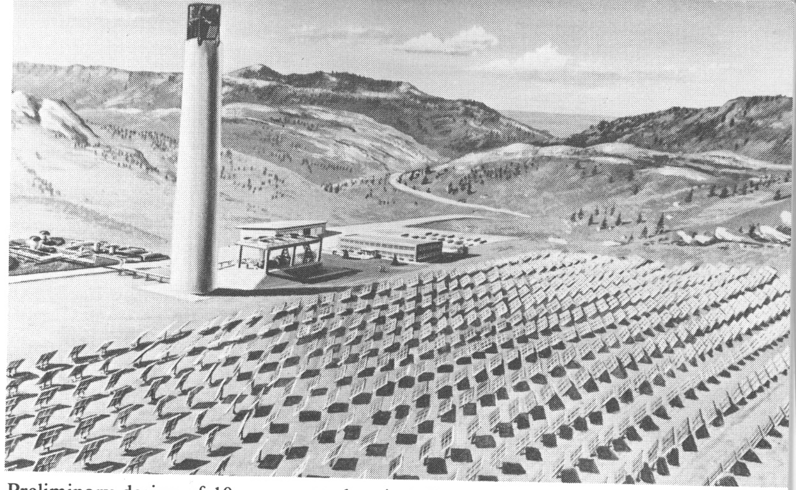


Central Receiver Solar Thermal Power System

This program has the objective of preparing a preliminary design of a 10 MWe Pilot Plant for generation of electrical power using solar energy. In this project Georgia Tech is teamed with the Martin Marietta Corporation, Foster-Wheeler Energy Corporation and the Bechtel Corporation. It is one of four multi-million dollar design programs begun by ERDA in the summer of 1975, whose goal is to demonstrate the technical and economic feasibility of generating electric power by solar thermal conversion. Upon completion of the four independent Pilot Plant preliminary designs, it is expected that the best features will be adopted and merged into final designs, followed by construction of one of two operating Pilot Plants.

A 10 MWe Pilot Plant will be a miniature commercial plant and will incorporate all the technical features needed to be compatible with the complex systems operated by the electric power generation industry in the United States. It will then be integrated into a commercial power net to demonstrate that it can perform within the rules and methods used to control such nets.

The Pilot Plant is divided into four subsystems: the Collectors Subsystem consisting of the heliostats (mirror assemblies) which collect solar radiation and direct it into the receiver; the Receiver Subsystem consisting of the solar boiler elevated on a tower; the Thermal Storage Subsystem which stores heat for generation of steam during cloudy periods and in the evening; and an Electrical Power Generation Subsystem which includes the turbogenerator, heat rejection apparatus and water supply equipment.

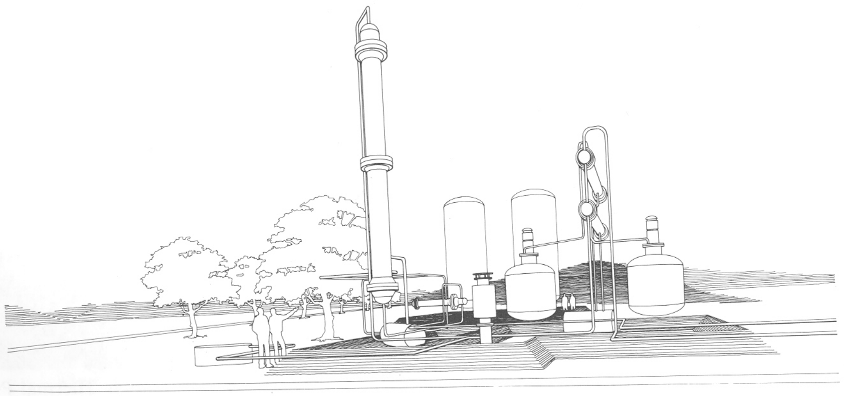


Preliminary design of 10-megawatt-electrical Central Receiver Solar Thermal Pilot Plant for generation of electrical power using solar energy.

Thermal Storage Subsystem Research Experiment

One of the intermediate objectives in preparing a preliminary design for a 10 MWe solar thermal Pilot Plant is the construction and operation of three Research Experiments. A Research Experiment is a model of one of the Pilot Plant subsystems; the Collector Subsystem Research Experiment will consist of four full-size heliostats with their controls; the Receiver Subsystem Research Experiment will consist of a 5 MWth (megawatt-thermal) solar boiler (about one-sixth the capacity of the Pilot Plant receiver); and the Thermal Storage Subsystem Research Experiment will consist of a 2 MWth thermal storage system (about one-twentieth the size of the Pilot Plant thermal storage system). The Research Experiments will furnish real operating experience which can be used to improve the Pilot Plant preliminary designs.

