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PERFORMANCE AND EVALUATION
OF
SWINE HOUSE HEATING
WITH A
SOLAR ENERGY INTENSIFIER-THERMAL ENERGY STORAGE SYSTEM

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BY

ALBERT J. HEBER

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

Mylo A. Hellickson
Thesis Advisor Date

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Head of Major Department Date

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INTRODUCTION

The urgency for energy independence in the United States is unprecedented in its history. The demand for energy is reflected in rising fuel costs which affects every segment of the economy. Among the most severely affected sectors is the agriculture industry, whose fossil fuel consumption is crucial to its efficient production of food and fiber.

Solar, one of several alternative energy sources being developed nationwide, has unique possibilities in the U.S. agricultural system. Large areas are available for locating collector units, and the energy requirements on the farm are low as compared with the available radiation falling on the area (11). Drying of harvested crops and space heating of farm buildings can efficiently utilize low quality heat which can be generated with simple, inexpensive, solar equipment. Consequently, the agriculture industry has excellent opportunities to develop widespread application of solar energy systems.

At least three serious problems exist in the development of a successful agricultural solar system. First, the seasonal variability of solar radiation, in the Great Plains region, is such that when the demand for energy on the farm peaks during the fall and winter, the amount of available radiation is at its lowest level. Second, thermal energy collection ceases during nighttime hours when the coldest temperatures occur. The third problem is the design and construction of an economical and reliable system that can be used for more than one application to increase its annual utilization.

A concentrator system can be used to intensify low level solar radiation onto a small collector and thereby achieve the required temperature range for agricultural applications. A thermal energy storage unit can be used to allow nighttime delivery of energy collected during the day. Finally, by producing air temperatures that are compatible with both grain drying and preheating of ventilation air, a single system can be utilized for a greater number of days during the year.

A solar energy intensifier-thermal energy storage (SEI-TES) system was designed to incorporate all three of these aspects and to enhance the feasibility of solar energy for agricultural use. A unique location for the thermal energy storage unit in the system was included in the design to reduce heat losses and improve performance.

To investigate the feasibility of the multiple-use SEI-TES system, research was conducted with the following objectives:

1. Test the SEI-TES for preheating swine house ventilation air under actual operating conditions.

2. Evaluate the performance and operating characteristics of the SEI-TES system.

LITERATURE REVIEW

Solar Availability

According to Löf (1960), "In comparison with practically all of our conventional sources, solar energy is characterized by immense quantity, universal availability, very low concentration, and extreme variability". Before the sun's rays reach the atmosphere, the intensity of radiation is essentially constant. Satellites and high aircraft have measured the solar constant at 1.353 kW/m^2. This extraterrestrial radiation is 7% ultraviolet, 47% visible, and 46% infrared with wavelengths mostly less than three micrometers. The amount of radiation that reaches the ground varies from almost none under heavy cloud cover to approximately 85 to 95% of the solar constant under very clear skies. Solar radiation on the ground consists of a diffuse component that has been scattered by molecules and particulate matter in the atmosphere and, when the atmosphere is clear enough, a beam component that is unchanged in its direction of propagation from the sun, Duffie and Beckman (1976).

Although solar energy is universally received, its quantities vary considerably. In the far northern and southern latitudes, the annual input is less than one-fourth of that received in a sunny temperate zone. Besides latitude factors, atmospheric conditions may reduce the annual, average, available radiation by substantial percentages. Typical, annual, average, radiation intensities in very sunny climates are around 22.7 MJ/m^2-day. The averages for the United States and London are around 17.0 and 10.2 MJ/m^2-day, respectively. Liu and Jordan (1963) stated that the variation of the local climate and the value of the atmosphere clearness index (k_t) is so large from one locality to another that latitude is a relatively unimportant factor to consider in solar-collection application. It is clear from these statements that the locality of each potential solar application should be analyzed for its availability of solar energy.

According to Löf (1960), a Texas oil well on a quarter section of land (0.65 km^2) would have to produce crude oil at a perpetual rate of 2500 barrels (400 kl) per day to have an energy output equal to the incidence of solar radiation on that quarter section. Buelow (1962) stated, however, that on cloudy days the diffuse radiation has little heating effect, since the incoming energy is only about 10% of that on a sunny day.

The low concentration of solar radiation is one major drawback in utilizing solar energy. It has a maximum intensity of only about 1100 W/m^2 and, in a sunny climate, an average of only about 630 W/m^2. Since a commercial heat exchanger would seldom be operated at heat transfer rates below several kW, large surfaces must be used for the recovery of appreciable quantities of energy. One other serious drawback is its intermittent nature, Butler and Troeger (1978) and Löf (1960). In addition to the regular and predictable variability from day to night, there is fluctuation due to cloudiness. Seasonal variability is also superimposed on these other fluctuations. The use of solar energy must, therefore, depend upon the existence of (a) no requirement for continuous energy supply, or (b) supplementary energy availability when solar energy is unavailable, or (c) the availability of some form of energy storage.

Flat-Plate Collectors

When an object is exposed to solar radiation, its temperature increases until its heat losses become equal to its heat gains. The losses depend on the emission of radiation by the heated material, the movement of the surrounding colder air, and the thermal conductivity of the materials in contact with it. The gains depend on the intensity of solar radiation and the absorptivity of solar radiation by its surface, Daniels (1964).

The solar collector is the essential item of equipment which transforms solar radiant energy to some other useful energy form, Duffie and Beckman (1974). The energy transfer is from a distant source of radiant energy to a fluid. Solar collectors are conveniently classified as focusing collectors and flat-plate collectors, which do not focus. The focusing collectors can use only the direct radiation but can produce much higher temperatures, Daniels (1964). For flat-plate collectors the area absorbing solar radiation is the same as the area intercepting solar radiation. These collectors can be designed for applications requiring energy delivery at moderate temperatures, up to perhaps 100 C above ambient temperature. The flat-plate collector utilizes both diffuse and beam solar radiation, Kreith and Kreider (1978).

Various designs of flat-plate collectors exist, but flat-plate collectors are principally composed of a blackened plate for absorbing solar energy, one or more transparent cover plates, insulation for reducing the heat loss through the back, supporting members, and provision for circulating either liquid through tubes in good thermal contact with the blackened plate or air over the entire absorber plate for the removal of the absorbed solar energy, Liu and Jordan (1963).

