GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

SPONSORED PROJECT INITIATION

Post No
2/5

Date: June 21, 1976

Project Title: Design of a Solar Collector & Energy Storage Systems for Greenhouses and Rural Residences

Project No: B-470

Project Director: Mr. J. M. Akridge

Sponsor: U. S. Department of Agriculture; Agricultural Research Services

Agreement Period: From June 8, 1976 Until August 15,1977

Type Agreement: Agreement # 12-14-7001-830

Amount:

$39,499	USDA
20,673	EES Cost-Sharing
$60,172	TOTAL

Reports Required: Quarterly Progress Report; Final Technical Report

Sponsor Contact Person (s):

Technical Matters

Dr. T. E. Bond, Research Leader
U. S. Dept. of Agriculture; Agriculture Research Service
P. O. Box 792
Clemson, S. C. 29631

Contractual Matters
(thru OCA)

Mr. Ernest R. George
Res.Contracts & Grants Officer
Agriculture Research Services
Southern Region
U. S. Dept of Agriculture
P. O. Box 53326
New Orleans, LA. 70153

Defense Priority Rating: None

Assigned to: Applied Sciences (School/Laboratory)

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GEORGIA INSTITUTE OF TECHNOLOGY
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SPONSORED PROJECT TERMINATION

Date: 1/20/78

Project Title: Design of a Solar Collector & Energy Storage Systems for Greenhouses and Rural Residences

Project No: B-470

Project Director: Mr. J. M. Akridge - 3656

Sponsor: US Dept. of Agriculture; Agricultural Research Services

Effective Termination Date: 9/30/77

Clearance of Accounting Charges: 9/30/77

Grant/Contract Closeout Actions Remaining:

39,499 USDA
20,673 EES
60,172 Total

Agreement #12-14-7001-830

_ Final Invoice and Closing Documents
X Final Fiscal Report (Form AD-453)
X Final Report of Inventions
X Govt. Property Inventory & Related Certificate
_ Classified Material Certificate
_ Other

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Agriculture Research Services
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Assigned to: Applied Sciences Laboratory (School/Laboratory)

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CA-4 (3/76)

B-470

Quarterly Report Number 1

Submitted to the

Energy Research and Development Administration
through the U. S. Department of Agriculture
Agricultural Research Service

from

Engineering Experiment Station
Georgia Institute of Technology
225 North Avenue, N. W.
Atlanta, Georgia 30332

DESIGN OF A SOLAR COLLECTOR AND ENERGY STORAGE SYSTEM FOR GREENHOUSES AND RURAL RESIDENCES

Period Covered
6/8/76 - 8/31/76

Project Director

James M. Akridge
Senior Research Engineer
(404) 894-3656

I. INTRODUCTION

The objective of this program is to design, fabricate, test and furnish plans for a solar collector and energy storage system suitable for heating greenhouses, farm buildings, and rural residences with possible secondary use as an agricultural dryer. The purpose of the system being developed is to greatly reduce the dependence of the greenhouse and farm communities on scarce and costly fossil fuels.

Review of commercially available flatplate collectors revealed them to be far too expensive, too complicated and in most instances too fragile to appear promising for the intended application. Review of the literature revealed several promising prototype or experimental collector designs but all either required auxilliary storage or used no storage at all. Since all of the intended applications for this collector require storage, a system currently under investigation at Georgia Tech(1) for agricultural drying applications was selected as showing the most promise.

This system has been termed a solar rock collector because it uses glazed blackened rock as both the collector and storage system. Figure 1 shows an initial concept for the collector-storage system. Basically the system consists of 3" - 4" rock approximately 12" deep enclosed by a simple concrete block perimeter and covered with one or more layers of plastic glazing. The upper surface of the rock is painted black to increase its absorptivity. Air is circulated over and through the rock to both distribute the energy absorbed by the upper rock throughout the depth and to heat the

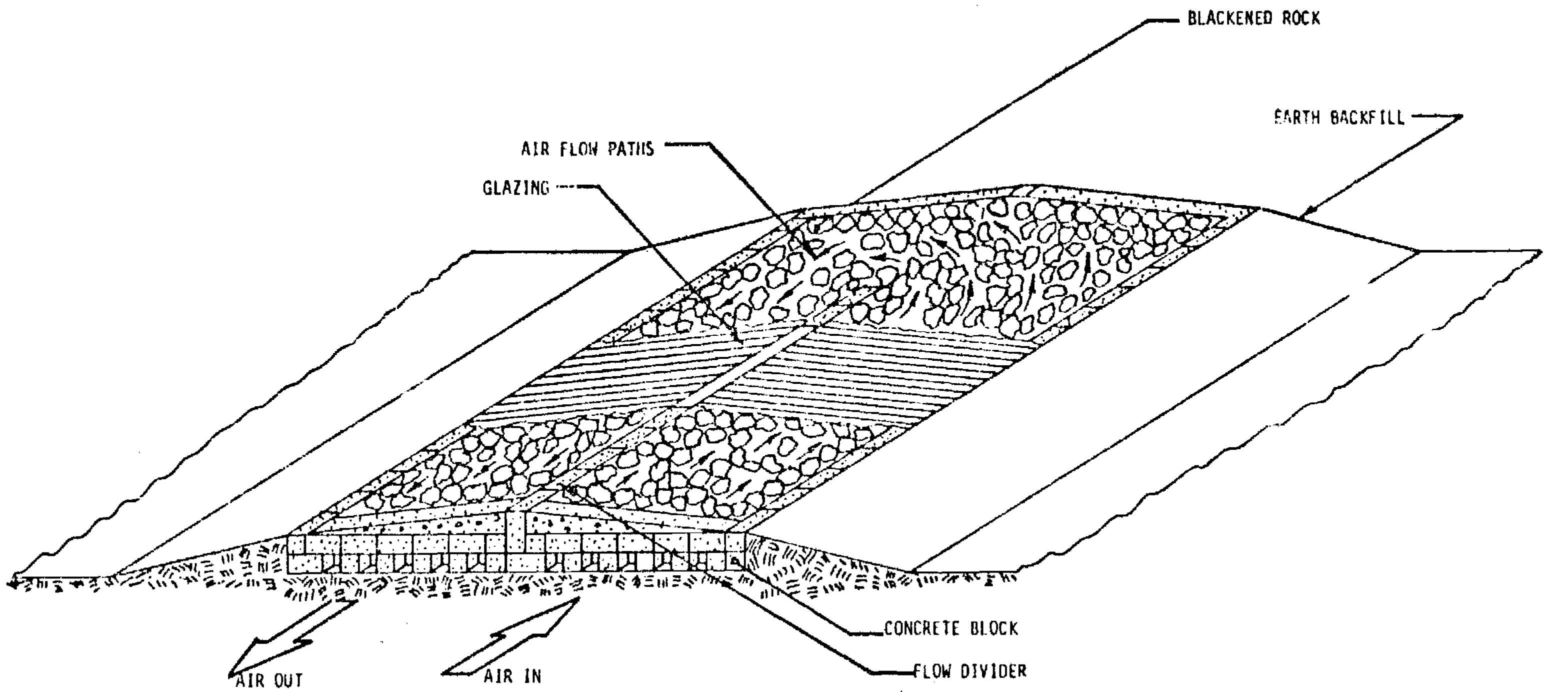

FIGURE 1. SOLAR ROCK COLLECTOR AND STORAGE SYSTEM

air which is supplied to the greenhouse or residence. The rock serve a triple function with this system. They serve as the absorber, the storage media and the heat transfer surface.

Although the solar rock collector is designed as a simple inexpensive collector and storage system which can be fabricated on-site by local labor with locally available materials, a thorough investigation and development of the concept is necessary to maximize the energy collected and stored; minimize the energy lost, the system complexity, and the system cost. It was obvious that rock size would have to be optimized to obtain the greatest storage capacity and the least pressure drop. If the rock are too small, pressure drop through the system becomes excessive and the pumping losses too costly. If the rock are too large, energy will not be conducted to the center of the rock, reducing the capacity of the system to store energy.

It was felt that certain paints may offer advantages over others and should be investigated. Although paints are only mildly wavelength selective, certain paints such as Caldwell Chemical's Solarsorb have proved to significantly improve flatplate collector performance when compared to flatblack paints.[2]

Air flow control was known to be important with the solar rock collector. Preliminary experiments[1] on the agricultural dryer collector indicated it might be difficult to get energy into the lower rock levels without resorting to vertical air flow with upper and lower headers. Since this approach is considered too costly and too complicated, air flow control was an additional parameter which needed to be thoroughly investigated.

COLLECTOR TEST APPARATUS

A parameter evaluation prototype collector was designed and put into operation during the first quarter. The prototype collector was designed specifically for evaluation of the various parameters which might have a significant bearing on a solar rock collector system. Figure 2 shows the prototype collector. Since only minor effects might be expected from several of the anticipated changes, it was felt that a dual system which would permit side by side comparisons would be much more accurate as well as more rapid than sequential tests using the same collector. Figure 2 shows the test collector to be two identical collector mounted in a single test box. This arrangement permits side by side evaluation of concepts usually identical except for one test parameter. Preliminary tests indicate the concept to be valid and the system capable of detecting minor changes.

Each collector is 17' long by 23" wide, insulated with 1 1/2 inches of urethane foam insulation on all sides and the bottom. Each collector is divided into five rock chambers, and inlet header chamber a fan shroud, an exit header chamber and a discharge tube with flow velocity and temperature probes.

It was decided that the initial experiment would evaluate the difference between two types of paints with all other factors being equal. Each of the five rock chambers in each collector was filled with 450 pounds of 2 - 3" crushed granite. The test apparatus was aligned North-South. The collector on the East side was sprayed with Glidden Spread Gloss Flat Black Number 908. The collector on the West side was sprayed with Caldwell Chemical Company's Solarsorb C-1077-3 Selective Coating.