Georgia Tech is responsible for the Thermal Storage Subsystem within the Martin Marietta Pilot Plant team, and will design, build and test the Thermal Storage Subsystem Research Experiment. The principle adopted for our thermal storage system involves storage of heat in liquids. Two storage media are used at different levels of temperature: a molten inorganic salt mixture to store heat at 850° F, and a hydrocarbon oil to store heat at 570° F. The storage temperatures are established by the steam conditions necessary to drive the



Perspective of 2 MW Thermal Storage Subsystem Research Experiment (without supporting structure) designed by Georgia Tech's Engineering Experiment Station.

turbogenerator when the turbine is running on stored energy; the Thermal Storage Subsystem will supply steam at 750° F and 600 psi to the turbine.

Georgia Power Company has cooperated with Georgia Tech on this project by providing access to 950° F, 1200 psi steam at their Plant Yates near Newnan, Georgia. The research experiment occupies an area of about one-third acre adjacent to one of Georgia Power's generating units.

In July 1976, construction began on the 2 MWth solar energy thermal storage subsystem facility at the Georgia Power Company Plant Yates. Tech engineers designed the facility which will become part of the first Pilot Plant constructed in the world and will help establish design criteria for the 10 MWe system.

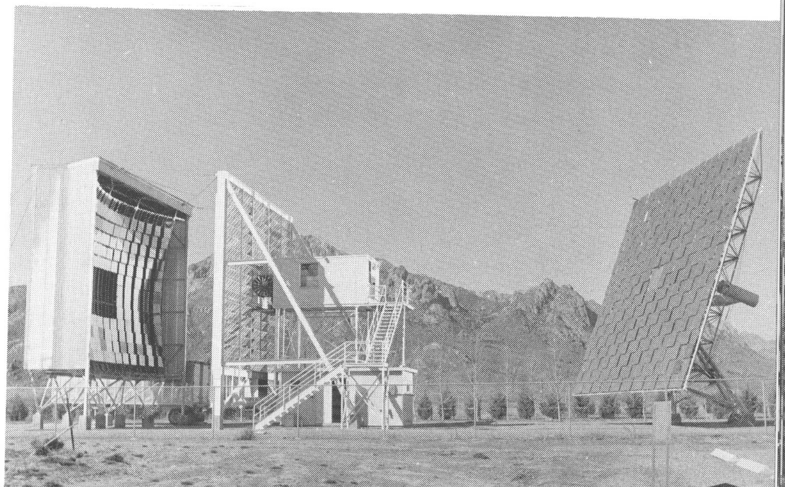
Five Megawatt Solar Thermal Test Facility

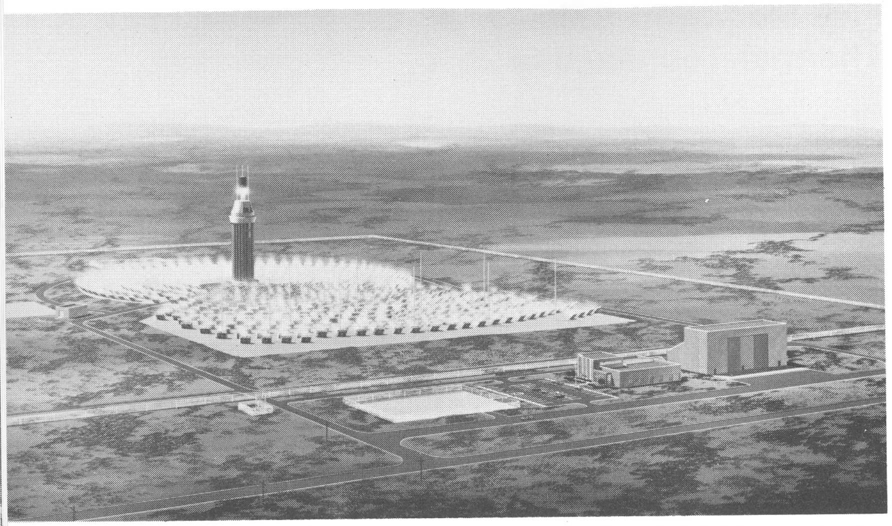
Although only 1/30th the size of France's solar furnace, the United States maintains a 35 kilowatt solar energy test facility in New Mexico, the U.S. Army White Sands Solar Furnace (WSSF). Presently, it is the only large scale high temperature test facility in the U.S. and services military materials tests.

In 1975 Georgia Tech completed several U.S. Army projects at the facility involving new measurement technology, checks of heat fluxes at the furnace focal point and recommended appropriate test methods and instrumentation for future solar energy programs.

In recognition of Tech's experience at the CNRS and White Sands locations, ERDA selected the Georgia Tech Engineering Experiment Station research team to contribute to the development of a new 5 Megawatt Solar Thermal Test Facility (STTF). It is to be built at the ERDA installation operated by Sandia Laboratories near Albuquerque, New Mexico. The purpose of the STTF is to test experimental designs of solar receivers, heliostats (mirror assemblies), thermal storage systems and other high-temperature solar equipment. It is scheduled for operation at the 1 MW power level in late 1976, and at the 5 MW power level in mid-1977. When completed, this center would be the largest solar thermal test facility in the U.S.