The important parts of a basic, flat-plate, solar collector are shown in Figure 1. The "black" absorbing surface converts the radiant energy to heat which is transferred to the collector fluid. The transparent covers reduce convection and radiation losses to the atmosphere. The back insulation reduces conduction losses as the geometry of the system permits, Duffie and Beckman (1974). According to Phillips (1965), the increase in fluid temperature, as it passes through the collector, is influenced primarily by the intensity of solar energy striking the collector surface, and the fluid flow rate through the collector.

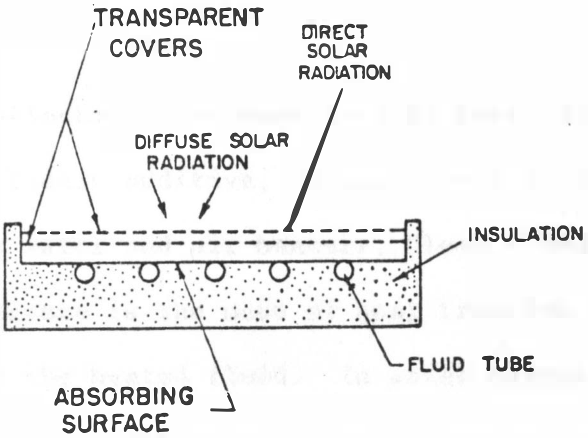

Figure 1. Basic flat-plate solar collector.

Duffie and Beckman (1974) presented a comprehensive study of the thermal performance of flat-plate collectors. The relationships important in collector analysis are the basic flat-plate energy balance equation, the collection efficiency, the overall heat transfer coefficient, the collector efficiency factor, the temperature distribution in the flow direction, the collector heat removal factor, the mean plate temperature, the effective transmittance-absorptance product and the flow factor. Under a steady state condition, the rate of useful energy collection is the difference between the rate at which solar energy is absorbed and the rate of heat loss, Liu and Jordan (1963).

According to Liu and Jordan (1963), the flat-plate collector is the simplest and one of the most effective means of collecting solar energy for use in systems that require thermal energy at comparatively low temperatures. The advantages of flat-plate collectors include the following: (1) no complicated mechanisms for following the apparent diurnal motion of the sun is needed for operation, (2) construction is simple and cost is low, and (3) diffuse as well as direct solar radiation is collected.

Flat-plate collectors have been used to heat fluids such as water, water plus an antifreeze additive, or gases such as air, ASHRAE (1978). On comparing solar water and air heaters, Close (1963) stated that the most obvious difference is the mode of heat transfer between the absorber plate and the heated fluid. In water heaters, the absorbed energy is transferred to the water tubes by conduction. This necessitates an absorber plate of high thermal conductivity, and therefore, copper is generally preferred. Copper water tubes also demonstrate good corrosion resistance. In the solar air heater, where the air stream can be in contact with the entire absorbing surface, the plate conductivity becomes less important. Corrosion of the absorber plate is also a secondary consideration and light-gauge steel or aluminum are possible plate materials. Hence, a solar air heater appears to be inherently cheaper than a water heater. Close (1963) gave the main factors determining the thermal efficiency of a solar air heater as the following:

1. Collector geometry; the length and aspect ratio.
2. Mass rate of airflow through the heater.
3. Spectral reflectance-transmittance properties of the transparent cover.
4. Spectral reflectance properties of the absorber plate.
5. Barriers to natural convection of stagnant air between the absorber plate and the air stream.
6. Heat-transfer coefficient between the absorber plate and the air stream.
7. Collector insulation.
8. Amount of incident solar radiation.

Flat-plate collectors have been built in a wide variety of designs from many different materials, ASHRAE (1978). For example, more than 100 patents were issued in Japan during a single decade for solar hot-water heaters, most involving some sort of flat-plate or the optical equivalent thereof, Meinel and Meinel (1977). However, according to the literature, there are several basic design criteria that the engineer must consider.

The glass cover provides thermal protection for the absorber and keeps rain and dirt from the blackened surface, Meinel and Meinel (1977). It can transmit as much as 90% of the shortwave solar radiation, while virtually none of the longwave radiation emitted by the absorber plate can be transmitted outward, ASHRAE (1978). Plastic films and sheets also possess high shortwave transmittance, but because most usable varieties also possess transmission bands in the middle of the thermal radiation spectrum, longwave transmittances may be as high as 0.40. Plastics are also generally limited in the temperatures which can be tolerated without deteriorating or undergoing dimensional changes. Only a few can withstand the sun's ultraviolet radiation for long periods of time. Breakage due to hailstones, thermal expansion, or vandalism can be minimized by the use of tempered glass, which is much stronger than window glass.

Daniels (1964) stated that, at a given temperature, an optimum number of cover plates provide the most heat at the lowest cost. It involves the gain caused by decrease in heat losses, the loss caused by reflection and absorption by the "transparent" cover plates, and the cost of materials and construction. Usually, one or two covers are used.

The loss of heat by radiation increases as the fourth power of the absolute temperature. Therefore, radiation losses become serious at high temperatures, Daniels (1964). Radiation losses can be reduced by using selective surfaces on the absorber plate, Meinel and Meinel (1977). Williams (1975) reported on tests which indicated that collector performance improved significantly when a selective coating was applied to the absorber plate. Such coatings effectively absorb the sun's incident energy, but retard reradiation of infrared heat, and thus allow the collecting surface to reach a higher equilibrium temperature. For a 38 C temperature difference between the outer glass and absorber, the collection efficiency increased from 35 to 55% when a selective surface was added. However, the cost of the collector was also increased, and therefore, no major change in cost effectiveness occurred.

According to Meinel and Meinel (1977), selective coatings can never attain the high levels of absorptance, which are possible with non-selective coatings. This limitation occurs because the solar spectrum extends into the thermal infrared with significant amounts of energy in the 3 to 4 µm region. On selective absorbing surfaces, the transition from absorptive to reflective occurs in the region between 1.5 and 3.0 µm.

Since it is uneconomical to construct a large surface on a movable frame, a collector orientation which will give the best results should be chosen, Buelow (1962). According to Becker and Boyd (1961), the optimum tilt angle for a stationary solar collector depends on the latitude and the seasonal demand. The daily, total incident radiation upon a surface will be a maximum if a south-facing surface is tilted so that the sun's rays are perpendicular to it at solar noon. Convection losses are also affected by collector tilt. Meinel and Meinel (1977) stated that the convection loss of a vertical surface is 80% that of a horizontal surface. In winter it is recommended that flat-plate collectors be tilted at the angle of latitude plus 15^{o} and in summer at the angle of latitude minus 15^{o}, Daniels (1964). According to Daniels, tilted flat-plate collectors with transparent covers can achieve temperatures of boiling water in good sunny weather, but it is difficult to produce temperatures higher than this and not easy to obtain temperatures above 70 to 90 C.