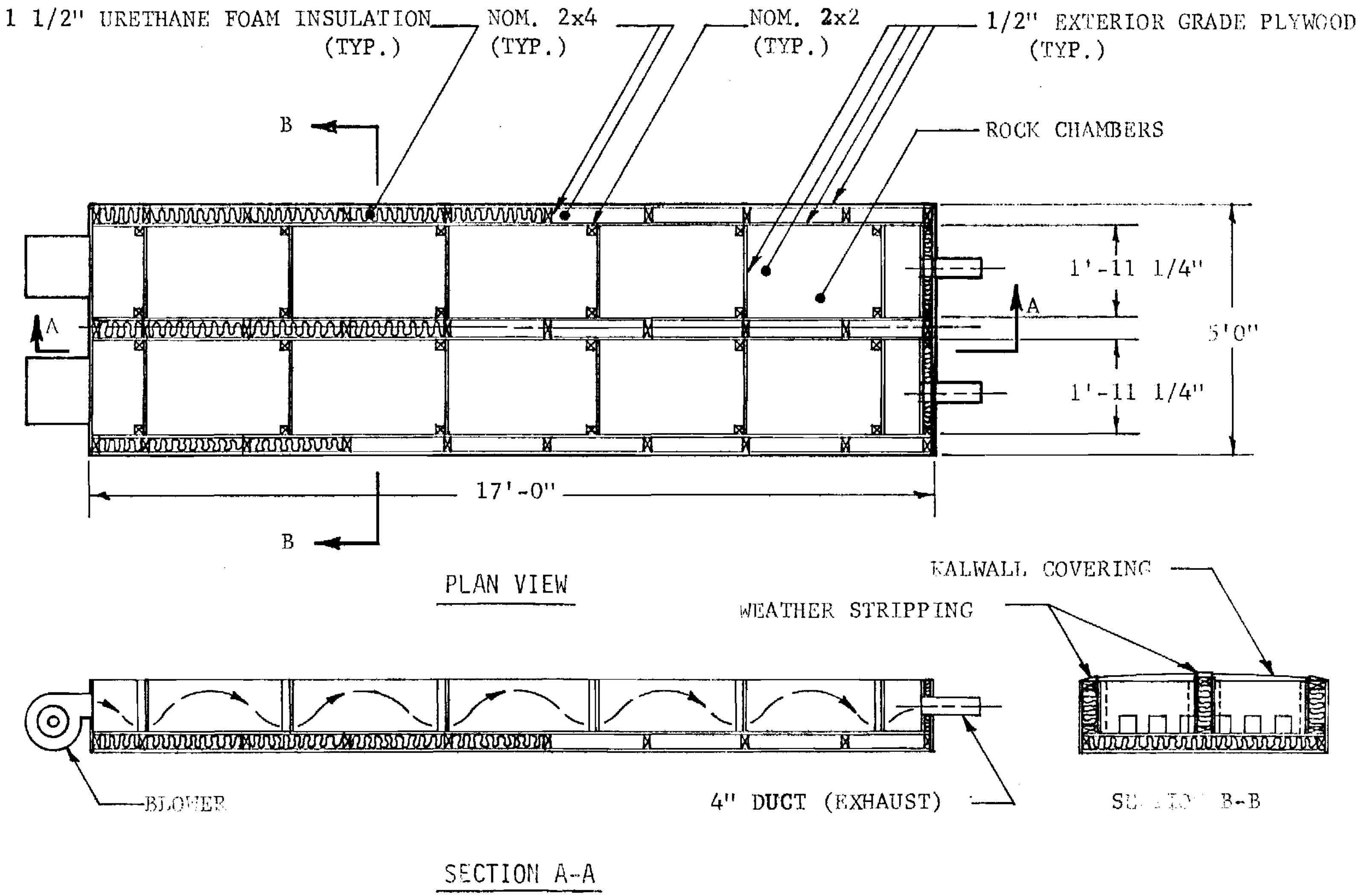

FIGURE 2. SOLAR ROCK COLLECTOR TEST APPARATUS

Both sides of the test apparatus were covered with a single 5' wide sheet of .029" Kalwall regular grade glass reinforced polyester glazing. Flexible foam weather stripping was used beneath the glazing, between the collectors, around the perimeter and along the top of the flow directors (separating the 5 rock chambers). Each chamber is equipped with a small centrifugal fan operating in a pushing rather than a pulling mode. Flow through each chamber checked out to be 120 CFM @ .86 inches of water pressure drop.

Each collector is equipped with 24 thermocouples, of which 8 are embedded in the center of individual rocks. Each rock with an embedded thermocouple also has a similar thermocouple bonded to the surface of the rock. By locating the instrumented rocks at various depths within each collector, a reasonable estimate can be made of the ability of the collector to not only collect energy but to distribute and store it.

Figure 2 shows that in the initial design, all air must flow to the bottom of the chamber dividers to reach the next chamber. Although some of the air remains along the bottom of the chambers, a significant percentage apparently flows throughout the chamber resulting in energy being moved from the upper rock to the lower rock.

INSTRUMENTATION

A variety of data systems are being evaluated to determine the system which gives the most reliable and most easily reduced data. These have ranged from single channel strip recorders to 24 channel strip recorders to 20 channel printing data loggers. Although the solar insolation station for the agricultural drying experiments is located only 200 yards from the greenhouse experiment, a complete solar and weather station is being added to the greenhouse instrumentation. This is necessary due to the different nature of the experiments and the requirement for data at different times. The need for this additional equipment was vividly emphasized when the computer which takes, stores and reduces all the data for the agricultural experiments failed just as the greenhouse experiment was put into operation.

EXPERIMENTAL RESULTS

The first quarter has been spent primarily in designing and fabricating the prototype equipment, getting the instrumentation and data system installed and designing the first experiments. Failure of the weather data computer made it difficult to take total insolation measurements. Since the new solar instrumentation will be on hand the second week in September, it was decided to prepare for immediate use of the new equipment rather than pull equipment from the agricultural experiment while the computer was being changed.

Although efficiencies could not be determined due to the lack of solar insolation data during this period, the apparatus was operated most days during the last two weeks in August. Results have been better than expected and very encouraging. Discharge air temperatures as high as 130°F at air flow rates of 120 CFM have been measured on relatively clear days. The system has demonstrated the ability to maintain temperatures 20°F above ambient over night if the fans are turned off. Discharge air temperatures on average days will remain at least 20°F above ambient even if the fans are turned on early each morning and allowed to run all day. Air discharge temperatures of 109°F have been observed on very cloudy days when one would have expected no energy to have been collected.

Temperature gradients through individual rocks have been very low, usually less than 4°F. Temperature gradient between the top rocks and the bottom rocks has been higher than desired but better than expected with the initial flow arrangement. Vertical gradients are dependent upon whether the fans are operated or not. Gradient as high as 20°F have been observed when the fans were not running.

WORK PLANNED FOR SECOND QUARTER

The system will be fully instrumented and become operational as a complete test apparatus during September. Continuous data will be taken over a two week period to determine efficiencies, best operating modes, the effect of small changes, differences between the two paints and what changes should be made to improve the performance. Modifications, tests, and performance analysis will continue throughout the second quarter.

REFERENCES

1. Sheppard, A. P., Schlag, S. H., "Design of Collectors and Instrumentation for Application to Solar Drying of Peanuts, Tobacco, and Forage", Quarterly Report submitted to ERDA from the Georgia Institute of Technology, 8 April 1976.

2. Private Communication with Mr. Jack Caldwell, Caldwell Chemical Coatings Corporation, Fayetteville, Tennessee.

B-470

QUARTERLY REPORT NUMBER 2

Submitted to the

Energy Research and Development Administration
Through the U. S. Department of Agriculture
Agricultural Research Service

From

Engineering Experiment Station
Georgia Institute of Technology
225 North Avenue, N. W.
Atlanta, Georgia 30332

DESIGN OF A SOLAR COLLECTOR AND ENERGY STORAGE SYSTEM
FOR GREENHOUSES AND RURAL RESIDENCES

Period Covered

9/1/76 - 11/30/76

Project Director

James M. Akridge
Senior Research Engineer

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EXPERIMENTAL RESULTS

Comparative tests of the Caldwell selective paint and the Glidden flat black paint showed the flat black to be slightly better overall, with rock surface temperatures reaching about 5° F higher than the selective paint. This is apparently due to the inability to closely control the selective coating thickness, the rough surface of the rock, and the lower temperatures experienced by the rock collector.

Figure 1 shows how several temperatures within the collector varied throughout a two day period. Ambient temperature is also shown on Figure 1. This plot shows that energy from the top rock is not being moved into the bottom rock as well as desired. A small continuous air flow was obviously needed to assist in moving the energy to the lower rock. Since the merit of parallel comparative tests had become questionable, the apparatus was modified to the configuration shown in Figure 3. This configuration uses a small blower to continuously circulate air through the rock. A series of dampers are used to prevent reverse flow and short circuiting. The recirculating blower only operates when insolation values are above a certain level. The optimum level has not yet been determined.

Figure 1 shows that the top rock temperature follows the ambient temperature quite closely. This is a manifestation of insolation level more than ambient temperature. It does show that the top rock is losing energy much faster than desired. Figure 2 shows the temperature gradient measured in one of the 4 inch nominal granite rocks used in these tests. The rock center temperatures, measured with a thermocouple imbedded in the rock, follows the surface temperature quite closely reaching a maximum gradient of only 5-6^{O} F. This low thermal gradient is partially responsible for the high energy losses from the top rock. The filter rock used in these earlier tests were removed and replaced with 10-12 inches nominal size crushed granite at the time the collector was modified to the recirculating configuration.

The temperature profiles shown in Figures 1 and 2 suggest that single glazing may be satisfactory when ambient temperatures are moderate, but would be totally unsatisfactory when minimum daily temperatures drop below 40-45^{O} F. The larger rock size and the recirculating fan, which moves the energy to the lower rocks, both assist in reducing energy losses and may make single glazing practical for slightly lower temperatures.

Transmissivity measurements made on the 0.029 inch regular grade Kalwall glazing revealed that transmissivity was only 77-79 percent at noon on days when the direct energy was low. The same material transmitted 86-88 percent when the direct radiation was high. This suggests that ASTM E424-71 may not be totally satisfactory for determining potential of glazing materials.

The pyronometer, pyreheliometer and weather equipment have arrived and are either installed or being installed at the present time. The weather has been so bad since the pyronometer was installed, meaningful collector performance data have not been taken.

Work Planned for Third Quarter

The experimental collector will be double glazed and evaluated during the third quarter. Proper control for the recirculating fan will be determined and implemented. Two ground based collectors will be designed for investigation of whether insulation is necessary beneath the rock or whether the ground can be used as part of the heat sink. The ground based collectors will also be used to determine satisfactory methods of preventing moisture from accumulating in the collector, to determine better methods of attaching the glazing and to investigate other potential problems related to locating the collector directly on the ground.

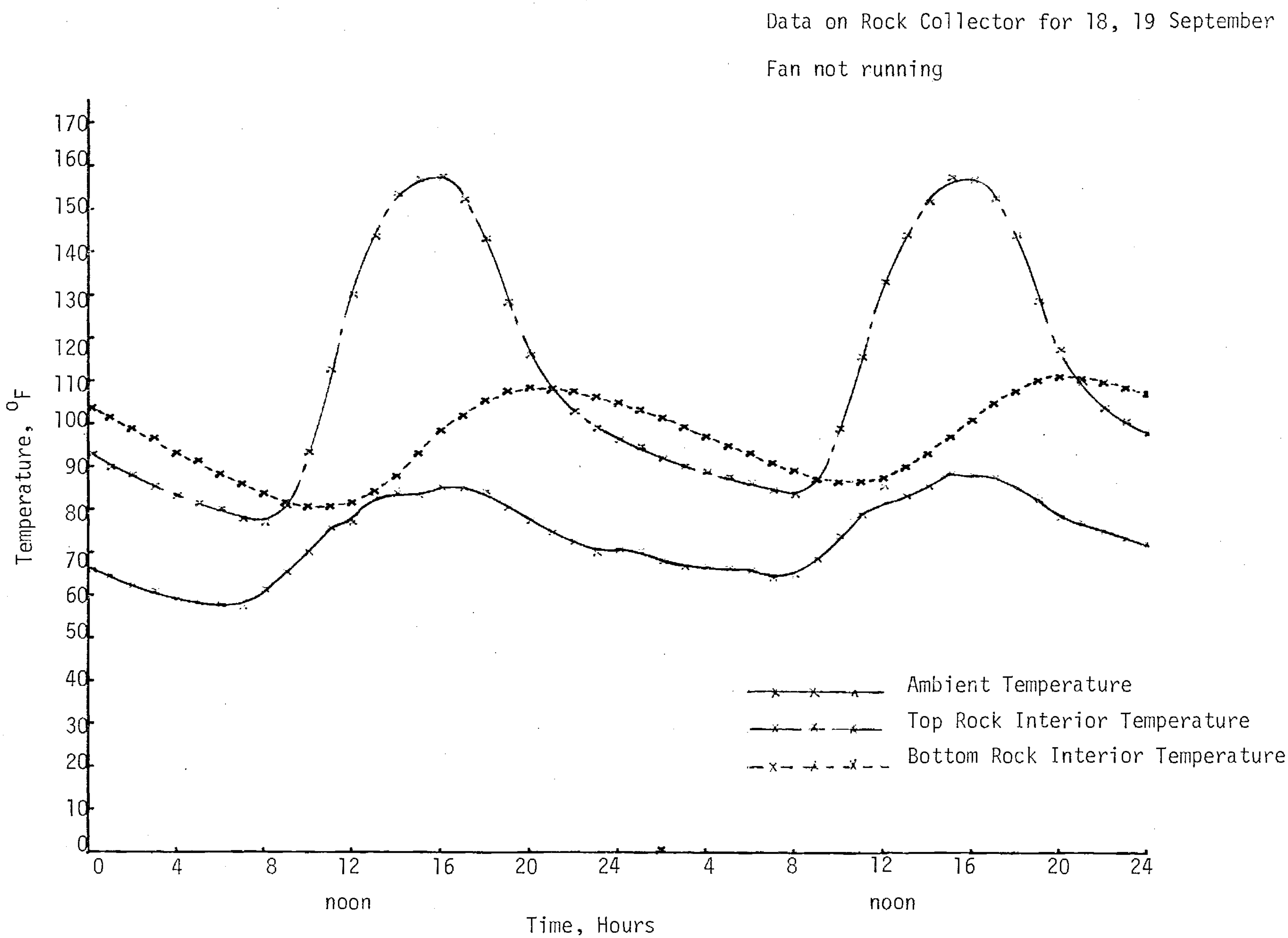

Figure 1. Performance of Experimental Solar Rock Collector.