View of the U.S. Army's White Sands Solar Furnace.





Artist's design of the 5 MW Solar Thermal Test Facility scheduled for operation by mid-1977 near Albuquerque, New Mexico.

Equipment to be tested will be supported on a central tower and illuminated by a surrounding field of heliostats. Additional buildings will provide office, laboratory and assembly space for the facility operators and test contractors.

The prime contractor for the STTF Conceptual Design was Black and Veatch, Consulting Engineers. Black and Veatch subcontracted with Honeywell, Incorporated and with Georgia Tech for technical assistance in their respective areas of expertise. Georgia Tech is one of the most experienced organizations in the United States in the conduct of research at large solar test installations; its work at the White Sands Solar Furnace and the CNRS Solar Furnace in France are unmatched by any other research group.

Georgia Tech has provided technical recommendations concerning facility layout, arrangement of working space, safety and operating procedures based on its previous solar testing experience. Georgia Tech has also performed a conceptual design for a 1 MW "Working Receiver" which will be owned by the STTF and used for heliostat alignment and testing, and has designed methods for protecting the test tower against damage by focused radiation inadvertantly directed onto the tower.

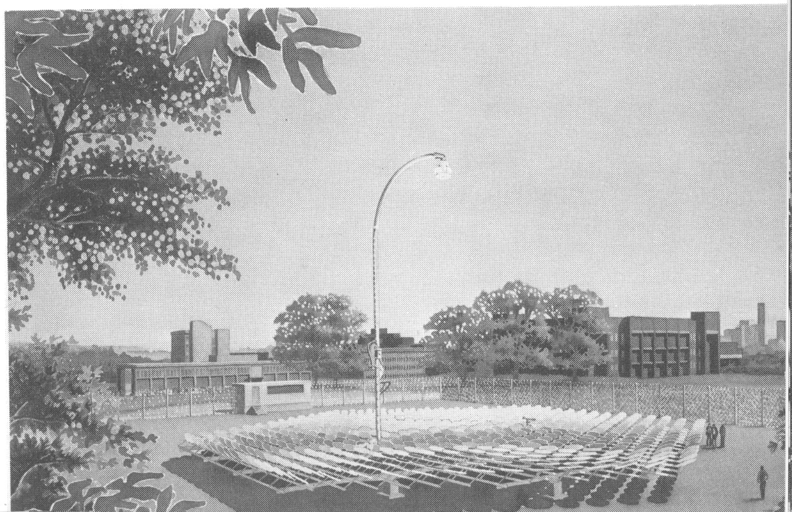
A 400 KW Solar Thermal Test Facility at Tech

The objectives of this program are to transfer and improve upon solar energy steam generation techniques first developed in Italy and to provide an important test facility in the United States.

For about 15 years, Professor Giovanni Francia of the University of Genoa in Italy has been engaged in the development of solar powered steam generators. His current design has progressed through four generations of development, with various modifications incorporated into the receiver and heliostat field. The present Francia Solar Steam Generation Pilot Plant in Genoa produces 100 KWth of superheated steam at 600°C and 150 atmospheres (1100°F and 2200 psi) which is well within the range preferred for electrical power generation.

The facility being erected on the Georgia Tech campus will be about four times as large as the Genoa facility, producing about 400 KWth of steam at the same output conditions. The proposed plant will follow the same general design used in Genoa and will be supplied by ANSALDO, S.p.A., an Italian industrial organization. ANSALDO will also supply professional services to assist in plant start-up and training of United States personnel.

Design of the country's first Solar Thermal Test Facility (400 kilowatts) now under construction on the Georgia Tech campus.

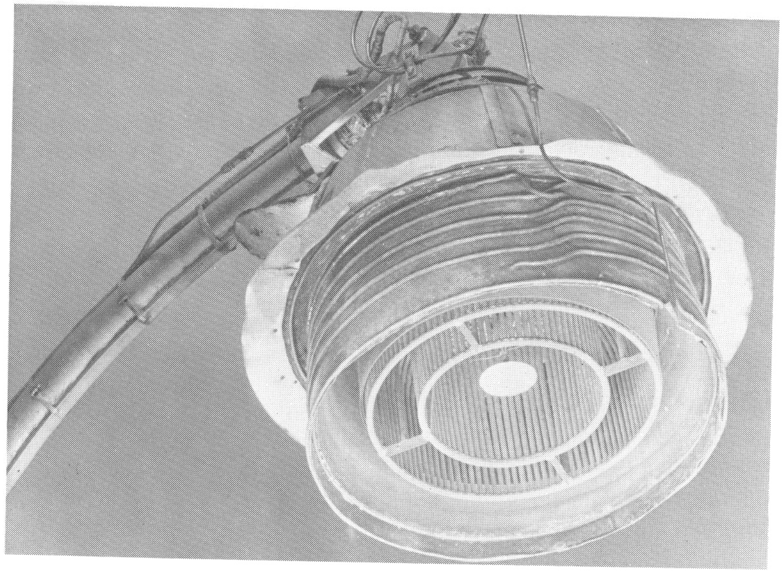


The proposed structure will contain 530 mirrors (the Italian plant uses 271) producing 50 percent ground coverage with a steam output of 950-1112° F.