Buelow (1962) reported that it is not economically feasible to design a collector for a constant air temperature rise throughout the day. For grain drying in particular, low temperature rises should be used because the heat losses from the collectors are less, the cost of construction is less, and the collector surface area needed is comparable to the roof area of the building required to house the crop being dried. Buelow and Boyd (1957) developed a general equation which showed that the temperature rise of the air passing through the collector is decreased when the entering air temperature is increased and the outside air temperature remains the same. For this reason, collector efficiency is the highest when the incoming air temperature is equal to or less than the ambient temperature. It was concluded that when only a part of a given air supply is to be heated, it is preferable to heat the cooler portion. For example, it is more efficient to heat the outside air entering a barn in winter then it is to recirculate the inside air through the collector and force outside air directly into the building.

Esmay (1977) stated that the velocity of the air over the collector plate should be near the turbulent flow range for the most efficient heat transfer. Close (1963) indicated that increasing the air velocity through a solar heater results in higher collection efficiencies, but also in increased fan operating costs. According to Buelow (1962), the flow of air through the solar heater should be relatively unimpeded so that larger fan capacities are not required when the solar heating feature is added to an unheated air drying system. A limit of about .25 cm of water pressure drop through the solar heater would meet this requirement. However, the air velocity through the solar heater must be high enough to give relatively good convection coefficients and achieve reasonable efficiencies.

For low to moderate temperature application, solar collector ducts of not longer than 7.6 m are contemplated, due to the excessive temperature increase and consequent drop in efficiency whenever the air makes a long pass across the absorber plate, Close (1963). Esmay (1977) also concluded that the length of run of air over the collector plate should be as short as practical to increase efficiency of heat transfer. Another design consideration is the collector area, which, according to

Duffie and Beckman (1976), is a major variable and is central to the fraction of the heating load to be carried by solar energy and, ultimately, cost.

Many variations of flat-plate collectors exist. One unconventional design involved matrix surface collectors. Akyurt and Selcuk (1973) experimented with a solar fruit and vegetable drier using a glass-covered, flat-plate collector with a 10 cm thick pillow of steel chips (absorptivity = .97) encased in chicken wire and painted black. The entering air traversed the packed pillow thereby cooling it. The low matrix surface temperatures decreased collector heat losses, and consequently, increased efficiencies. Maximum temperature rises of 50 C were achieved.

Conventional designs for flat-plate collectors have always followed the pattern of exposing one side to the sun and insulating the other side. However, Souka (1965) reported on a double exposure flat-plate collector, which was designed to absorb heat from the back as well as the front, with the usual insulation being omitted from the back. A flat reflector was used to reflect solar radiation onto the back of the collector. The peak energy collection was increased by 48%, as compared with a conventional flat-plate collector.

Hall (1968) also reported on a system which omitted the insulation on the back of the absorber. In this particular case, the collector was incorporated into a roof and ventilation air was drawn through it. At a 24.4 C temperature rise, the calculated heat gain would have been over 102.5 kW from a 212 m^2 roof. About 15,200 kJ of heat lost per hour through the ceiling was picked up and returned to the building through the ventilation system. Consequently, the daytime heat loss through the roof was considered insignificant.

The roof of a building may be used to incorporate or support a flat-plate collector. Phillips (1965) reported that a metal roof of a coffee-drying shed was used as a solar radiation collector at the University of Puerto Rico. Air was circulated beneath the roof. During the middle hours of a normal day, the air temperature would increase from 28 to 43 C in the solar collector with an airflow of about 13,390 m^3/hr. The additional cost of construction necessary to provide a solar heat collector in the roof was more than that recovered by reduced operating costs during the first two seasons of operation.

Hall (1974) concluded that a swine house, solar heating system is possible with any type of floor or any pen arrangement. Air can even be exhausted below slotted floors, if desired. Either negative or positive pressure ventilation can be used. There must be continuous air movement during cold weather to avoid condensation on the solar collector unless some type of anti-back draft device is incorporated into the system.

There are many possible designs for solar air heaters, with variations of both materials and configurations. These in turn lead to a variety of costs and collection efficiencies, Close (1963). The engineering challenge is to discover the most cost-effective solar process for a given application, calculate its true cost, compare it with alternative energy sources, and finally build it to meet its expectations, Kreith and Kreider (1978).

Solar Concentrator Systems

Concentration of solar radiation becomes necessary when high temperatures are desired, or when the cost of the absorber is much higher than the cost of mirrors. According to Rabl (1976), the heat losses from a collector are proportional to the absorber area and, hence, inversely proportional to the concentration. Intimately related to the concentration ratio is the acceptance angle, i.e., the angular range over which radiation is accepted without moving all or part of the collectors. Williams (1975) stated that concentrators may be used to produce temperatures in excess of 150 C for efficient electrical power generation, for industrial and agricultural drying, and for other applications where high temperature heat is required.

Meinel and Meinel (1977) indicated that the optics important in solar energy are generally of two types: the Fresnel lens and the concave mirror. Solar optical systems differ from general optical systems in that costs limit the optical element to simple surfaces and the need for concentration requires that the aperture-to-focal length ratio be as large as possible. Solar energy optics usually involve configurations which serve merely to collect or redirect the sun's rays. Williams (1975) indicated that for high concentration the ideal form of the concentrator, from an optical standpoint, is parabolic. To achieve this high concentration, however, the reflector must be steered to remain directed toward the sun, and the heat exchanger must remain located at its focus. This has prompted researchers such as Tabor and Zeimer (1962) to investigate possibilities of producing stationary mirror-type collectors with the following characteristics: low cost, accurate optical shape, high rigidity, protected mirror surface, and easy transportability. Tabor and Zeimer (1962) reached the disappointing conclusion that the maximum possible concentration with a stationary collector was three.

