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1. COMPREHENSIVE ENERGY-MANAGEMENT PROGRAM
2. HYBRID PHOTOVOLTAIC/THERMAL ABSORBER

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by

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TABLE OF CONTENTS

	Page
Abstract	1
Chapter I Comprehensive Energy Management Program	4
Chapter II Hybrid Photovoltaic/Thermal Absorber	17
Chapter III Work to Be Completed During the Period January 1982 to August 1982	26

ABSTRACT

This report presents the efforts of research work done during the reporting period on the two-part research program: (A) to improve energy conservation through increased unit and system efficiencies, energy management, and system optimization and (B) to develop a novel, low-cost hybrid photovoltaic/thermal absorber. Additional objectives of this effort are to increase energy research capability at a minority institution - with regional technology transfer potential, to enhance faculty expertise and student energy-training opportunity, and to contribute to the national pool of energy alternatives.

A. COMPREHENSIVE ENERGY MANAGEMENT PROGRAM

A more efficient use of energy through conservation technology is needed at traditionally minority institutions. Their antiquated physical plants and historically weak operating budgets provide an opportunity to develop a comprehensive energy management program of direct benefit to the institution and with application to other colleges.

Performance tests were conducted on all the boilers and chillers on campus. Several corrective measures were indicated. After corrective measures were implemented retests were made which showed considerable improvement in their efficiencies and thus considerable savings in energy. A detailed survey of energy use by functions and consumption/demand study has been in progress. This includes determining spaceheating requirements, hot water requirements, cooling load requirements for each building on campus on an hour to hour basis.

A preliminary computer simulation model of the entire campus has been developed and made operational. Computer codes have been developed to

determine the ambient temperature and relative humidity on an hour to hour basis for each day of the year based on the U. S. Weather Bureau Data. Considerable progress has also been made in the development of a computer code for the optimization and energy management studies of the entire system. A preliminary optimization program has been made operational.

Relevant findings and methodologies will be communicated to similarly situated institutions.

B. HYBRID PHOTOVOLTAIC/THERMAL ABSORBER

A high efficiency absorber is essential if thermal and thermal/photo-voltaic solar power systems are to be economically competitive. We have demonstrated both analytically and experimentally under NASA grants that the re-radiation losses from the absorber can be reduced significantly by utilizing a light-pipe absorber. Additional testing is required, particularly at higher absorber temperatures, to establish with more certainty the operating characteristics of the absorber and over a broader range of conditions.

An interesting as well as a potentially useful solar device, although not at all new, is the concentration of light on a small receiver area, so that high temperatures may be achieved without large losses. Hopefully, cost is reduced by replacing expensive receiver area by less expensive reflecting area, and a thermodynamic match between temperature level and task can be achieved.

Of the various concentrators that have been proposed, the two-axis point focusing type will collect the most energy at the highest temperatures. The efficiency of a paraboloidal dish is the highest of all the collectors proposed. The reflector axis is always kept parallel to the sun's incident rays

~~and the cos θ loss is avoided.~~ In the present study, two paraboloidal dishes, one of 6 ft diameter and the other of 20 ft diameter have been utilized. Collector efficiencies have been measured at coolant outlet temperatures up to 282°C with a square light-pipe absorber and with 6 ft. diameter concentrator. Efficiency tests using the 20 ft. diameter concentrator have been delayed due to concentrator cover failures the details of which are mentioned later. Laser ray testing was conducted on both the 6ft. and 20 ft. diameter concentrators.

Design of the total energy absorber has been completed. Initial testing will be with a single $G_a Al A_s$ cell which can be moved to different locations near the base of the absorber. The single-cell test data will be valuable for positioning and sizing the solar cell array which will replace the single cell. However, the investigations have been long delayed due to the above mentioned concentrator cover failures.

CHAPTER I

COMPREHENSIVE ENERGY MANAGEMENT PROGRAM

Motivation for the Work

Conservation is a major avenue of available solutions to the energy crisis. At traditionally minority institutions the need for more efficient energy use is accentuated by the often antiquated physical plant with inefficient components and historically weak operating budgets. A comprehensive program of energy management presents immediate benefits to the institution, potential application to sister institutions, and enhancement of institutional capability in energy research by both faculty and students. Keeping these in mind, the present study was conducted by the School of Engineering of Tuskegee Institute.