The test facility operates with a series of flat mirrors which track and direct the sun's rays into a receiver (or boiler) that resembles a modern street lamp. The receiver then converts water to superheated steam through a heat-exchanger process.

This facility will be capable of providing the range of radiant thermal energy values needed to conduct a wide range of solar-thermal experiments. It will be possible to realistically evaluate numerous receiver concepts with respect to optical-geometric performance. Experimental receivers which will then be evaluated would include steam boiler-superheaters, and hot air (gas), oil, molten salt and liquid metal heat exchangers. The facility also would be suitable for carrying out high temperature thermo-chemical reactions and the evaluation of thermionic. The overall system is ideally suited for incorporation into total energy systems studies as well as high temperature thermal storage experiments.

Close up view of the Italian model boiler (receiver).

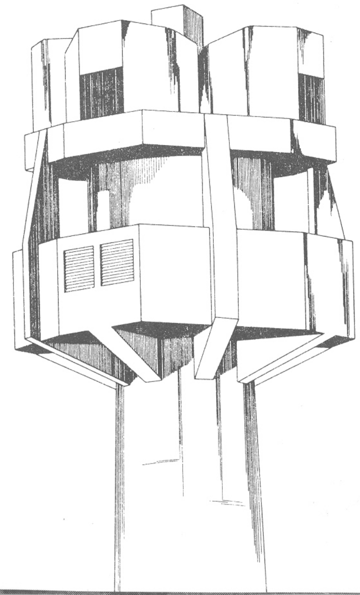


Solar Thermal Conversion To Electricity Using A Central Receiver, Open Cycle Gas Turbine Design

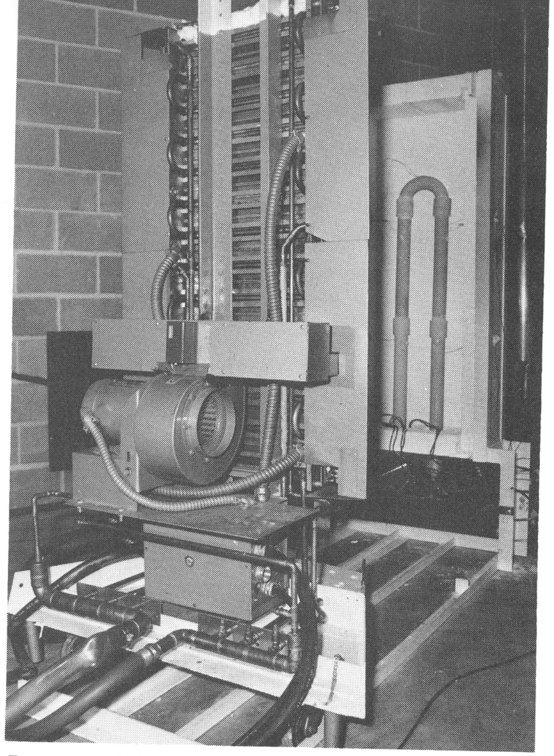
Research engineers at Tech are working to develop a conceptual design for a solar electrical generation system using air, rather than steam, as the working fluid. The program is sponsored by the Electric Power Research Institute (EPRI); Black and Veatch is the prime contractor and Georgia Tech is a subcontractor. Georgia Tech is concentrating on the application of ceramic materials technology to the design of an energy receiver employing ceramic structured parts.

The ERDA-sponsored work in solar thermal conversion is based on the use of the Rankine thermodynamic cycle with steam as the working fluid. EPRI is sponsoring two programs to investigate solar thermal conversion using the Brayton thermodynamic cycle with gases as the working fluids; one of these is the Black and Veatch-Georgia Tech effort based on a gas turbine driven by heated air.

In this system the gas turbine, electrical generator and heat receiver are all mounted at the top of a tower and surrounded by a field of heliostats. The gas turbine operates in much the same manner as a jet aircraft engine, except that the engine's combustion chamber is replaced by a solar-heated receiver in which the temperature of the air is raised to the range of 2200° F.



Conceptual design for a solar electrical generation system using air, rather than steam, as the working fluid.



Prototype of Open Cycle Gas Turbine.

There are several technical advantages to this approach for electrical power generation: no equipment is needed for cooling the working fluid because the used air can be exhausted directly to the atmosphere, gas turbines are less expensive than steam turbines of the same capacity, and higher cycle efficiencies are possible in the gas system than with steam, thereby reducing the number of heliostats required for a given electrical output.