Williams (1975) described a simple type of concentrating collector, which uses a parabolic cylinder reflector to concentrate solar radiation onto a collecting pipe within a quartz or pyrex envelope. The pipe can be coated with a selective coating to retard infrared emission, and the transparent tube surrounding the pipe can be evacuated to reduce convective heat losses. The reflector was automatically adjusted during the day to keep sunlight focused on the collector. Whereas, the parabolic concentrator has a temperature range of 540 to 2200 C, the parabolic cylinder has a range of 260 to 650 C. The actual temperature obtained would depend on the optical performance of the reflector, the accuracy of the tracking device, and the absorption efficiency of the receiver.

Concentrating devices have been utilized in many variations to produce an intense distribution of solar radiation over a small area. However, such devices have only rarely been used in combination with the simple flat-plate collector, McDaniels and Lownder (1975). Since a reflector is inherently cheaper to construct and maintain than a conventional collector, substantial cost reductions are anticipated for a combined system. Seasonal tracking of the sun, if desired, is easily accomplished with a lightweight reflector, Seitel (1975). According to McDaniels and Lownder (1975), success was achieved at the solar home of Henry Mathew in Coos Bay, Oregon utilizing a reflector and flat-plate collector combination. Preliminary results indicated a considerable improvement over that expected from a simple flat-plate collector. It was concluded that for typical winter operating conditions, the enhancement in received solar radiation with the reflector-collector combination was about 1.4 to 1.7.

Seitel (1975) indicated that specular reflectors are preferable to diffuse reflectors, and, in a south-facing geometry, should be used with collectors elongated in the east-west direction to minimize edge effects. Abernathy (1979) observed during periods of high thin cloudiness that direct normal insolation declines more than that which was originally anticipated. Any decrease in this type of solar intensity appeared to be highly detrimental to collector performance.

Storage Systems

Because available solar energy is intermittent, it must be stored or used to produce some other product which can be stored, if solar energy is to significantly help solve energy problems, Butler and Troeger (1978). A thermal energy storage unit is normally designed to accumulate solar energy when it is obtainable and to make it available to meet energy needs at other times, Duffie and Beckman (1976). Kreith and Kreider (1978) concluded that although thermal storage represents extra cost and additional complexity in solar-thermal systems, it is almost always required to buffer the fluctuations of energy collection and demand in a solar system. The thermal capacitance effect is needed to match fluctuating energy collection to energy demands, which tend to be more uniform on a temporal basis.

Some applications have been reported which use liquid storage units. Meador et al. (1979) used water as a heat storage medium in a solar system that provided heat for baby pigs. It was stored in two 4.480 m^3, steel tanks that were insulated with 150 mm of urethane foam insulation. The tanks were buried in a bed of gravel to conserve heat and to provide drainage. Energy storage at the Willard solar facility was accomplished with a stratified hot oil tank, Abernathy (1979). It was estimated that the efficiency of the energy storage system was about 90%, with most of the heat loss due to expanding warm oil into the overflow system. The 10% loss was based on a 24-hour operation. Kreith and Kreider (1978) recommended that a typical U value of about .25 W/m^2-K should be used for liquid storage tanks utilized for space heating and/or cooling. For particle bed storage used in space heating systems, U values of about twice those for liquid storage were recommended.

Butler and Troeger (1978) concluded that water is a very practical storage medium for domestic water heating or when liquid is used for collecting and distributing the heat. For space heating and crop drying applications, however, rock has the advantage of not requiring a heat exchanger. Muehling (1979) indicated that rock is also considerably less expensive than water. Holmes et al. (1978b) stated that many agricultural applications, e.g., space heating of livestock shelters, require heating at night and during cloudy periods when solar insolation is unavailable. According to Muehling (1979), the majority of agricultural solar applications have included attempts to preheat the ventilation air as it enters the building. Without a method of heat storage, the total amount of heat available through such a system is limited because the sun shines during only a part of each day. Therefore, attempts have been made to add storage units to heated-air solar collectors. Jordan et al. (1979) also reported that air-type solar systems are becoming more popular in animal shelters such as swine housing. Data from an air-type system showed that the rock storage as a "delay line" improved overall energy efficiency of the system, Sokhansanj et al. (1979). It was concluded that the savings resulting from a "delay line", which shifts daily high temperatures to cooler periods at night, are more than that from a solar collector without any storage.

Jones and Bundy (1979) experimented with using concrete blocks integrated into a massive collector wall to store thermal energy. It was observed that the wall was significantly warming the incoming ventilation air up to 18 hours after last sunlight, and the peak gain out of the baffle inlet occurred one to two hours later than peak temperature rise at the collector surface.

Butler and Troeger (1978) stated that although rock does not hold as much heat as either water or phase change materials, it does have several advantages in crop drying applications. The collectors can be more cheaply constructed, problems of freezing and corrosion are limited, damage due to leaks is minimal, and the storage tank or bin is less expensive. Louver et al. (1979) reported that drying experiments have shown that energy stored in 3.4 kg of limestone rock, when heated to an average temperature of 107 C, is sufficient to dry 0.454 kg of grain from 25 to 15% moisture content.

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Baird and Waters (1978) concluded from greenhouse studies that the storage capacity should be approximately equal to the energy collected during one day. Present day solar economics make it impractical to store heat for a longer period of time.

According to Duffie and Beckman (1976), a well-designed pebble bed has good heat transfer between air and pebbles, a low heat loss rate, and a high degree of temperature stratification. It was also stated that mechanical energy for pumping can be an item of significant cost, and care is required in designing for minimum pressure drops. Baird et al. (1977) suggested that the use of larger rocks will result in less pressure loss, but that when large rocks are used, there is more concern with the time lag in transferring heat to and from the rocks, due to the large temperature gradients produced.

According to Kreith and Kreider (1978), the geometric shape of particle storage beds is a compromise of heat-transfer and pressure-drop requirements. Decreasing the length of the flow path will lower the pressure drop for a given volume of storage. However, for flow paths that are very short, the fluid residence time in the bed is not long enough to permit effective heat transfer. A convenient way to determine the length of a rock bed with air as the working fluid is to require that the length be greater than that required to transfer more than 90% of the energy contained in the working fluid to the storage medium. Eshleman et al. (1977) developed a numerical model that gave results which, according to the authors, should enable further development of guidelines for the analysis and design of rock beds for storage and release of heat. Included in the model is a method for determining the bed convective heat transfer coefficients.