Description of the Work

The present study consisted of two parts, namely, (1) determination of system parameters, and (2) system simulation and management studies. The first part covered mainly performance tests on various boilers and chilling plants, suggestion and incorporation of corrective measures for units of low efficiency, and conducting retests to note the improvements. The second part covered the development of a simulation model for the heating and cooling systems and management of the present supply and demand levels.

Determination of System Parameters

The most important system parameters from an energy conservation point of view are the boiler efficiencies and the coefficient of performance (COP) of the chilling plants. All the boilers on the Tuskegee Institute campus were first tested for their combustion efficiencies. The tests showed serious under-performance and remedial measures were prescribed. These are listed in reference (1) and will be included in the final report. After these measures were implemented, the boilers were ready for re-testing, which was done during the period January 1980 - December 1980. The re-testing showed considerable improvement in performance as indicated by higher combustion efficiencies. Considerable improvement in performance was also indicated by higher boiler efficiencies. Table 1 shows the combustion efficiencies before and after retesting. These efficiencies were computed using a computer code developed for the purpose (ref. 2) which will be included in the final report.

The chilling plants were tested for COP during the summers of 1980 and 1981. The COP's of the various chilling plants tested are shown in Table 2. Some of the chilling units, especially the main unit near the School of Engineering, showed some under performance and remedial measures are suggested and retesting will be done during the summer of 1982.

System Simulation and Management Studies

A computer code was developed to compute the gas and electricity demand of the whole campus on an hour-to-hour basis. The flow diagram of the computer code is shown in Figure 1. The heating and cooling (sensible) loads are approximately linear functions of the temperature difference between

TABLE 1

COMBUSTION EFFICIENCIES OF DIFFERENT BOILERS

Boiler	Location	Combustion Efficiency (%)	
		Before Retest	After Retest
Superior-7	Main Plant	--*	79.87
Superior-8	Main Plant	60.73	79.59
Keystone-L	Main Plant	68.06	80.84
Keystone-R	Main Plant	66.43	71.78
Kewanee-L	Veterinary Medicine	73.02	79.78
Kewanee-R	Veterinary Medicine	63.79	78.57
Kewanee-L	Wilcox-C	72.38	83.42
Kewanee-R	Wilcox-C	73.77	82.40

*Boiler was down for repairs and could not be tested.

TABLE 2

COP OF CHILLING PLANTS

Chilling Plant	Type	COP
Main Plant Unit I	Vapor Absorption System	0.4424
At School of Unit II		0.5015
Engineering Unit III		0.4959
Huntington Academic	Vapor Absorption System	0.5623
Adams Hall	Vapor Absorption System	0.522
Frissell Library	Vapor Compression System	2.425
Carnegie Hall	Vapor Compression System	3.976
O'Connor Hall	Vapor Compression System	2.672
Olivia Davidson Hall	Vapor Compression System	4.086
College Union Building	Vapor Compression System driven by a gas engine	0.6452*

*COP computed by dividing the net refrigerating effect by the calorific value of fuel supplied to the engine.

Fig. 1. Flow diagram of the computer code.

the outdoor temperature and the indoor temperature. Hence, a subroutine was incorporated in the code to compute the ambient temperature at each hour of each day in a year. This subroutine was constructed using the data of U. S. Weather Bureau (Ref. 3) and will be detailed in the final report.

For the sake of computation of energy requirement, the year was divided into three periods-- a heating period (winter season), a cooling period (summer season), and a no-heating-no-cooling transition period. Depending upon the period for which computation is made, the computer code calculated the corresponding load. The buildings on the Tuskegee Institute campus belong to three heating systems viz: (a) air-water induction system, (b) fan coil system, and (c) room radiator system. These systems are shown schematically in Figures 2, 3, and 4. For computing steam consumption on an hour-to-hour basis, appropriate subroutines for the three heating systems were incorporated in the computer code. In cooling load computation, the buildings on the campus were divided into four categories, namely, 1) central cooling with absorption-type chilling plant, 2) central cooling with compression-type chilling plant, 3) cooling by window cooling sets, and 4) no cooling. The computer code made appropriate calculations for each category. Hot water is supplied to the campus buildings during all of the seasons and energy consumption for supply of hot water was computed (hour-to-hour) for the entire year.