Data on Rock Collector for

18, 19 September - Fan not running

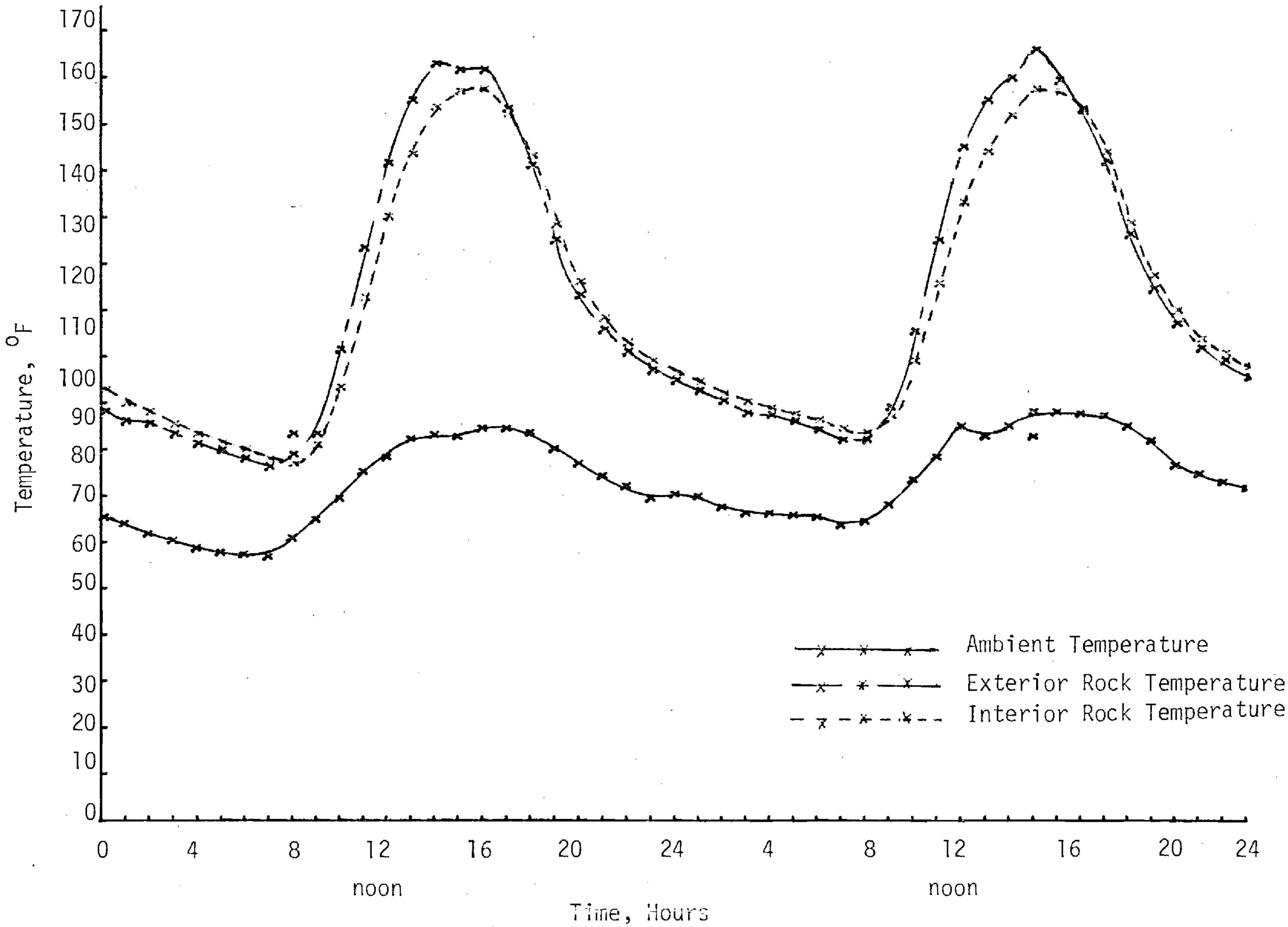

Figure 2. Interior and Exterior Temperatures of 4-Inch Granite in Solar Rock Collector.

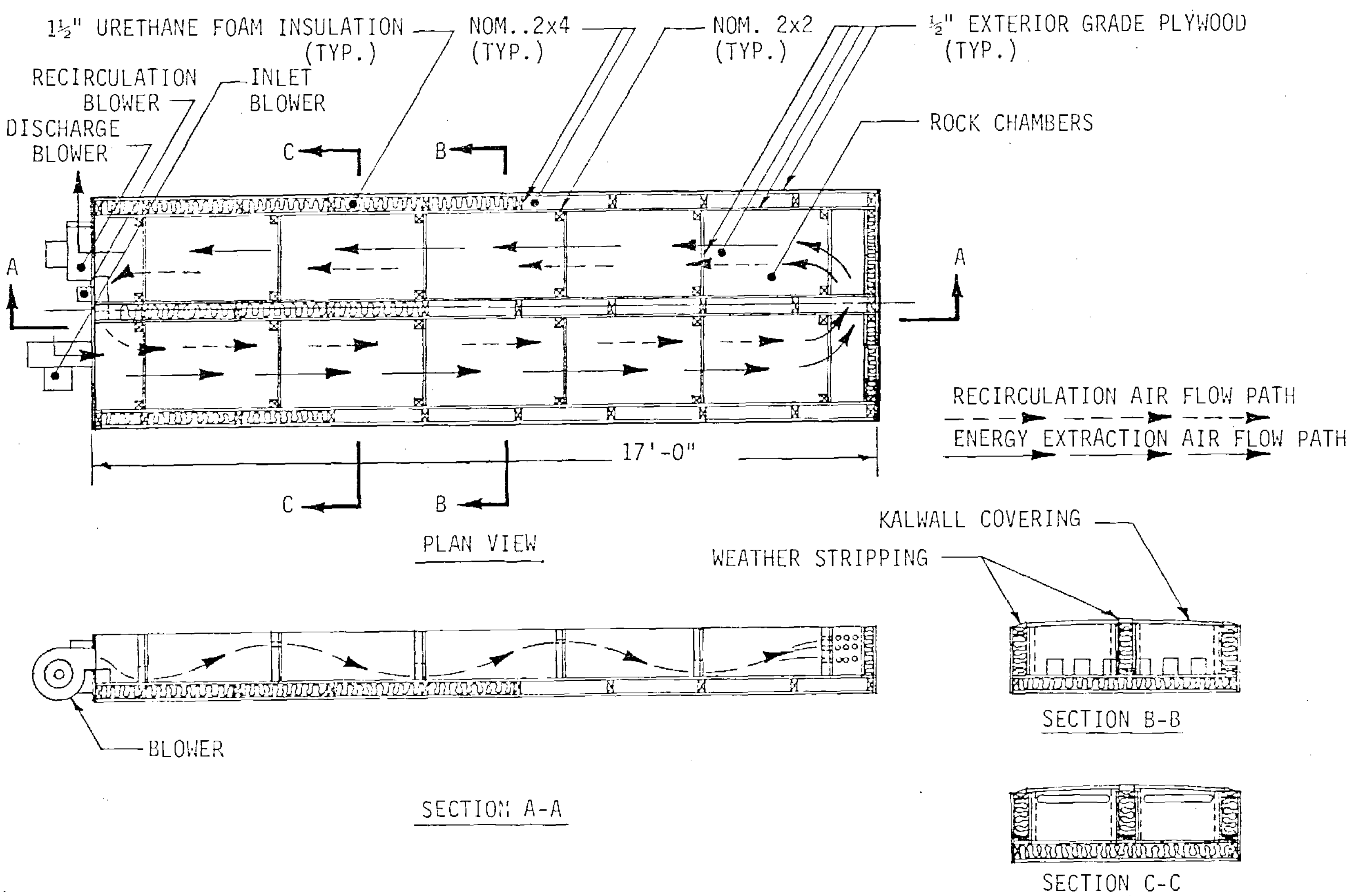

Figure 3. Solar Rock Collector Test Apparatus (modified).

B-470

QUARTERLY REPORT NUMBER 3

DESIGN OF A SOLAR COLLECTOR & ENERGY STORAGE SYSTEMS FOR GREENHOUSES AND RURAL RESIDENCES

Submitted to

Energy Research and Development Administration
Through the U. S. Department of Agriculture
Agricultural Research Service

By the

Engineering Experiment Station
Georgia Institute of Technology
225 North Avenue, N.W.
Atlanta, Georgia 30332

Period Covered

12/1/76 - 2/28/77

Project Director
James M. Akridge
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RESULTS OF THIRD QUARTER WORK

Work on the experimental solar rock collector has been seriously hampered by the severe weather experienced in late January and early February. The collector was double glazed using tedlar coated corrugated glass reinforced polyster. Experience with the single glazed collector showed the glazing surface had too little slope, resulting in a tendency to collect water on the glazing rather than draining as desired. The center of a second glazing was raised an additional 1½" above the edges resulting in a pronounced crown as shown in Figure 1. The double glazed collector has sufficient crown to drain properly.

Water condensation between the two glazings has been traced to breathing past the neoprene washers around the aluminum nails used to hold down the second glazing. The air between the glazing becomes hot on sunny days and exhausts around these washers. At night the air cools, pulling moist outside air past the washers. The moisture in this air then condenses on the top glazing. Examination of the washer sealing revealed that the manufacturer recommended 5/32" diameter hole is too small, resulting in the aluminum nail binding on the glazing. This prevents the neoprene washer from sealing. The hole size was increased to 7/32" which permits the washer to seal properly.

Double glazing resulted in a substantial improvement in the collector performance. Figure 2 shows a top rock and a bottom rock temperature profile over a 72 hour period. Ambient temperature and solar insolation are also plotted on Figure 2. The data shown in Figure 2 follows several days of cloudy weather with little or no solar insolation. Although the rock collector

Figure 1. Solar Rock Collector and Storage System.

was not designed for storage over several days, Figure 2 shows the storage temperature to be approximately 20^{o} F above ambient. The first day plotted, March 6, was also cloudy as shown by the insolation plot. Although storage temperature had dropped to 56^{o} F by 7:45 March 7th it maintained a temperature 20^{o} F above ambient. The weather was very clear on March 7th and 8th resulting in the storage temperature increasing substantially. Storage temperature was 73^{o} F, 32^{o} above ambient, at 7:45 am on March 8th and 82^{o} F, 40^{o} above ambient, at 7:45 am on March 9th.