There are also disadvantages: attainment of high cycle efficiency requires that air be heated to very high temperatures and this in turn demands that the receiver be constructed of ceramic materials rather than metals, a much more difficult fabrication task, and the pressure drop caused by flow of air through the receiver must be kept very low to avoid severe penalties in cycle efficiency.

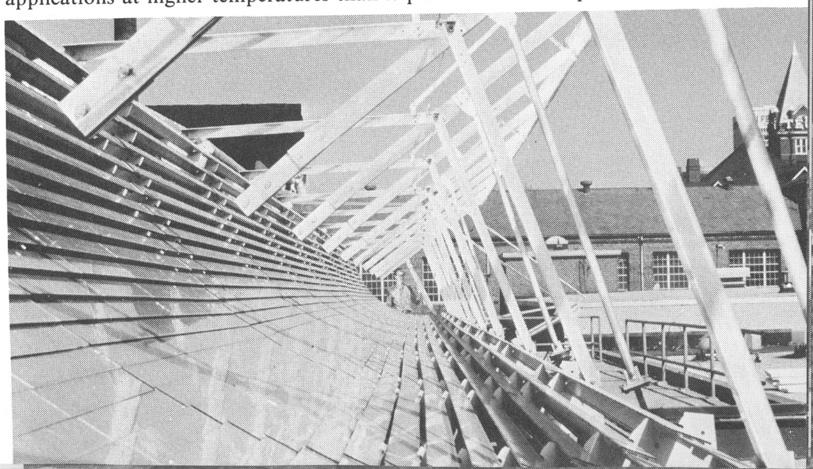
The gas-operated solar electrical power generation processes thus require more fundamental development than the steam processes, but offer possibilities for better efficiency when success is achieved.

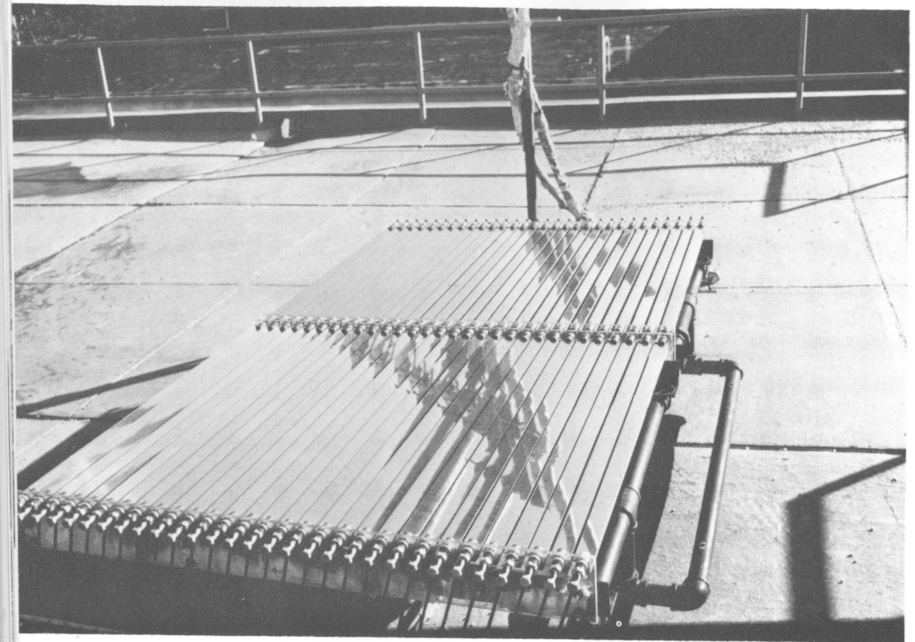
Solar Collectors For Process Heat

Two solar collector systems are under development at Georgia Tech which are particularly well suited for the production of process heat. One utilizes a fixed mirror concentrator and is composed of long narrow flat mirror facets arranged on a concave cylindrical surface. The angles of the mirrors are fixed so that focal distance is twice the radius of the cylindrical surface. The heat exchanger pipe is pivoted at the center of the reference cylindrical surface to remain at the focal point as sun direction changes. The surface area of the experimental model is 61 square feet and peak thermal collection capability of the concentrator is 10,000 Btu/hr. A large demonstration model has been constructed on a Tech building under a grant from the National Science Foundation. This model has 540 square feet of mirror surface area and was developed jointly by the Georgia Tech School of Mechanical Engineering and Scientific Atlanta, Inc. This demonstration model provides the largest quantity of process heat (at 500° F) thus far produced by this type of collector. This system has the potential for providing air conditioning and electric power for large buildings.