The electrical load on the campus included lighting, running miscellaneous equipment and appliances, and running the compression-type chilling units during the cooling period. Proper steps were included in the computer code to take care of the following facts:

Fig. 2. Air and water induction system.

Fig. 3. Fan Coil System.

Fig. 4. Steam Radiator.

- 1) Dormitories were heated or cooled, where applicable, for 24 hours a day, while office and school buildings were heated or cooled, where applicable, from 8 in the morning until 5 in the evening.
- 2) Dormitories were heated (or cooled), where applicable, for 7 days a week, whereas office and school buildings were heated (or cooled), where applicable, for 5 days a week.
- 3) Dormitories were not heated (or cooled), where applicable, during vacation periods.
- 4) Office and school buildings were scantily lighted during non-working hours of work : days and 24 hours on weekends.

However, a new energy-conscious heating schedule has recently been adopted on the Tuskegee Institute campus. This new schedule will be incorporated in the computer code and the energy saved will be evaluated.

At present, the computer code developed was used for the Tuskegee-Institute campus where the management problem investigated had two directions: 1) to study the possibility of waste-heat recovery by using economisers at least at the main plant boilers, and 2) to prescribe an hourly peak load which should not be exceeded. The purpose of the first study was to reduce expenditure on gas through waste-heat recovery. The second study was necessitated since the Institute has to pay for 75% of the peak electrical load even if the actual consumption is less than this value. However, the code can be used for any other management study with suitable modification. Some of the output information that can be obtained from the computer code has been listed in Table 3.

TABLE 3

OUTPUT INFORMATION

No.	Item
<u>Hourly Basis for Building Groups</u>	
1.	Steam demand per hour of a building group.
2.	Fuel demand per hour of a boiler group.
3.	Electricity demand per hour of a building group.
4.	Fuel saved per hour by attaching economizers to the main plant boilers. Five values are obtained for five effectiveness.
<u>Hourly Basis for the Whole Campus</u>	
1.	Hourly steam demand.
2.	Hourly fuel demand.
3.	Hourly electricity demand.
<u>Daily Basis for the Whole Campus</u>	
1.	Daily steam demand.
2.	Daily fuel demand.
3.	Daily electricity demand.
4.	Daily savings in fuel by attaching economizers to main plant boilers. Five values are obtained for 5 values of economizer effectiveness used.
<u>Yearly Basis for the Whole Campus</u>	
1.	Yearly fuel demand.
2.	Yearly electricity demand.
3.	Yearly fuel cost.
4.	Yearly fuel cost if main plant meets all the steam demand.
5.	Saving in fuel cost when main plant meets all the steam demand.
6.	Yearly saving in fuel by attaching economizers to the main plant boilers. Five values are obtained for 5 values of economizer effectiveness.
<u>Other</u>	
1.	Peak electrical load for the year.
2.	The day in which the yearly peak occurs.
3.	Average electrical loads for each month.

Summary of Results

As mentioned earlier, towards the goal of improving the component efficiencies, considerable improvement in the performance of boilers on campus have been achieved as shown in Table 4. Tests on chillers showed considerable underperformance. Remedial measures are underway and retesting will be made in the summer of 1982.

As far as energy management and optimization studies are concerned, a computer code has been developed which simulates all the systems on the Tuskegee Institute campus and can calculate on an hour-to-hour basis for each day of the year all the parameters listed in Table 3. A preliminary computer code has been made operational and several refinements to the code are underway to include all the alternatives so that a thorough and comprehensive optimization and energy management program can be obtained from the computer code for a wide variety of systems. Details of work to be completed are given in Chapter III.