The present collector has a collector area of 62 ft^2 and a rock storage load of 5500 lbs. giving approximately 89 lb of storage per pound of collector area. This storage to collector area is approximately correct for separate collectors and storage, but appears to be high for a combination collector storage system, resulting in lower storage temperatures.

The solar instrumentation and data acquisition systems have been refined considerable during this quarter. Figure 3 is a schematic of the system instrumentation. The continuous insolation integration has proven to be a considerable improvement over manual integration of stripchart plots.

Work Planned for Fourth Quarter

The ground based collectors will be put into operation during the fourth quarter to determine the optimum storage depth and insulation requirements. These systems will be designed to be less experimented and more applied in nature, i.e., emphasis will be put on building systems which can be easily fabricated by others who may wish to use such a system.

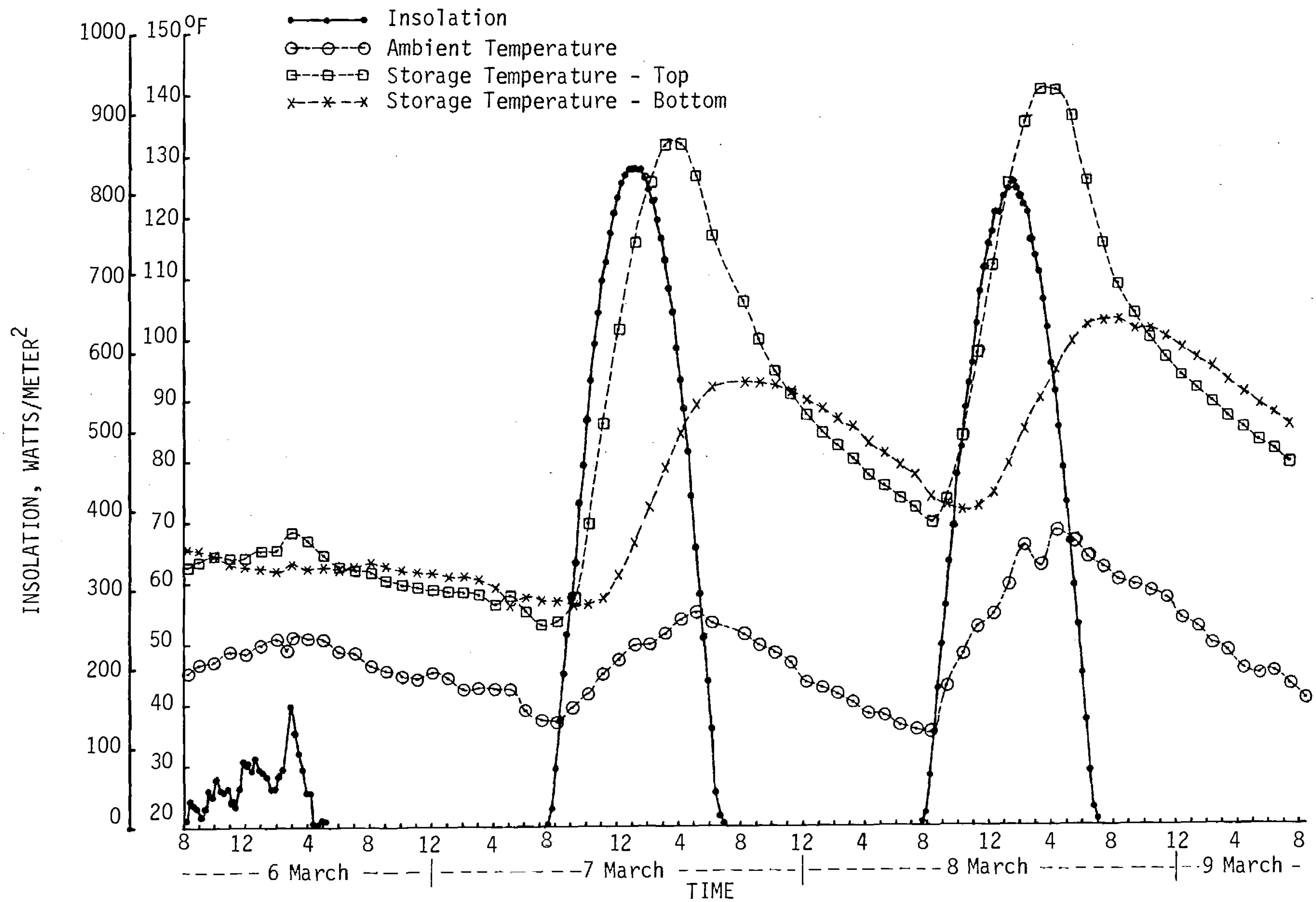

Figure 2. Solar Rock Collector Thermal Performance

INSOLATION, WEATHER, AND SOLAR TEST FACILITY
OF SOLAR ENERGY AND MATERIAL TEST DIVISION

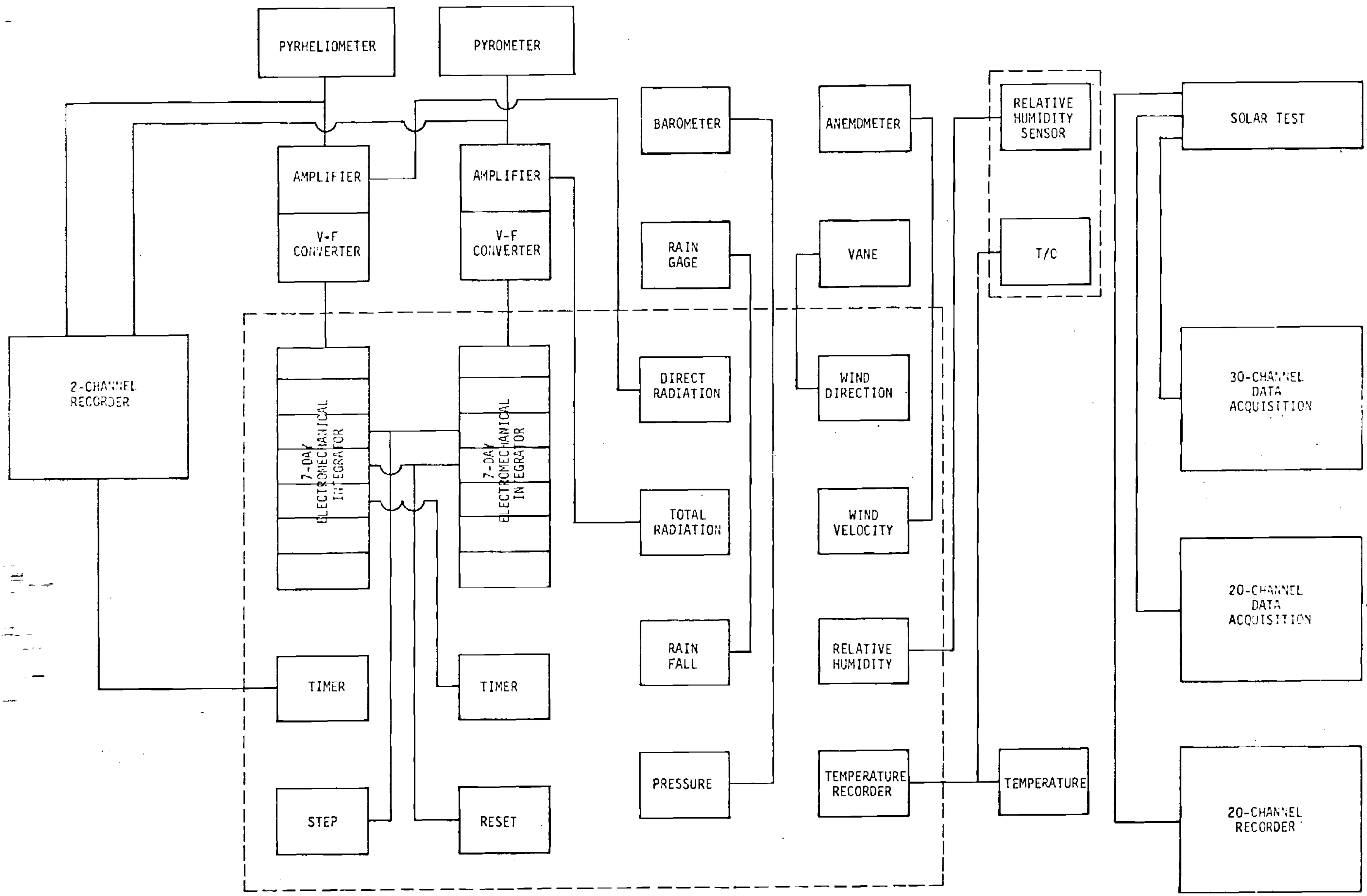

Figure 3. Instrumentation and Data Acquisition System.

QUARTERLY REPORT NUMBER 4

DESIGN OF A SOLAR COLLECTOR & ENERGY STORAGE SYSTEMS FOR GREENHOUSES AND RURAL RESIDENCES

Submitted to

Energy Research and Development Administration
Through the U. S. Department of Agriculture
Agricultural Research Service

By the

Engineering Experiment Station
Georgia Institute of Technology
225 North Avenue, N. W.
Atlanta, Georgia 30332

Period Covered

March 15, 1977 - June 15, 1977

Project Director

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RESULTS OF FOURTH QUARTER WORK

Work during the fourth quarter has concentrated on determining the performance characteristics of the Solar Rock Collector (SRC), designing systems which are very easily constructed at low cost, and developing a simplier operating procedure than currently used with the experimental SRC.

The performance characteristics are being determined by imposing different load or energy extraction profiles on the system. This is accomplished by operating the energy extraction fan for varying periods of times at different times during the day or night.

Since the SRC was originally conceived and is presently being developed for relatively short term (less than 24 hours) energy displacement and was never intended for long term storage, it has a higher loss coefficient than more elaborate and expensive storage systems. Complete operational characteristics make it possible to determine how the system should be used to obtain the greatest energy displacement.

Figures 1, 2 and 3 show the performance of the SRC under three different load profiles. Although these data were taken when ambient temperatures were higher than when greenhouses and residences typically need heat, they can be extrapolated to months and temperatures when the greenhouses do need significant energy. Due to the relatively high loss coefficient of the SRC, it is better to use the energy as early as possible and displace fuel rather than wait until peak demand times such as very early morning as one night with more elaborate systems.