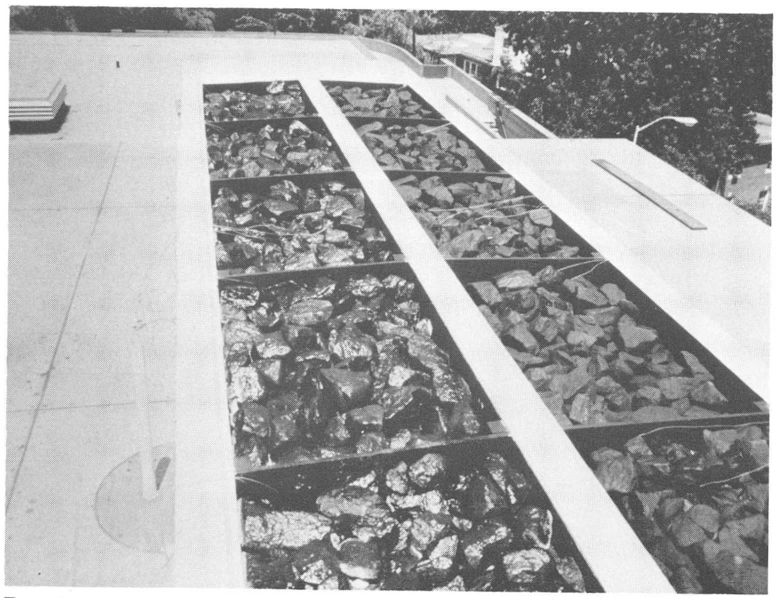
The second system also utilizes a linear heat exchanger, but in this case it is illuminated by rotating facets. Each facet is oriented at the appropriate angle to reflect sunlight onto the heat exchanger pipe. As the sun moves a single bar rotates each facet the same amount so the sunlight remains focused on the heat exchanger.

The Faceted Fixed Mirror Concentrator at Georgia Tech provides energy applications at higher temperatures than is practical with flat plate collectors.





A linear heat exchanger is being studied at Georgia Tech for the production of process heat.



Experimental solar rock collector constructed on rooftop of Georgia Tech building.

Agriculture Drying Experiments

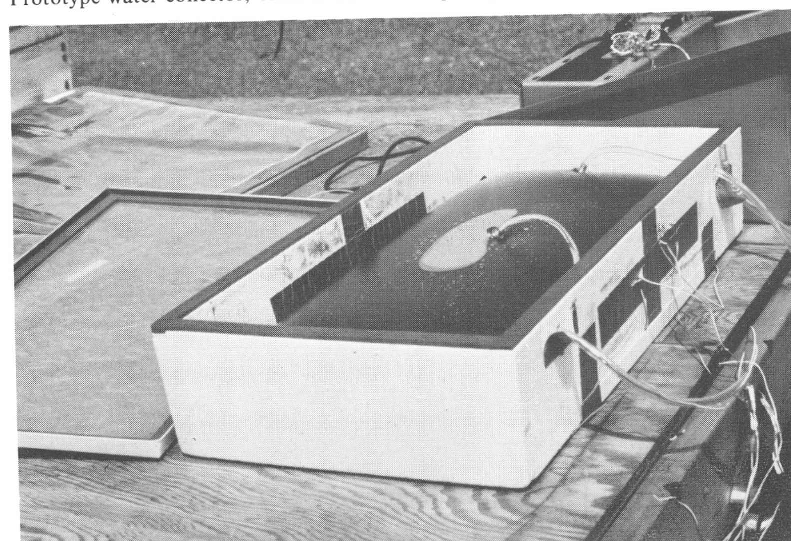
Solar drying of tobacco, peanuts and grain are currently being tested by Georgia Tech researchers in efforts to improve methods of agricultural drying.

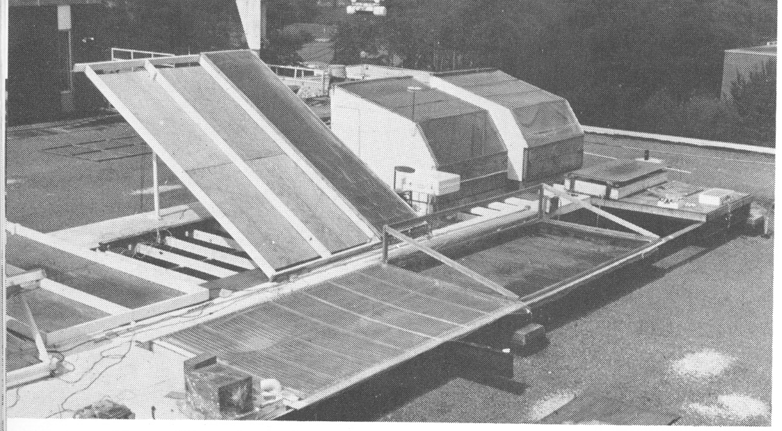
Even today, tobacco is often cured in crude wooden barns; forage is cut and left to dry in an open field, thus losing essential nutrients; and peanuts are still frequently field-dried subjecting them to wide temperatures and environmental conditions which can reduce or even ruin the quality of the crop. These techniques are still used because energy for agricultural drying is very expensive. On the other hand one of the least expensive ways to apply solar energy is in the collector designs that are applicable to agricultural drying.

Three types of solar collectors are being investigated for use in crop drying: 1) hot air collector 2) rock collector and 3) water collector.