TABLE 4

COMPARISON OF BOILER PERFORMANCE BEFORE AND AFTER CORRECTIVE MEASURES WERE IMPLEMENTED

Boiler	Flue Gas Temperature °F		Excess Air %		Combustion Efficiency %		Fuel Cost \$/Year		Savings	
	Old	New	Old	New	Old	New	Old	New	\$/Year	%
SU-L	442	442	120.1	5.1	59.18	79.87	203,700	152,700	51,000	25.04
KY-L	605	385	42.70	1.4	68.34	80.84	176,400	149,100	27,300	15.48
KY-R	603	540	50.9	29.0	67.56	71.78	178,900	167,900	10,500	5.88
KW-L	385	348	4.5	25.8	72.73	79.78	39,400	36,000		8.63
KW-R	400	406	100	17.7	63.31	78.57	45,300	36,500	8,800	19.42
KE-L	311	346	55.2	6.6	72.56	83.42	158,200	137,600	20,600	13.02
KE-R	364	376	44.0	7.10	74.7	82.4	153,700	130,300	14,400	9.36

Total	-	-	-	-	-	-	955,100	819,100	136,000	14.24

LITERATURE CITED

1. Kumar, G. N. and Dybczak, Z. W. Memorandum to Mr. D. C. Carter and Mr. G. L. Howell of Tuskegee Institute Physical Plant, June 1980
2. Dyer, D. F. and Maples, G. 'Measuring and Improving the Efficiency of Boilers', Department of Mechanical Engineering, Auburn University, Auburn, AL.
3. National Oceanic and Atmospheric Administration/Environmental Data and Information Service, Montgomery Local Climatological Data.
4. Procedures for Simulating the Performance of Components and Systems for Energy Calculation. American Society of Heating, Refrigerating and Air Conditioning Engineers, 3rd Edition, 1975.
5. Jennings, B. H. Environmental Engineering International Text Book Co., 1969.
6. Steam Tables. Combustion Engineering, Inc., Windsor, Connecticut, 1979.
7. ASHRAE Guide and Data Book-Systems, 1970.

CHAPTER II

HYBRID PHOTOVOLTAIC/THERMAL ABSORBER

Program Objectives

An interesting as well as a potentially useful solar device, although not at all new, is one that concentrates light on a small receiver area, so that high temperatures may be achieved without large losses. Hopefully, cost is reduced by replacing expensive receiver area by less expensive reflecting area, and a thermodynamic match between temperature level and task can be achieved.

Of the various concentrators that have been proposed, the two-axis point focusing type will collect the most energy at the highest temperatures. The efficiency of a paraboloidal dish is the highest of all the collectors proposed. The reflector axis is always kept parallel to the sun's incident rays and the $\cos \theta$ loss is avoided.

The paraboloidal dish has not been used as a solar collector extensively in the past because of the costs of compound curvature structures which direct the light on the small receiver area and the additional expense of the necessary sun tracking mechanisms. The advantage derived from the higher efficiency of the paraboloid permits some higher costs, but obviously only up to a certain point.

For power systems, higher temperatures provide an advantage in that higher thermal to mechanical energy conversion efficiencies are achievable. This trend of increasing performance with more sophisticated collection systems is accompanied by increasing costs per unit of collector area. It has been said (1) that research and development programs on technology advancement and cost reduction of concentrator manufacturing and receiver materials should be regarded as setting the pace for the development of point focusing solar thermal conversion systems.

Concentrators are also important since one of the most promising methods for reducing the presently prohibitively high cost of solar cell arrays is to replace expensive semiconductor area with relatively inexpensive reflecting concentration area. As in thermal systems, the optical efficiency and concentration effect per unit cost must be high.

Before concentrators can be expected to be used extensively, a means must be found for fabricating them cheaply, but still can be used without loss of concentration and efficiency over a sufficiently long period of operation that the cost of the thermal and/or electrical energy yield is, at worse, only slightly higher than the energy available from competing sources. To be able to meet this challenge, and in effect provide a major solar energy breakthrough, there is an urgent need now for novel concentrator design concepts that will open the door for high performance at lower costs.