Agricultural Solar Applications

Solar energy can be utilized by three technological processes: (1) heliochemical, (2) helioelectrical, and (3) heliothermal. The heliochemical process, which occurs naturally in agriculture, maintains life on this planet through photosynthesis by producing food and converting CO_2 to O_2. The second process, through the use of photovoltaic converters, provides power for spacecraft and is already proving to be useful for many terrestrial applications. However, feasibility for its use in agriculture remains in the future. The third process, which includes this research, can be used to provide much of the thermal energy needed for domestic water heating and for space heating and cooling, ASHRAE (1978). Power generation can also be accomplished through the use of thermal cycles. During the 1960's, support for solar energy research in the United States was essentially nonexistent, Esmay (1978). As conventional energy resources become more expensive, however, significant changes in U.S. agriculture will take place, Pimental et al. (1973). Since large enough areas are available for collectors and storage units, and since temperatures required for drying products and for ventilating livestock buildings are lower than in other applications, the agriculture industry has many opportunities to use heliothermal processes, Becker and Boyd (1961).

In a properly insulated and operated farrowing building, about 2/3 of the total winter heat requirement is needed to raise the temperature of the cold, incoming ventilation air, Murphy et al. (1977). Much of the energy required for heating confinement swine housing is used to maintain temperatures that can also be achieved with solar systems, Vaughan et al. (1976). Solar heat can be used to supply low quality energy for preheating ventilation air for livestock buildings, which may include calf nursery buildings, poultry brooding houses, or the nursery phase of swine production, Murphy et al. (1977). Since any amount of temperature rise would be useful to preheat ventilation air, less expensive materials and construction methods may be used for solar collectors, Jones and Bundy (1979). Preheating ventilation air with energy collected from solar radiation will increase the moisture carrying capability of the air thereby lowering the humidity and improving environmental conditions within livestock confinement buildings, Yexley (1977). Warmer "preheated" air at the room inlet would also have less tendency to fall to the floor than direct, cold outside air and therefore may be easier to distribute and mix with the interior room air, Jones and Bundy (1979).

Residential solar applications use recirculation of air through the collector. However, using recirculation with animal shelters can create a problem because of dust and pathogenic bacteria dispersed in the air, Sokhansanj et al. (1979). For example, Holmes (1978a) had concluded, from experience with solar assisted heat pumps for livestock housing, that air filtration is a definite necessity in heat transfer devices used in animal housing units.

During 1977, a study of a solar energy intensifier-thermal energy storage system was conducted at South Dakota State University to evaluate the system's performance characteristics and effectiveness for space heating. Comparisons of building energy consumption were made between a space heated conventionally and a space heated with both solar and conventional energy sources under actual climatic conditions during winter in South Dakota, Julson (1977). The system collected 41% of the energy available on a horizontal surface or an equivalent of 106 liters of propane during the 28-day study. Conventional energy usages of 2377 and 919 MJ were measured in the electrically heated space and the solar and electrically heated space of the building, respectively. It was concluded that the solar energy intensifier-thermal energy storage system functioned satisfactorily as a means of supplementing space heating.

Yexley (1977) reported on a study conducted at the Grain Terminal Association Feed Division's modern, livestock, research facility located approximately four miles west of Sioux Falls, South Dakota. It was concluded that the low-temperature rise, bare-plate solar collector constructed on the vertical south wall of a beef confinement building provided significantly more heat per unit of area to the ventilation air than did similar solar collectors constructed along the roof slope or along both the sidewall and roof slope. The sidewall collector was predicted to provide the equivalent of 8629 MJ of electricity or 337 liters of propane per heating season. Its repayment period was calculated to be 0.6 and 1.1 heating seasons for electricity at a rate of 7.2¢/MJ and propane at a price of 7.9¢/liter, respectively.

Research of solar energy air preheaters at Kansas State University showed favorable performance in two field demonstrations. The Kansas researchers tested the performance of a massive solar wall which served as an integrated collector-storage system for a ventilated swine house. A progress report gave results that were quite favorable for the solar assisted buildings versus those conventionally heated. Using actual and projected tax credits in Kansas, the calculated break-even price was 13.7¢ per liter of propane, Spillman et al. (1976).

Researchers at Michigan State University have designed and constructed a 366 m^2 flat-plate collector to provide supplemental heating for a 5000-bird, laying hen, cage-type poultry house, Esmay (1978). It was used to dry poultry excreta during the months of August, September, and October, 1977. The waste was dried to reduce its weight, odor, and pollution potential, to make it easier to handle, and to utilize the solar collector during more days of the year. The combination in-house and solar-assisted, tunnel drying succeeded in removing at least 45% of the total excreta water on a daily basis. The collector system was used to heat the poultry house during the winter months of 1977 and 1978. The collector itself operated at 38.5% efficiency for a sunny day in August, 1977. The efficiency was determined from the calculated energy striking the collector plate and the heat energy delivered to the drying tunnel, Esmay (1978). Research conducted at the University of California at Davis demonstrated that solar energy can be used effectively in California for the drying of cage-house poultry waste. A fossil fuel savings of approximately 10.0 GJ/day resulted when drying the daily manure production of 24,000 layers, DeBaerdemaeker and Horsfield (1976). The manure was dried in three days.

In earlier work Hall (1968) reported that three swine production buildings in western Illinois had utilized a solar heating system for ventilation. Fresh air was pulled in directly under and perpendicular to the 7.6 cm corrugated steel roofing in a 4.1 cm air space, which was the thickness of the 4.1 cm x 8.9 cm purlins that supported the corrugated steel roofing. The turbulence created by moving the air perpendicular to the corrugations helped collect thermal energy from the steel roofing. Air was drawn into a central collection duct and an inside distribution duct which extended nearly across the entire length of the building.

According to Muehling (1976), the early, solar heated, hog buildings described by Hall were constructed in the fall of 1964. Several such solar heated swine buildings of similar design were constructed from 1964 to 1968, but during these years, power costs were low and the solar design did not become popular.

The University of Missouri is conducting research to develop solar heating of water for baby pig environmental control. A 50 m^2 collector with two 4.48 m^3 storage tanks was installed at a cost of \$20.00/m^2. Past the initial testing stages, the research is now directed toward developing an optimum design of the system, Meador et al. (1979).

McFate (1976) observed that substitution of solar heat for conventional sources of energy used in swine confinement-type production facilities has potential because: (1) the facilities are normally well insulated, (2) the energy use is at fixed locations, (3) the energy use patterns are variable at specific geographic locations, and (4) solar energy utilization will affect electrical energy demands and overall costs.