The SRC has proved to be a relatively efficient collector with all day efficiencies above 40 percent. It has been difficult to define efficiency

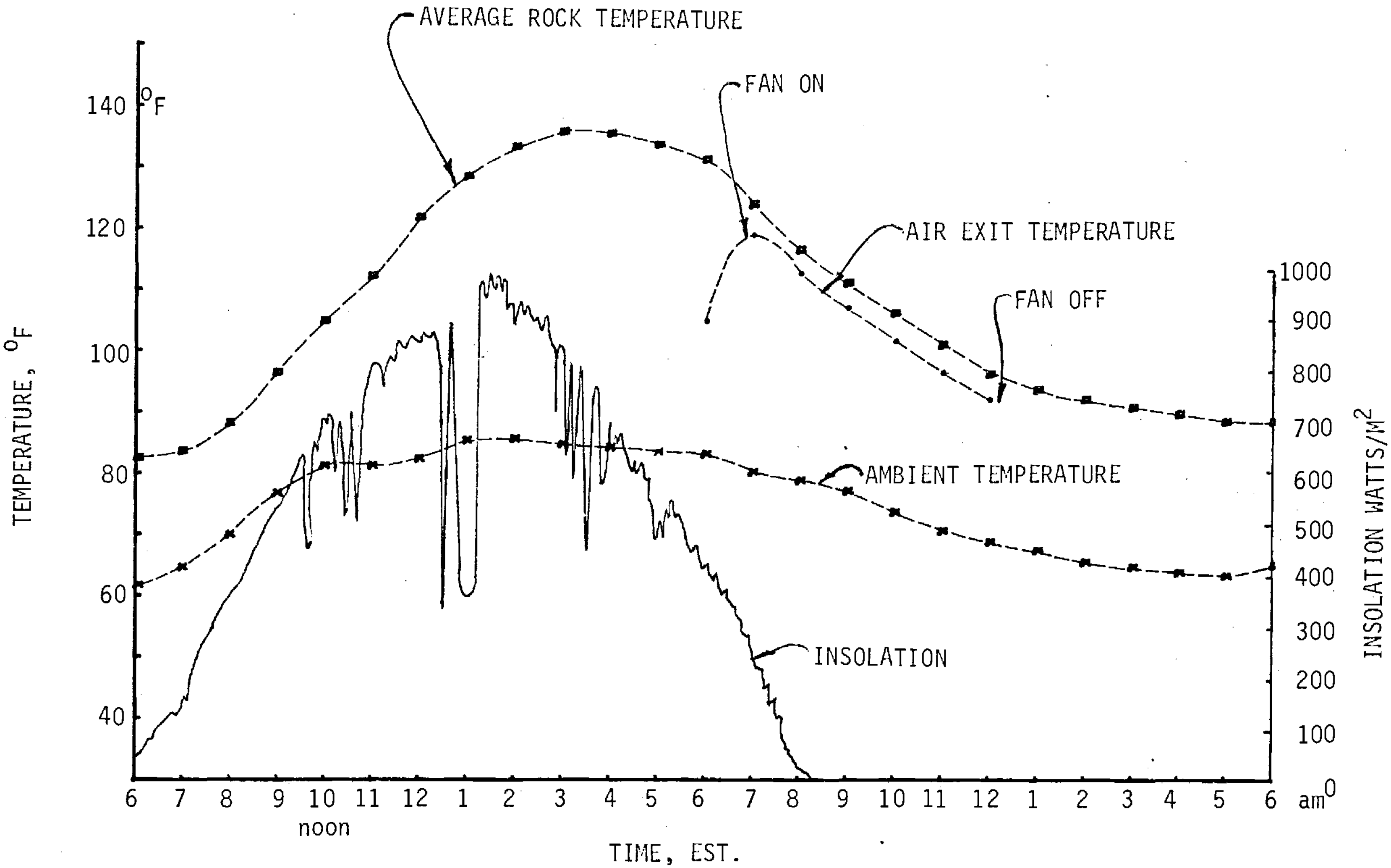

Figure 1. Performance of Solar Rock Collector - 18 May 1977.

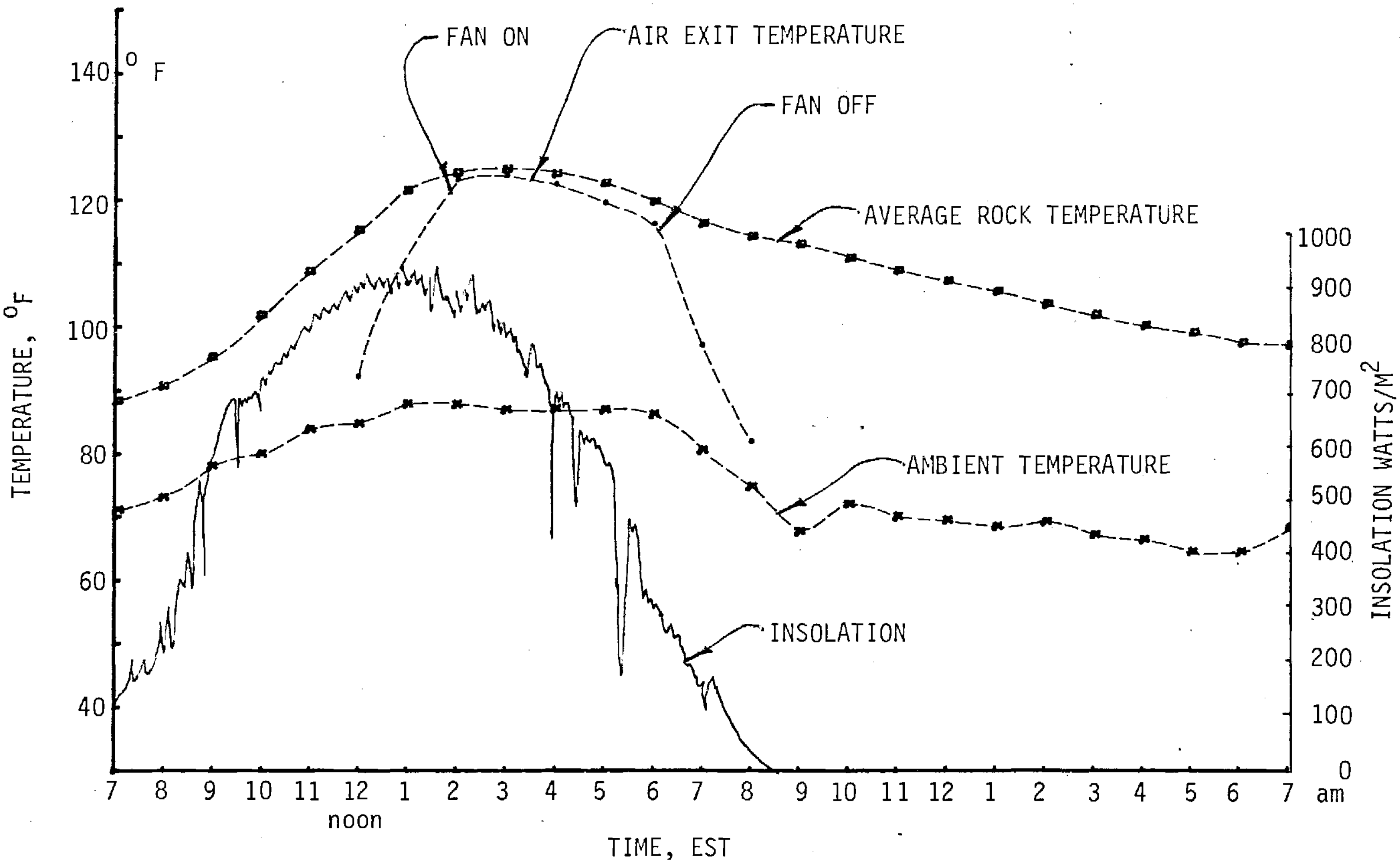

Figure 2. Performance of Solar Rock Collector - 15 May 1977.

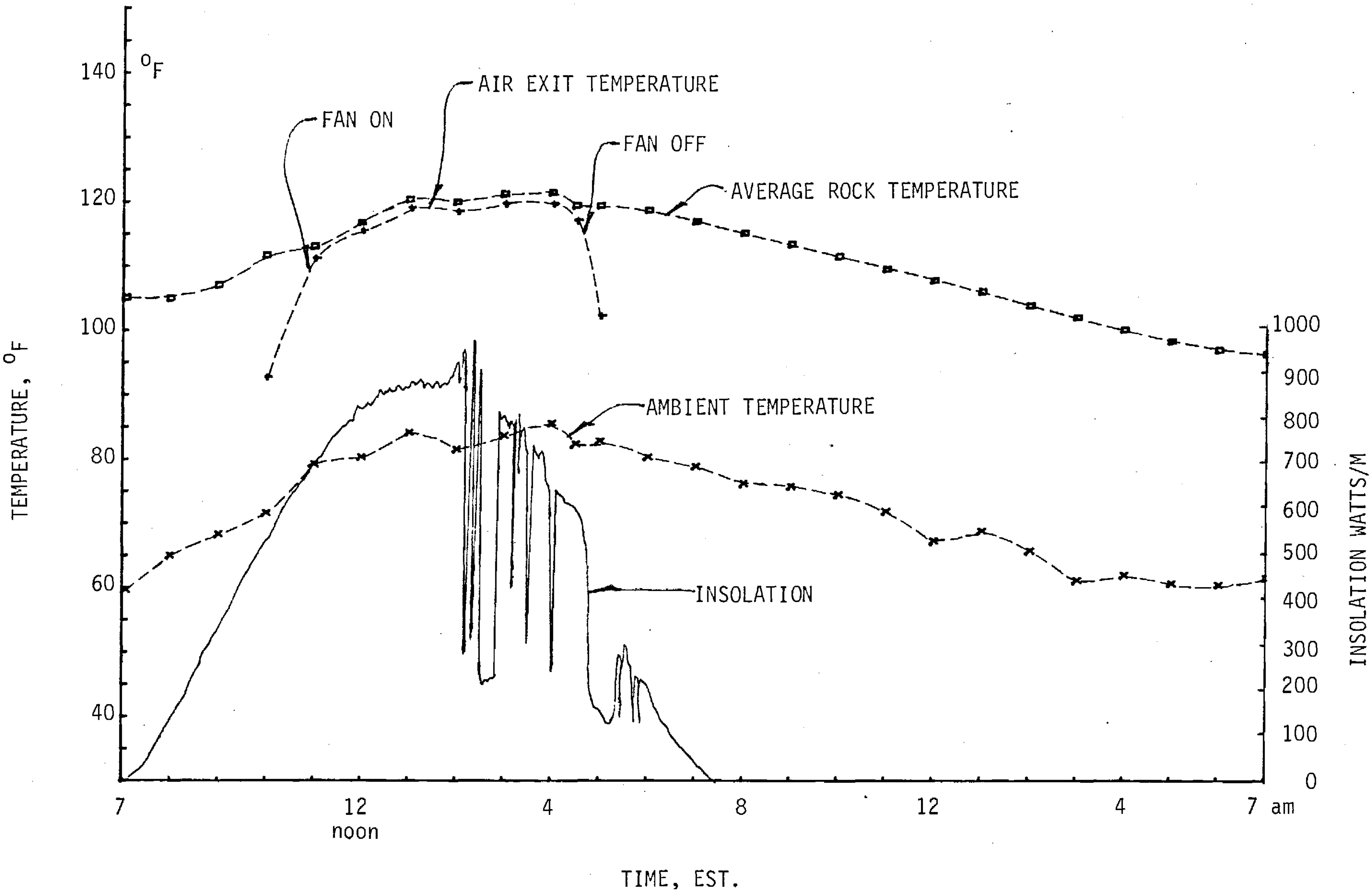

Figure 3. Performance of Solar Rock Collector - 14 April 1977.

for a combination collector storage system such as the SRC. The 40 percent efficiency quoted above was determined by dividing the increase in energy within the system from sunup to sundown by the solar energy received during that period and multiplying by 100. This method of defining effiency leaves much to be desired, but does provide an indication of system performance.

It has been determined that there is significant leakage past the dampers when the recirculating blower is operating and when the system is inoperative such as at night. These losses and the additional complexity and control necessary when a recirculation system is used, prompted a design study to determine whether the system could be redesigned to both improve performance and reduce complexity and cost. Temperature profiles of individual rocks have established that even the 10-12 inch nominal size granite experiences a maximum of 6^{o} C (10^{o} F) temperature gradient. Figures 4 and 5 shows the performance of the SRC on 10 June 1977, when the maximum total radiation reached a peak of 980 watts/m^2 with a total of 8520.3 watt-hrs/m^2 for the day. Internal and external temperatures of a top rock are plotted in Figure 5, showing how the gradient varies.