In September 1977 a NASA grant (2) was negotiated with Tuskegee Institute for a research investigation of a novel absorber design concept applicable to solar power systems. To more nearly simulate actual conditions it was desired to test the absorber at a high solar intensity level. The major problem associated with the manufacture of a point focusing concentrator is developing the contour. One concentrator concept that had been studied by BEC and NASA Marshall engineers (3) is evacuating the space behind a thin aluminized film to make a solar reflector. Consequently, a pressure stabilized solar concentrator (PSSC) was constructed by the latter group to deliver to the absorber 150-250 suns. The PSSC concept became a worthy addition to the overall research task and this unique low cost reflector was combined for the first time with the equally novel light pipe absorber. In 1979, Tuskegee Institute received a DOE grant (4) to help support the program.

The research task includes an evaluation of a hybrid photovoltaic/thermal absorber containing G_a Al A_s cells, the most developed cells suitable for use with high concentrations. This portion of the research, however, has been delayed due to a greater amount of time spent on concentrator development than originally anticipated.

Initial research efforts featured thermal tests conducted on the 6 ft. diameter PSSC concentrator. As a result of this experience, it was felt that a significant size increase of the concentrator would provide several benefits and enhance appreciably the overall value of the research program, especially from the applications viewpoint. In particular, an increase of the absorber coolant (H_2O) flow rate from the 1.0 GPH (a low flow which becomes several orders of magnitude lower when in the steam production mode) to a larger value was desired for component compatibility and metering considerations. Also, the small absorber surface area of the 6 ft. diameter concentrator was marginal for the installation of a solar cell array. Finally, a larger concentrator was attractive so that, hopefully, then sufficient energy would be collected for a useful application of solar energy; e.g., space heating and cooling a reasonably sized structure.

As a result of these considerations, a 20 ft. diameter PSSC concentrator, funded jointly by NASA and DOE and built by Summit Industries, Blountsville, Alabama was installed on the campus of Tuskegee Institute, Figures 5 and 6, in late 1980 and 1981. The availability of the 6 ft. and 20 ft. sizes greatly enhanced the breadth and flexibility of the solar concentrator research at Tuskegee.

Summary of Previous Results

Collector efficiencies above 50% at medium absorber temperatures were obtained early in the program with a cylindrical light pipe/6 ft. diameter concentrator (5). Analytical studies (5) of the light pipe absorber indicated that receiver temperatures as high as 1500°F could be maintained efficiently with concentrations as low as 150. In these studies, however, losses due to conduction and convection were neglected.

The early (1978) results (5) demonstrated, for the conditions of the tests, the feasibility of the PSSC, particularly with regard to its durability, seam strength, and the use of adhesives for making the seam and rim attachment. Control of the vacuum to maintain the dish shape was easily achieved. Not so certain, however, was the stability of the Z axle concentrator design, particularly for automatic fine tracking even under moderate wind conditions.

Summary of Latest Results

In later tests (thermal only), collector efficiencies were measured at higher coolant outlet temperatures (up to 282°C) with a square light pipe absorber and with the 6 ft. diameter concentrator. The results were in general agreement with the efficiency values obtained with the cylindrical light pipe, which were made at lower temperatures. No detectable loss of efficiency due to the increase of receiver temperature level occurred. For complete verification of the light pipe reradiation analysis, however, testing with higher receiver temperatures is necessary, which will require substituting a heat transfer fluid for the more convenient fluid water.

Laser ray tracing was conducted on both the 6 ft. and 20 ft. concentrators. Special mounts were devised to provide proper alignment of the laser with the axis of the concentrators. The ray tracing was accomplished indoors on the 6 ft. concentrator, which was portable, and outdoors on the 20 ft. concentrator, with it in its normally stowed position. Since there are five seams in the 20 ft. mirror, the effect of the seams on the optics is extremely important and was studied using the laser. (For comparison, the need for research on a PSSC concentrator without seams was indicated.) It was also possible to determine the mirror optics near the rim, since the cover rim wrinkles that plagued the 6 ft. concentrator were not as noticable, at least at first. The improvement was attributed to design modifications and in the technique used in attaching the cover to the rim.

The initial installation phase of the 20 ft. concentrator (not including tracker and absorber) at Tuskegee required only 3 weeks. Considerable concentrator time with full vacuum and much more at 3/4 vacuum has now been accumulated and seam failure occurred on the first cover and also on a replacement cover. In addition, some permanent stretching of the covers was evident, which resulted in rim wrinkles.