Milking parlors use warm water for the operation of prep stalls, udder washing, sinks and showers, and hot water for pipe line and bulk tank sanitizing. Development of solar supplementation for these heat loads would be attractive to the agriculture industry, Hayden and Thompson (1977). A full-scale solar heating system was operated at the USDA's milking parlor in Beltsville, Md. and focused on the milking parlor's high energy demands. Heat recovery from the refrigeration condensers of the bulk tank cooling system was combined with energy received from roof-mounted solar collectors to reduce the conventional energy demand. The main storage tank was a 38,000-liter, underground, concrete silo insulated with 8 cm of sprayed-on, urethane insulation applied externally in contact with the soil. An 8 cm thick foam float insulated the water surface and a fiberglass silo cap was used to prevent debris and people from falling into the tank. Modification of the milking parlor's original, hot water plumbing were made to enhance the effects of using solar supplementation. This involved the connection of two electric water heaters in series, rather than in the parallel mode, and using one for warm water and the other for hot water. According to Hayden and Thompson (1977), the combination of solar energy supplementation and plumbing modifications resulted in a 58% reduction in the electrical energy required for hot/warm water heating. After two years of operation, further optimization and refinement of the system were needed for feasibility.

A considerable amount of recent study has been conducted on solar heating of greenhouses. Many technically feasible designs have been tested, including conventional hydronic (water-type) systems, low-cost hydronic systems, and air-rock type systems, Baird and Waters (1978). The earliest experimental systems used conventional components, which were proven very uneconomical, but which provided an important core of data for the analysis of operating characteristics. In an attempt to develop a more economical system, a study of low-cost hydronic systems was conducted as a joint effort between the University of Florida and Rutger's University. Satisfactory operation of the Rutgers greenhouses has led to a full-scale, commercial installation sponsored by the U.S. Departments of Energy and Agriculture at Kube Pak Garden Plants, Inc., Allentown, New Jersey. An air-type system with storage was built and tested at the Agricultural Research and Education Center at Bradenton, Florida. Operation during the winter of 1977-78 resulted in an estimated fuel savings of \$300 over a 150-day heating season based on propane at 11.1¢/liter, Baird and Waters (1978). Staton (1978) reported the progress of an ERDA-funded project to demonstrate the feasibility of heating a commercial greenhouse using solar energy. The Ulery Greenhouse Company in Springfield, Ohio will use a 558 m^2, hydronic, flat-plate collector system to heat an 804 m^2 greenhouse area. It is expected to provide 60% of the total heat requirement at a cost of about \$15.17/GJ. Baird and Waters (1978) concluded that general acceptance of solar heating systems for greenhouses will be slow due to the high initial investment, uncertainty about future energy costs, and some unanswered questions regarding the effect of new systems on various crops and management schemes.

According to Meinel and Meinel (1977), solar crop drying can be divided into two general categories, each with several subdivisions.

These two categories are (1) drying of grains and (2) drying of leafy crops or crops of high moisture. Buelow (1962) stated that a given rate of energy input can be used most effectively for crop drying when the energy is used to raise the temperature of larger quantities of air a few degrees, rather than smaller quantities of air to higher temperatures. Since drying can be accomplished without using high temperature rises, rather simple and inexpensive solar collectors may be used. Heated air from the collectors can be applied directly to the grain drying process without an intermediate energy-storage facility. A successful solar grain drying installation was reported at the University of Wisconsin at Madison where solar heat was obtained from the galvanized roof of a metal building located next to a low-temperature drying bin. After two years of drying, 58% of the cost of materials for collecting solar heat had been recovered in the form of savings in fuel costs, Baumann et al. (1975).

Early work at South Dakota State University by Peterson (1963) consisted of three experimental bins, two of which used solar energy collectors and one which used electric resistance heat. Although the resistance-heated bin completed drying somewhat faster than either solar bin, it was learned that results were more satisfactory in the continuously-operated solar bin than in the humidistat-controlled solar bin.

Siegel (1978) conducted further solar grain drying research at South Dakota State University using a solar energy intensifier system. Equivalent amounts of 111 and 126 liters of propane were saved during 14 and 15 days, respectively. Calle' (1979) demonstrated that a solar energy intensifier-thermal energy storage system is feasible and can function satisfactorily for low-temperature hay drying. During the day and night operation with a thermal energy storage unit, energy provided to the bales was sufficient to double the drying rate as compared to a continuous, ambient air drying system.

Baker and Shove (1977) illustrated several operating solar collectors used to dry crops. The systems included bare-plate collectors on bins and roofs of buildings, covered-plate collectors on bins, walls, and roofs of buildings, portable collectors, collectors utilizing the complete attic space of buildings, suspended-plate collectors on grain drying and storage buildings, and other "home made" collectors.

An array of 672 air collectors at the Gold Kist Soy facility at Decatur, Alabama was used to temper the inlet air to three 106 m^3/hr (3000 bu/hr), continuous-flow soybean dryers. Guinn and Fisher (1978) reported Phase I of the three-phase, ERDA sponsored program which included the design and computer simulation analysis of the solar drying experiment. An economic assessment, using 1977 prices, estimated that with ground-level construction of the collector array, the installed cost would be \$414,354(\$340.26/m^2), and the cost per GJ would be \$15.26. Completion date was estimated to be May, 1978.

Carnegie and Niles (1978) reported another ERDA sponsored demonstration using solar energy to provide commercial agriculture process heat to the L & P raisin dehydration facility in Fresno, California. In the design and construction phase report, the authors established the viability of a 1944 m^2 solar collector, a 354 m^3 rock heat storage and a heat recovery system capable of providing 70% of the heat required by one tunnel of the dehydration facility. The installed solar system cost was $176.43/m^2.

Some work has been conducted to develop solar power systems for pumping irrigation water. A medium-temperature, solar, thermal power facility has been designed and constructed at Willard, New Mexico. Abernathy (1979) concluded in a report of the Willard experiment that available equipment to convert solar energy to shaft horsepower is very expensive and probably too complex for the average farmer to operate. It was stated, however, that the solar power option appeared to have potential, but further development of equipment and systems will be required before solar irrigation can be considered practical.

Photovoltaic devices convert light (photons) directly to electricity. A complete solar panel is currently on the market that will produce 19 volts DC at 1.3 amps with peak noontime radiation (1 kW/m^2) for a cost of $420. This amounts to approximately $17,000 per kW at peak capacity for this 12% silicon array. If the panel were to be used continuously for 20 years with no further costs entailed, the electricity produced would cost nearly 13.9¢/MJ, as compared with 1¢/MJ, which was the average utility rate for domestic electricity in 1978, ERDA (1978).