The solar hot air collector substitutes solar energy for bottled gas as the main heat source. The unit consists of two (2 × 4 foot) sandwich-like transparent plastic sheets, separated by one half inch of air space. One side contains a two-inch layer of insulation while the space between contains a layer of black polyethylene. Air, heated by the sun as it strikes the black surface, is circulated through the middle of the plastic by a blower or fan.

Prototype water collector, often called a solar pond, heated by the sun.





View of hot air, rock and water collectors on the Georgia Tech campus.

The second method, the rock heat collector, uses a 6 to 10 inch stack of black painted rocks as a heat storage base. A layer of black polyethylene is placed under the rocks to prevent ground moisture from absorbing stored heat. A blower sucks air through the heated rocks and then through the crops.

The advantage of a rock collector is twofold; it serves as a solar collector and energy storer. Once heated, the rocks remain warm for an extended period of time. This method is beneficial to the farmer who can use the stored heat for drying crops on a cloudy day.

The third method is a water collector or solar pond. This 8 × 15 foot collector consists of a top layer of clear plastic, an air gap, a layer of clear polyethylene floating on six inches of water topped by another layer of black polyethylene. The pond water is heated by the sun. Various heat exchanger methods can be used to transfer the energy to crop drying.

The data resulting from these experimental drying methods are measured daily by a number of thermocouples which feed into a computer and record variations in wind direction, wind speed, humidity, temperature, direct solar radiation, inlet and outlet air temperature and the amount of heat collected and stored.

In the study of solar heat collectors, Georgia Tech is also evaluating life properties of vinyl and plastic coverings used in two experimental solar greenhouses. Both units contain rock bed insulated energy storage bases and temperatures of 170×F have been reached during optimum conditions.

These studies are sponsored by the Georgia Institute of Genetics and supported by the U.S. Department of Agriculture.

Installation and Monitoring of Flat Plate Collectors At Towns School

Tech scientists and research engineers are actively involved in studies of test data from flat plate solar collectors which were installed on the roof of the George A. Towns Elementary School in Atlanta to provide solar heating and cooling.

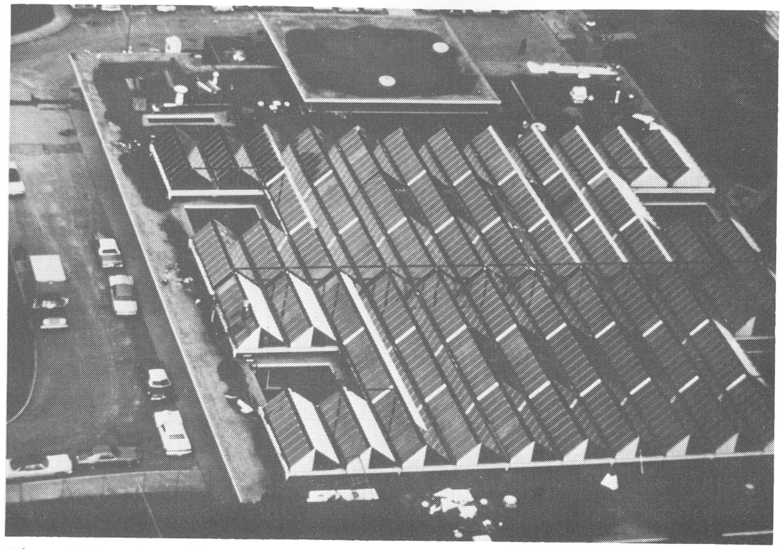
The National Science Foundation (NSF) sponsored Westinghouse Special Systems for the design and provision of this large scale solar heating and cooling system, and Georgia Tech is to monitor the performance analysis.

The system, one of the largest undertakings of heating and cooling utilization provides solar heating for the school building, solar heating of the domestic hot water supply and solar powered air cooling.

The 32,000 square foot building uses 10,000 square feet of flat plate collectors (576 units) placed at a 45 degree angle facing south, installed on the roof of the school. To collect additional radiation in the summer, aluminum reflectors were mounted adjacent to the collector at a degree angle facing 36 North, covering 12,000 square feet.

The school building is expected to receive 60 percent of its total winter heat and 60 percent of its summer cooling from this system. In mid-winter the circulating water from the collectors are maintained at an average temperature of 140° F and in mid-summer 200° F.

The George A. Towns Elementary School is totally heated and cooled by solar flat plate collectors.



View of flat plate collectors on roof of Towns School.

Components of the flat plate collector include two rectangular pieces of tempered glass, interlaced with copper covered pipes, which circulate heated water throughout the collector and through header pipes into a hot water storage tank. The school has three 15,000 gallon underground steel thermal storage tanks (two for hot water and one for chilled in the summer) which provide 45,000 gallons of water.

The hot water is used to drive a 100 ton absorbtion chiller which can provide 100 percent of the school's cooling needs. Solar energy is expected to provide 60 percent of the energy requirement for the chiller. The large volume of chilled water storage enables the system to be operated during a cloudy period.