The absorber reradiation loss study was implemented by the results of an analytical investigation made for JPL* on auxiliary IR reflectors.

Design of the total energy absorber has been completed. Initial testing will be with a single G_a Al A_s cell which can be moved to different locations near the base of the absorber. The single-cell test data will be valuable for positioning and sizing the solar cell array which will replace the single cell. However, the investigation has been long delayed due to the above mentioned concentrator cover failures.

REFERENCES

1. Wen, L., "Thermal Performance Trade-Offs for Point Focusing Solar Collectors," 13 IECEC Conference, August 1978, San Diego, California.
2. NASA, NSG-8054, "Investigation of Absorbers and Radiators for Solar Power Systems," Tuskegee Institute, Tuskegee, Alabama.
3. Brantley, L. W., "Pressure Stabilized Solar Collector (PSSC)," Solar Concentrating Collectors, Proceedings of the ERDA Conference on Concentrating Solar Collectors, Georgia Institute of Technology, Atlanta, Georgia, Sept. 26-28, 1977.
4. DOE, Grant Number ER-78-G-05-6055, "Comprehensive Energy Management Program and Hybrid Photovoltaic/Thermal Absorber," Tuskegee Institute, Tuskegee, Alabama.
5. Sellers, J. P., "Investigation of Absorbers and Radiators for Solar Power Systems," NASA, NSG-8054, Tuskegee Institute, Alabama, April, 1979.

Figure 5. 20 ft. Pressure Stabilized Solar Concentrator
Installed on the Campus of Tuskegee Institute.

Figure 6. Vice President Bush's Visit to The Campus of Tuskegee Institute. 20 ft. Concentrator Can Be Seen in the Upper Left Hand Corner.

CHAPTER III

WORK TO BE COMPLETED DURING THE PERIOD JANUARY 1982 to AUGUST 1982

A no-cost extension of the research grant from January 1982 to August 31, 1982 is requested to completed the following phases of the research program listed below. This is necessiated because of unforeseen delays explained earlier and since two of the principal investigators are on leave of absence.

ENERGY MANAGEMENT PROGRAMComponent Efficiencies

Performance tests of each component of the various systems on the campus have been compared with the design data to effect the necessary correction of disparities. The corrective measures have already been made on the boilers, and they are under way for the chillers and other components. Retesting of the chillers and other components will be done during the summer of 1982 to conduct the tests under proper load conditions. This is expected to be a continuous iterative process.

System Simulation and Optimization

The preliminary computer code developed needs considerable modifications to include all possible types of HVAC systems encountered on campuses and to include several alternatives to be studied for the optimization and energy management phase of the program. Also, a need to develop a very comprehensive computer code which can readily be applied by other institutions and the instructions that are needed to be included for adopting the computer code and the instructions needed to obtain the required output in the desired format,

is taking considerable time and will be completed by April 1982. The comprehensive computer code developed will be applied to the Tuskegee Institute campus. The recommendations from the code will be put to practice to evaluate the physical realization of the improvements and savings. These will also be included in the final report to demonstrate the effectiveness of the program suggested.

Thus, a comprehensive energy management program will be developed which will

- 1) list the component efficiency tests to be performed and the corrective measures to be undertaken to improve the component efficiencies,
- 2) instruct how to apply the system simulation and optimization code to any particular campus (or combination of systems),
- 3) enable studying a wide variety of alternatives and other parameters like
 - a) component replacement and alternatives
 - b) suggest a priority/importance matrix for load staggering decisions
 - c) select most appropriate fuel sources - availability and unit costs.

HYBRID PHOTOVOLTAIC/THERMAL ABSORBER

Tests with the 20 ft. concentrator, which were delayed because of the concentrator cover failures, will be completed. Initial testing with the Ga Al As cell absorber will also be completed during the period January to August 1982. The cell will be moved to different locations near the base of the absorber. The single cell test data will be valuable for positioning and sizing the solar cell array which will replace the single cell. All the phases of the project mentioned in the original proposal will be completed and the relevant findings will be included in the final report.