At this high rate, the only economical applications are in remote locations, such as battery chargers for mountain top weather stations, radio repeater stations, forest lookout towers, warning lights for offshore structures and channel buoys, and cathodic corrosion inhibitors for pipelines. Various research and development activities have been directed toward reducing the cost of photovoltaic power sources. As much as 90% of the funding for these programs originates from the U.S. Department of Energy. Development of the use of photovoltaic cells for irrigation is being studied and demonstrated at an experimental farm near Mead, Nebraska. The solar array generates approximately 25 kW of electric power, which is stored in batteries and used to operate the pump for 12 hours per day. The unit can pump 3750 liters of water per minute from a reservoir into irrigation pipes. Off-peak electricity during the night is used to pump water from an irrigation well to refill the reservoir. During the fall and winter months, the cells can be used to dry harvested corn, ERDA (1977). As previously stated, photovoltaics are too expensive for agricultural applications at this time.

Dunn (1976) stated that of the several alternative energy technologies, the use of solar energy for space heating will have the earliest widespread public exposure. This is attributed to: (a) the level and current status of the respective technologies of various alternate energy systems, (b) the probable degree of public acceptance of the basic concept of solar energy usage, and (c) the significant stimulus to nationwide use being provided by the federal solar energy program and local electric utilities.

Multiple-Use Systems

Spillman et al. (1979) indicated that since the initial investment in a solar collection system is the main cost of ownership, the more energy the system can provide over its lifetime, the more economical it becomes. Agriculture has a number of potential uses. Pelletier (1959) stated that the seasonal nature of usage with a consequent low load factor on the collection device makes the economic aspects of solar heat utilization even more critical in agriculture than in the industrial or domestic field. Extremely low cost or multi-use portable devices are probably the answer to this problem.

There is a year-round requirement for warmed air because a solar energy system that will heat air efficiently and economically could be used on the farm for drying hay and grain in the summer and fall, and for supplying heat to farm buildings in the winter and spring, Buelow and Boyd (1957). The Kansas State University researchers have suggested that the massive wall collector system could be used alternately to dry grain during the fall and to cool summer ventilating air, Spillman et al. (1979). The operating scheme would be to cool the blocks at night with ambient air and then pull ventilating air through the cooled blocks during the day. For grain drying, it would be necessary to locate a bin near enough to the building. Baker and Shove (1977) reported that several of the present solar collector installations have limited multiple-use capability. Shop areas included in machinery storage buildings are being heated by circulating solar heated air under the concrete shop floor and/or through the shop space. Solar collector surfaces on livestock buildings can provide heat to the animals after corn drying is completed.

To provide flexibility in multiple systems, however, it is necessary to make a collector which is portable. Tabor and Zeimer (1962) built a portable focusing collector and stated that the collector should not be so large that it cannot be handled. A length of 12 m is about the longest dimension that can be carried on normal road vehicles.

Performance Evaluation

According to Buelow and Boyd (1957), the amount of testing required to completely define the operating characteristics of a solar energy system would be extensive. And according to Sokhansanj et al. (1979), the performance evaluation of a solar collector under field conditions is of much debate. When designing solar energy systems using commercially available solar panels, performance data provided by the manufacturer are often based on results of tests conducted under highly favorable environmental and operating conditions. In sizing the collectors for a specific agricultural application, the designer must know its actual performance under average weather conditions. Literature was cited which indicated that there is generally a difference between the results of standardized tests and that of actual field conditions, ASHRAE (1977). It was stated, however, that the methodology of evaluating and reducing the standardized test data can be utilized for experimental field data.

The heat transfer in a solar collector occurs through simultaneous radiation, convection, and conduction. The net rate of useful heat energy collected per unit area is the difference between the amount of absorbed solar energy and the heat lost as a result of the collector being hotter than its surroundings. It is difficult to directly evaluate the rate of energy collection on an average daily or seasonal basis, because of random weather fluctuations, Gupta and Garg (1967). Liu and Jordan (1963) stressed the importance of including the long-term, average performance, instead of the instantaneous rate of energy collection, since the latter is extremely variable due to differences in cloudiness.

The most commonly used characteristic for rating the thermal performance of solar collectors is the thermal efficiency, taken as

$$\eta = \frac{Q_u}{I_t \; A_c} \text{ , Thomas and Vaughan (1978),}$$

where η = efficiency, Q_u = useful heat collection, I_t = total incident radiation, and A_c = collector area. Reference 5 specified that efficiency be based on the gross collector area, i.e., overall length times width. The primary purpose of efficiency in test results is to provide potential users with accurate information for comparing the performance of different collectors and for the designing of solar systems. Thomas and Vaughan (1978) reported studies which showed that the actual environment should be considered when estimating the collector efficiency. Using long-term, monthly, average-day weather data, the predicted efficiencies were substantially less than those obtained under test conditions. While effects of individual weather parameters were not separated, the combined effect of higher wind speed, higher fraction of scattered radiation, lower solar irradiation, and larger average incident angles contributed to the reduction in thermal efficiency.

Hall (1968) noted that the intensity of solar radiation and the wind velocity appear to be the most important factors in the amount of heat gained from the steel roofing which was used as a solar collector. Siegel (1978) also suggested the recording of wind velocity for use in developing the prediction equations for energy collection.

Economic Performance

There is an important difference between the technological feasibility of utilizing solar energy processes and the prospects for immediate use of these processes, Kreith and Kreider (1978). In a free economy, the criteria determining whether solar energy or some other energy source will be used is economic competitiveness. For a solar heating system to be attractive to the producer, it must be economically competitive with other heating systems presently in use and the farmer must be able to "manage" the system with minimum time and maintenance, Yexley (1977) and Löf (1960).

Duffie and Beckman (1976) stated that as fuel costs rise and as the supplies of low-cost natural gas become increasingly difficult to obtain, solar energy will become more competitive, and optimum fractions of annual loads to be carried by solar energy will increase. As collector and other solar energy system costs decrease as a result of mass production, by improved technology, or by users "doing it themselves", similar improvements in the relative economics of solar energy will occur. Kreith and Kreider (1978) predicted that the use of solar energy would also be expected to have the effect of reducing air pollution, of conserving scarce fossil fuels for use as petrochemical feedstocks, and of increasing industrial energy usage in the sectors providing materials for solar collectors. On a national macroeconomic scale, such factors are quite important.