Since the recirculating system is required only to move energy from the upper rock to the lower rock, it would not be needed if the collecor was only one rock deep. Figure 6 shows one version of the improved SRC. This system not only doesn't require a recirculating system and related controls, it employs an air inflated double glazing which could be of polyethylene, PVC, Lexan, etc. This is only one of several variations of the single layer solar rock collector which are much simplier, less expensive, and should perform better than the experimental collector presently being tested.

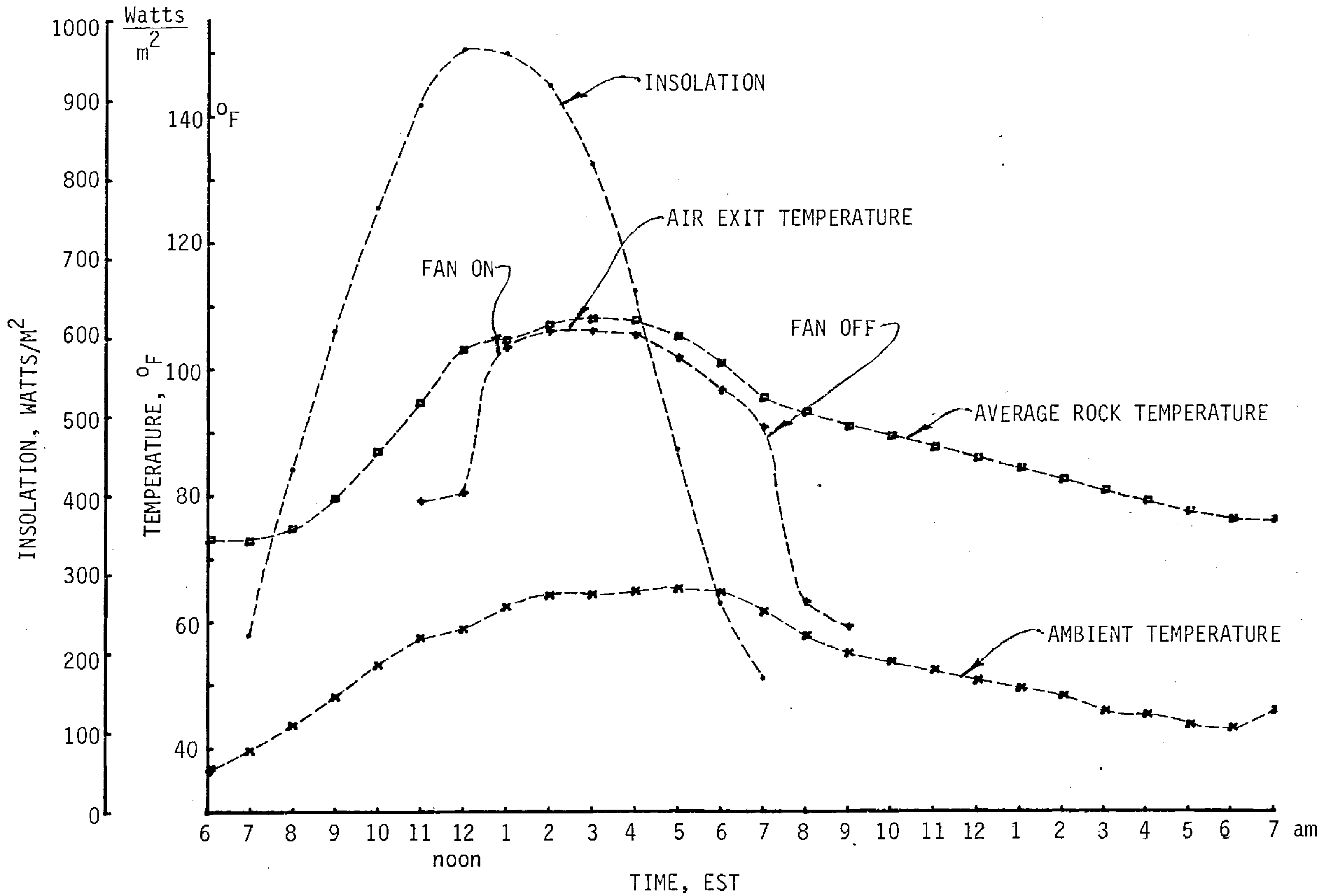

Figure 4. Performance of Solar Rock Collector - 10 June 1977.

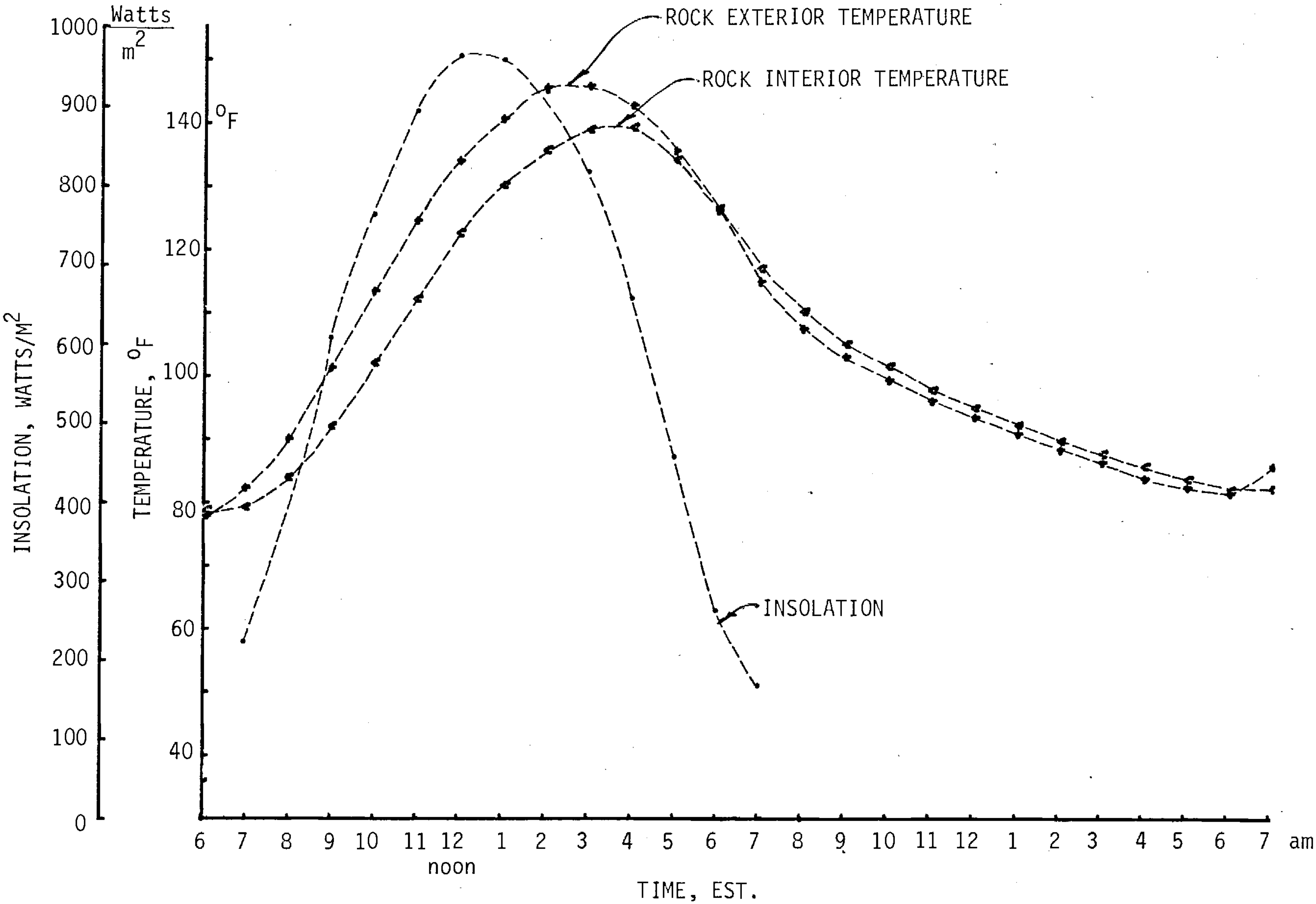

Figure 5. Comparison of Interior and Exterior Rock Temperatures - June 10, 1977.

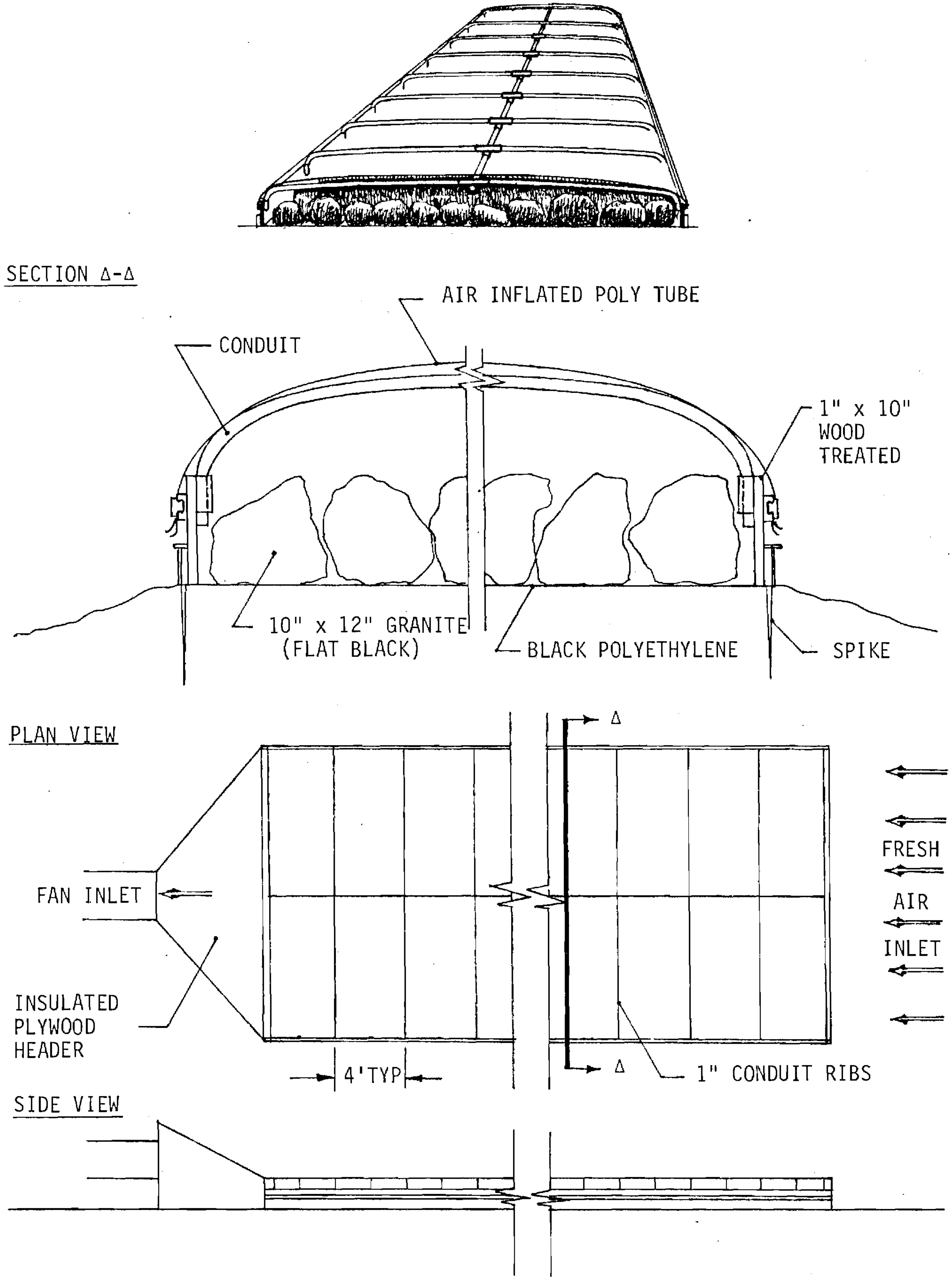

Figure 6. Single Layer Solar Rock Collector.