The entire solar panel system was completed in November 1975. The school's gas-fired boiler is maintained as an auxiliary system to provide heating and cooling during periods of inclement weather.

Performance levels of the solar system instruments are computed daily by a team of engineers from Georgia Tech's Schools of Electrical and Aerospace Engineering.

Tech Contributes to Shenandoah Solar Community Project

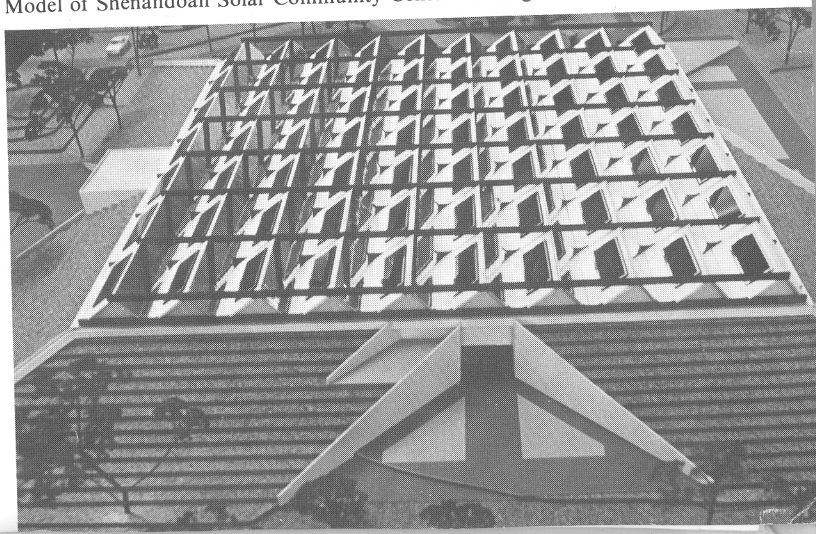
As a leading developer of solar energy for homes and buildings, Georgia Tech was awarded a contract by ERDA for the design and engineering of a total solar community center being constructed in New Town, Shenandoah, Georgia, 25-miles southwest of Atlanta. The center will contain a multi-purpose complex of offices, ice skating rink, gymnasium, theater, game rooms and swimming pool. A solar housing development is also planned for the community. The ERDA funds provide for the solar portion in the construction of a $2.4 million multi-purpose center which is scheduled for a September 1976 completion.

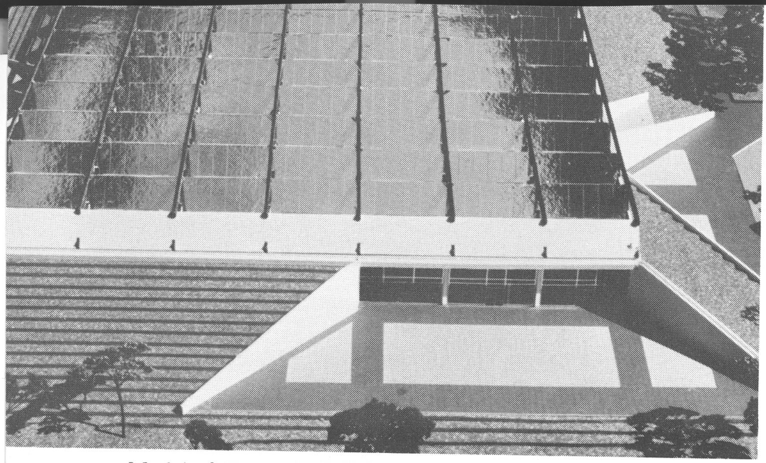
The roofing of the center structure is to be covered with 10,500 square feet of flat plate solar collectors augmented by 14,000 square feet of polished aluminum reflectors. The solar collectors are factory assembled for low-cost installation and will yield temperatures up to 200° F.

The system is expected to provide over 90 percent of the total energy required for winter heating and 60 percent of the total energy required for summer cooling.

Domestic hot water will also be supplied and in the spring and fall, heat collected from the solar panels will be used to heat an adjacent outdoor pool.

Model of Shenandoah Solar Community Center showing solar collectors.





Model of Shenandoah Solar Community Center.

Thermal hot water storage for the system is provided by a 15,000 gallon tank while cold water is stored in two 30,000 gallon steel tanks. Another 4,000 gallon hot water storage unit will be used to prevent excessive cycling of the 100-ton absorption chiller.

As an additional energy conservation effort, the building is being constructed partially below ground level.

Upon completion, researchers will observe and analyze the performance and public acceptance of the solar energy community concept.

One of the major factors contributing to Tech's involvement in developing various methods of solar heating and cooling for homes and buildings, stems from the urgency of the nation's energy crisis. The nation's supply of common heating and cooling fuels are being rapidly depleted. Successfully putting the sunbeam to work providing new sources of heat and energy for mankind will be vastly important to the future quality of life on this planet.

For additional information concerning solar research contact:

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