This program is scheduled to end on 15 August 1977. Work during the remaining two months will concentrate on developing several optimized variations of the single layer solar rock collector with drawings of sufficient detail to permit construction. The experimental collector will continue to be used to determine performance characteristics over a wide range of loads.

B 470

QUARTERLY REPORT NUMBER 5

DESIGN OF A SOLAR COLLECTOR AND ENERGY STORAGE SYSTEM FOR GREENHOUSES AND RURAL RESIDENCES

Submitted to

Energy Research and Development Administration
Through the U. S. Department of Agriculture
Agricultural Research Service

By the

Engineering Experiment Station
Georgia Institute of Technology
225 North Avenue, N. W.
Atlanta, Georgia 30332

Period Covered

June 16, 1977 - August 15, 1977

Project Director

James M. Akridge
Senior Research Engineer

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RESULTS OF FIFTH QUARTER WORK

Work during the fifth quarter has concentrated on analyzing the data and results from Solar Rock Collector (SRC) systems tested over the past year. The objective of this detail review was to determine how the SRC rates as a low cost solar collector and energy storage system for greenhouses and rural residences; to determine which versions work best with which end use, and to decide where additional effort, if any, should be directed.

Summary

Tests were conducted on Solar Rock Collectors in a number of different configurations. Analysis of these results permit the following general statements:

1. All day efficiencies of better than 40 percent are possible with SRC's, even with recirculating versions.

2. Single layer (one rock deep), non-recirculating SRC's can be fabricated in place for less than \$2.00/ft^2 with rigid double glazing (Figure 1), and for less than \$1.50/ft^2 with air inflated double film glazing (Figure 2).

3. Single layer non-recirculating collector are not only simplier and less expensive than recirculating SRC's, but are more efficient due to elimination of damper and forced convection losses.

4. When granite is used as the absorber and storage media in Solar Rock Collectors, the individual rock should be 10-12 inches nominal diameter.

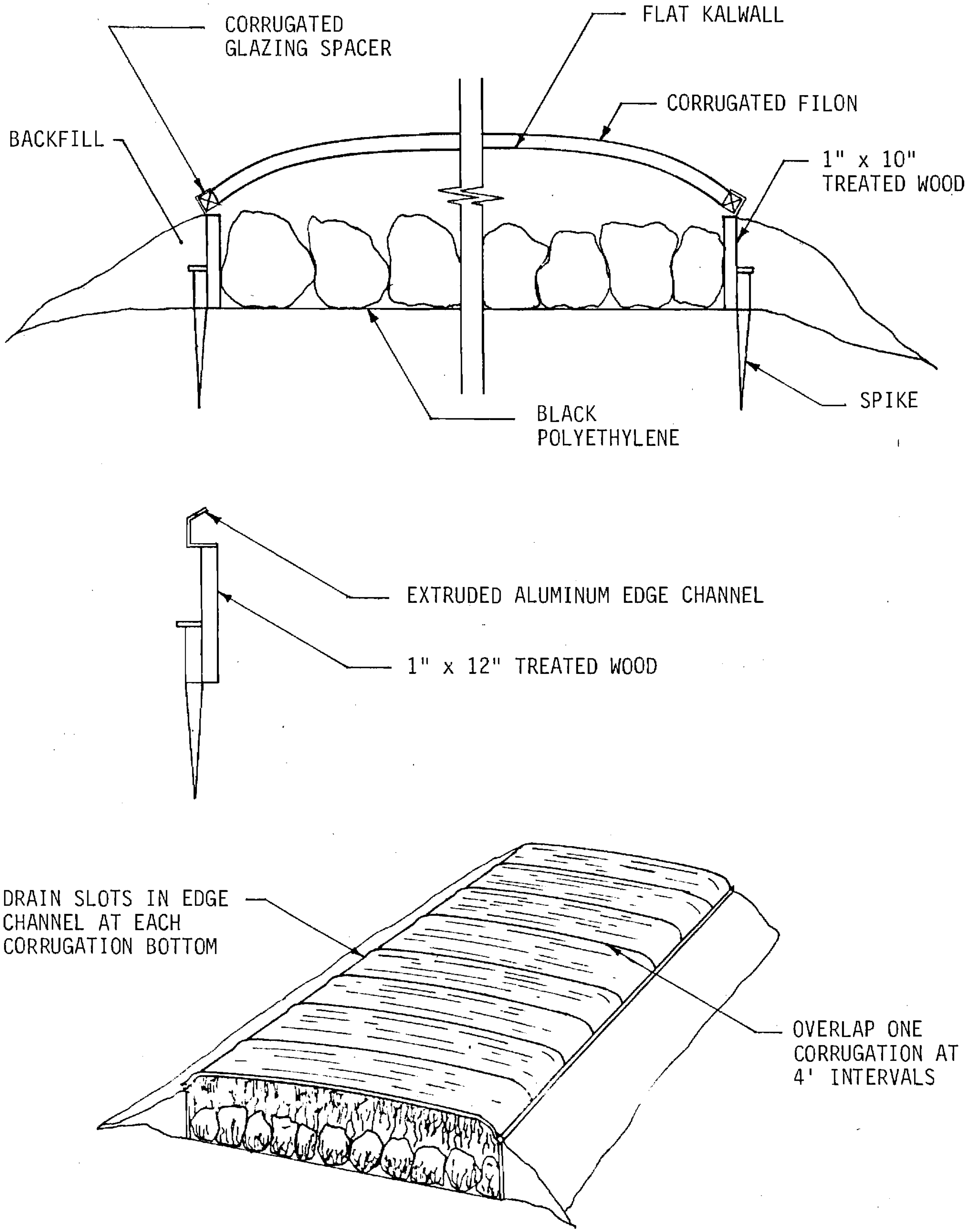

Figure 1. SRC with Double Rigid Glazing.

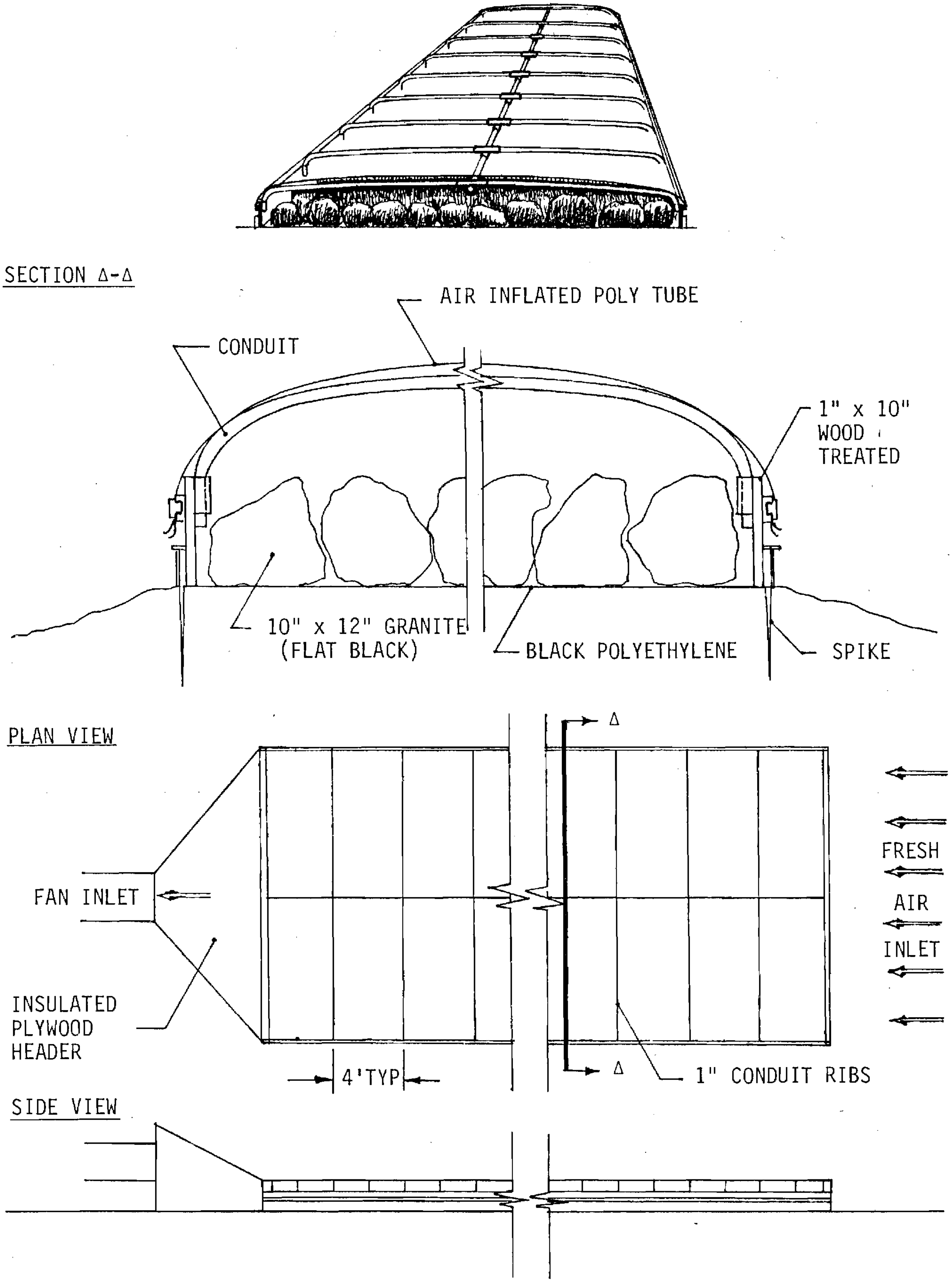

Figure 2. Single Layer Solar Rock Collector.

5. The Solar Rock Collector appears to be an economically practical energy source for single greenhouses of less than 5000 ft^2 and for attached greenhouse-residence combinations.

6. The SRC appears to have significant potential for heating rural residences, especially when used in combination with air-to-air heat pumps.

7. The SRC should be located along the south wall of a greenhouse or residence.

8. Continuous air recirculation is needed while collecting solar energy with SRC's that are more than one rock deep.

9. Recirculation is not needed nor desired for SRC's which are only one rock deep.

10. If placed directly on the ground, a vapor barrier must be placed beneath the rock.

11. Dry earth will work well as insulation if care is exercised to eliminate moisture, such as the use of a vapor barrier both below and above the earth insulation (Figure 3).

12. Plastic glazings, which frequently fail during the summer months when used with flat plate collectors, appear to be more durable when used with SRC's because the thermal mass of the rock limits the maximum collector temperature.

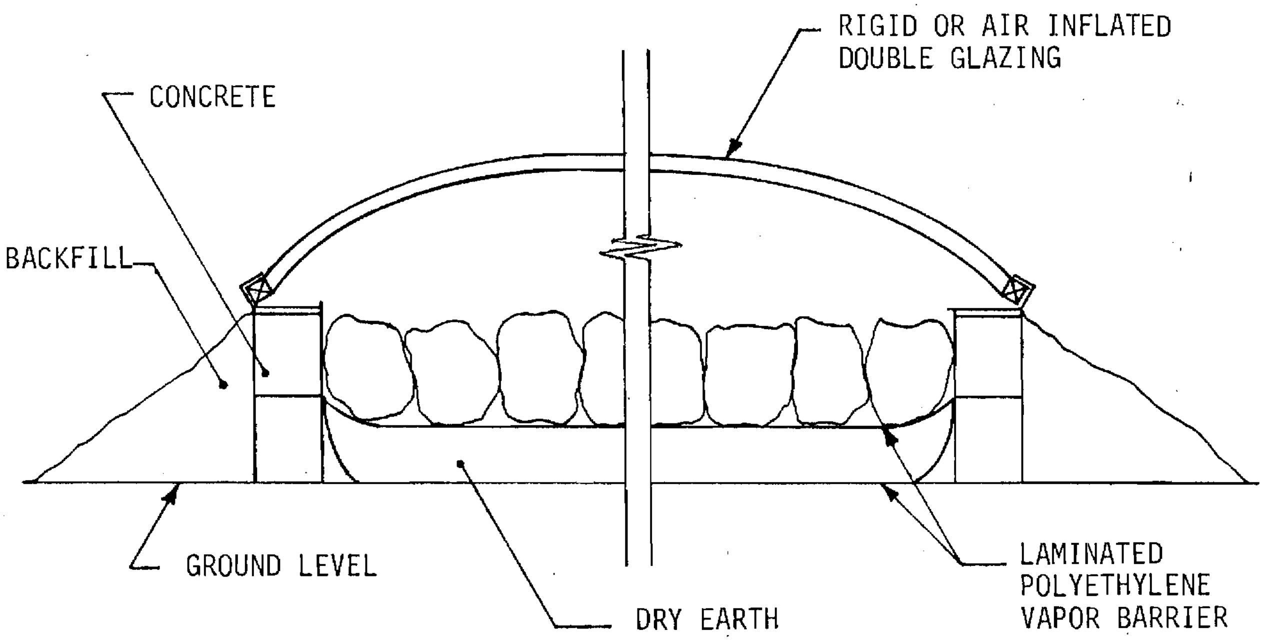

Figure 3. Sandwiched Dry Earth Used for Ground Insulation.

13. The Solar Rock Collector will work satisfactorily when located horizontally, as demonstrated by the experimental collectors, but becomes more efficient when located on a south facing hill.

14. Energy storage times can be improved significantly with an insulated top cover for use at night or during inclement weather.

15. Single glazed Solar Rock Collectors are less costly and are satisfactory for locales where minimum daily temperatures are above 7^{o} C (45^{o} F).

Tests with the experimental Solar Rock Collector have demonstrated its ability to collect and store energy at temperature levels useful for greenhouse and rural residence heating. Figures 4 and 5 show the performance of the SRC when subjected to two different load profiles. These curves also show the collector to have a high loss coefficient, indicating the collected energy should be used as soon as possible as fuel displacement, rather than being stored until a period of maximum demand.

Average rock temperature can be controlled by changing the rock mass to collector area ratio. The experimental collectors used in these tests have all had 85-90 pound of granite per ft^2 of collector aperture. It is believed this is high and should be reduced to approximately 75 lb/ft^2.

Further Work

The data from the tests conducted during the past year are sufficiently complete and promising to justify the installation of a Solar Rock Collector as a supplemental heat source for a commercial or large residential greenhouse or as a supplemental heat source for a residence.

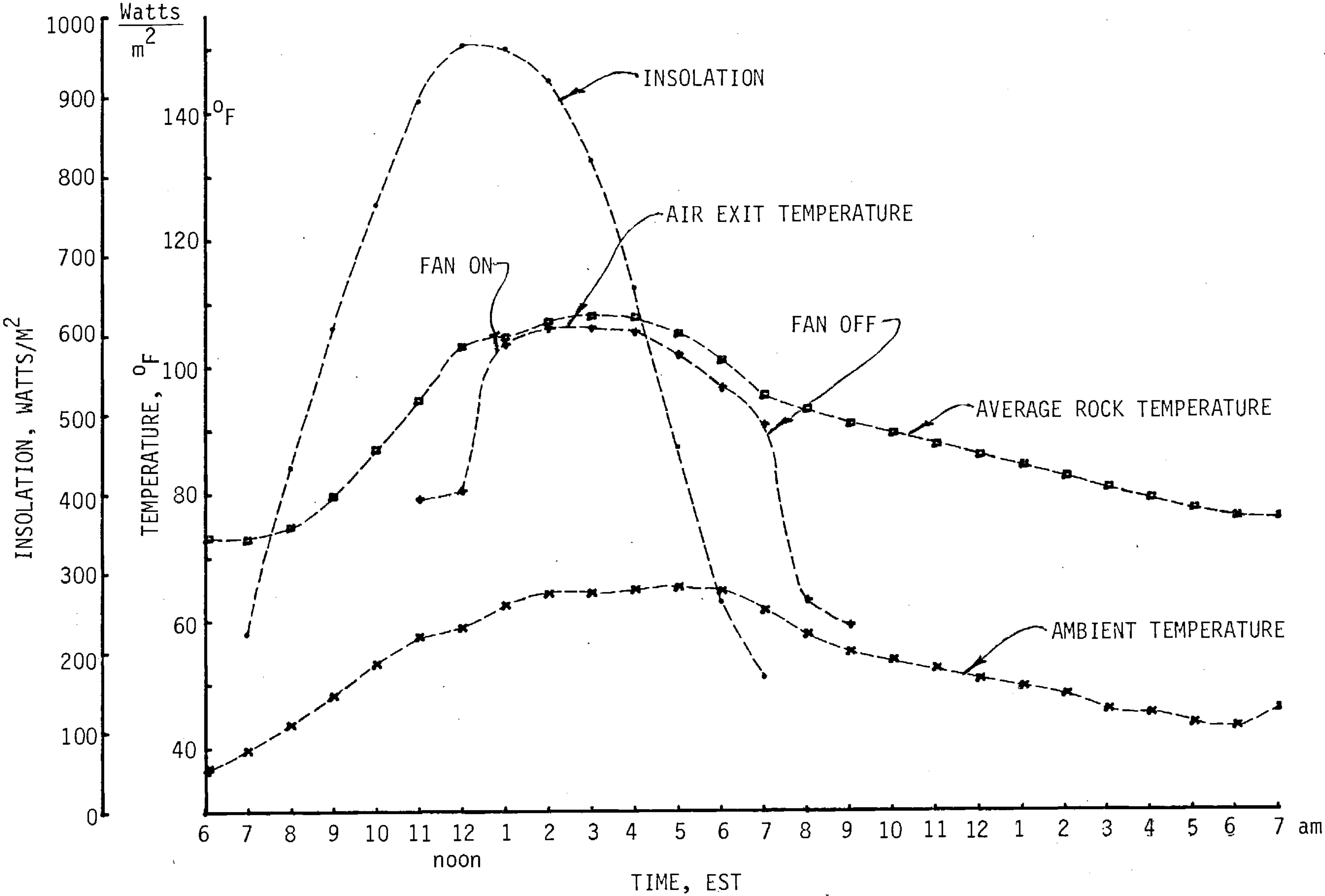

Figure 4. Performance of Solar Rock Collector - 10 June 1977.

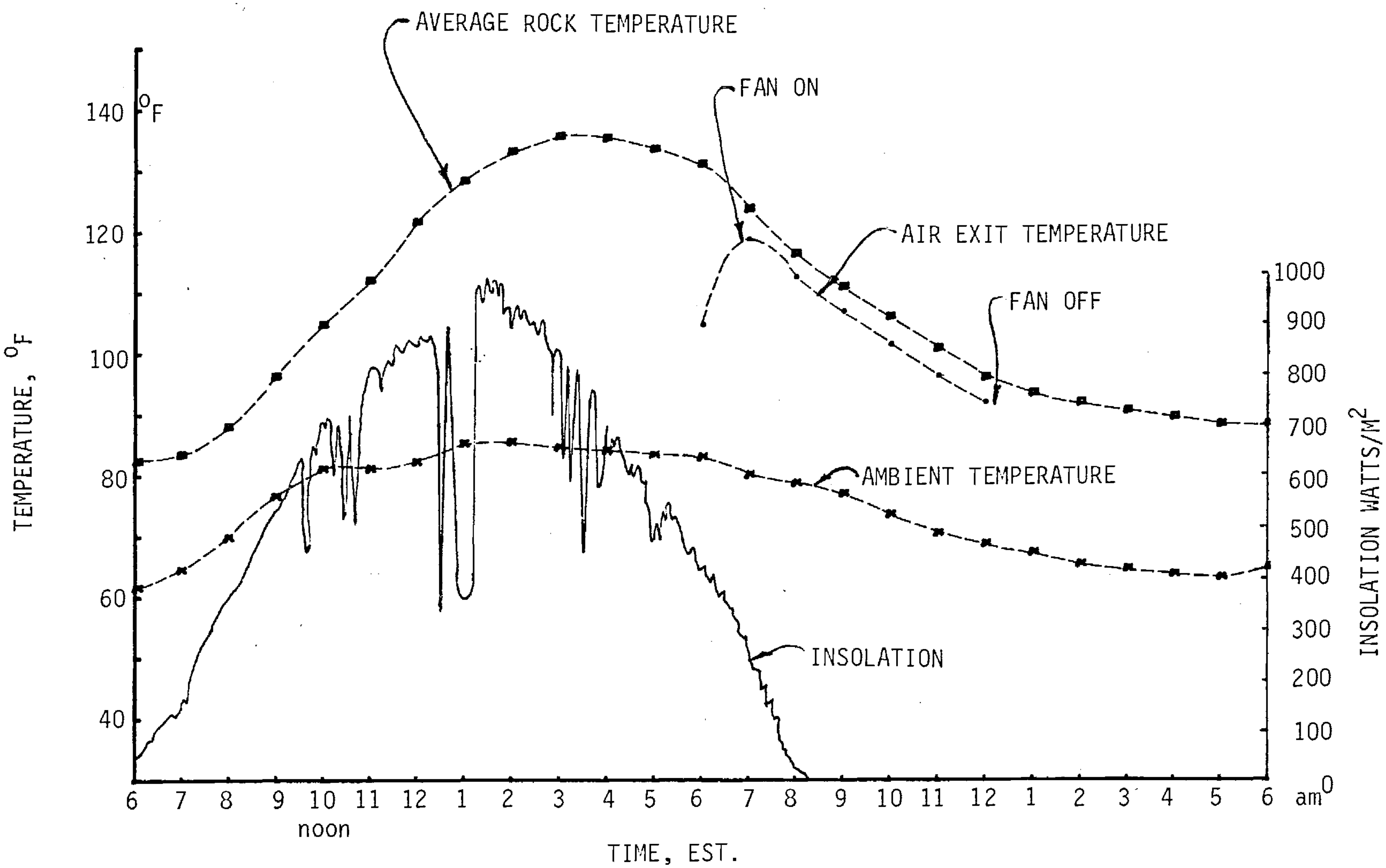

Figure 5. Performance of Solar Rock Collector - 18 May 1977.

Work has also concentrated on the use of solar energy in the heating of greenhouses during the winter months. In the southeast, summer cooling is as much of a problem as winter heating. Temperatures and relative humidities in much of the southeast becomes so high in June, July and August, evaporative coolers are unable to keep temperatures within desirable limits. The Solar Rock Collector should be capable of supplying air at temperatures high enough to drive moisture from liquid desiccants which could be used to assist in cooling the greenhouses.