A solar energy installation appears to users as a huge additional investment that must be paid before any benefit is derived from it. If, however, solar energy is viewed as a long-term investment, then its cost can be prorated just like the cost of oil and gas. Acceptance of this view is necessary to assess the cost-effectiveness of solar energy, Kreith and Kreider (1978). Since the initial cost is large as compared to the operating cost, it is important to estimate the life of the system and the value of fuel saved over the period, Baird and Waters (1978). Hellickson (1979) developed a means of evaluating the cost/performance relationships for agricultural solar collectors. It was stated that any cost/performance evaluation should be conducted for a well-defined solar system, identified according to the type of application and geographic location. Kreith and Kreider (1978) indicated that it is rarely cost-effective to provide all the energy requirements of a thermal system by means of solar energy. If this were done, the system would be required to be capable of providing 100% of the energy demand during the worst set of operating conditions ever expected such as inclement weather, maximum demand, and no sunshine. A solar system with such a low load factor is uneconomical and impractical. The best use of solar energy is in conjunction with conventional fuel, Hall (1974).

Kreith and Kreider (1978) stated that local and federal governments can provide tax incentives for the adoption of solar systems by eliminating property taxes, initiating special tax credits, subsidizing solar equipment manufacturers, offering low-interest loans, or conducting grant programs for the purchase and installation of solar systems.

RESEARCH FACILITIES AND PROCEDURE

General

The design of the multiple-use solar energy intensifier-thermal energy storage (SEI-TES) system evolved from the application of basic solar design principles, the consideration of economics, the previous research and development of a similar model, and the subsequent incorporation of new ideas. The SEI-TES system included a concentrating, parabolic reflector, a triangular-shaped collector, a thermal energy storage unit, and a duct for air transport. Simplicity of the components was emphasized to reduce costs while still satisfying the needs of the farmer. Material availability, ease of construction, and convenience were also considered in the design.

Reflector

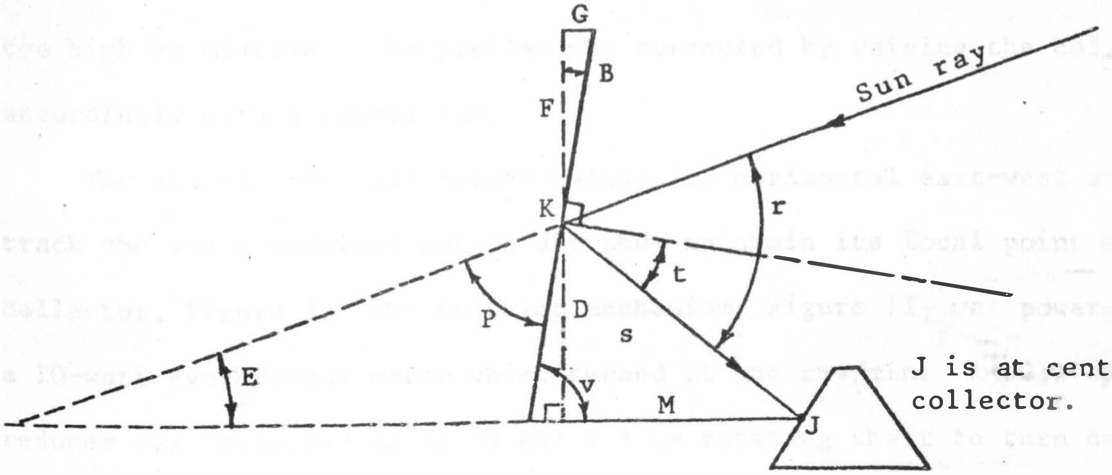
The cost per unit area of reflector was less then that of the collector. The investment required to receive the desired amount of radiation would, therefore, decrease by increasing the area of the reflector and decreasing the collector area. The reflector was designed and constructed with a specific curvature, which caused it to focus the direct rays of the sun onto the north side of the collector. The curvature of the reflector was determined using the following equations corresponding with the terms illustrated in Figure 2 (32):

✓ $P = 90 - E$
✓ $s = \arctan(M/D)$
✓ $r = 180 - s - e$
✓ $t = r/2$
$B = 90 - t - s$
$v = 90 - B$
$G = F(\tan B)$

$M_2 = M_1 \pm G$
$D_2 = D_1 \pm F$

where: E = solar altitude
K = point on curve
J = point on collector
M = horizontal distance from point J to point K
D = vertical height of K above J
v = angle with horizontal
G = change in M
F = change in D

The reflector area divided by the collector area, i.e., the concentration ratio, was 3.53. Based on the width of the focused band of light, Figure 9, the solar radiation was actually concentrated by a factor of at least 10.



J is at center of collector.

Figure 2. Angles used in determining the reflector curvature.

An aluminum, solar reflector sheet was used as the reflecting surface (Appendix C). The polished aluminum (.3 mm thick) had a total reflectance of 87.6% with a specular to total reflectance ratio of .963. Coated with a two micron thick, anodic film oxide, the surface showed no deterioration after the equivalent of one year's radiation at the Desert Sunshine Exposure Tests, Inc. at Phoenix, Arizona, Anderson (1978). The surface had an abrasion resistance of 56 g/micron.

The aluminum surface was glued onto 1.2 mm sheet steel with an adhesive (Appendix C). The steel sheets were spot welded to a support frame consisting of angle and channel iron. The 12.20 m x 3.05 m reflector was constructed in four sections, weighing 182 kg each, and was supported with nine wooden posts (15 cm x 15 cm), which were braced to withstand 129 km/hr winds. A wooden beam (10 cm x 26 cm) was bolted to these posts and eight, 20 cm, steel brackets were attached to it. These brackets served as the reflector pivot, which was located 2.07 m above the ground level. During assembly, the reflectors were attached .25 m too high by mistake. The problem was corrected by raising the collector accordingly with a gravel pad.

The concentrator was rotated along its horizontal east-west axis to track the sun's vertical motion and thus maintain its focal point on the collector, Figure 3. The tracking mechanism, Figure 11, was powered with a 10-watt synchronous motor which turned at one rev/min. A 60:1 speed reducer was installed to allow the 2.5 cm rotating shaft to turn at one rev/hr. The shaft transmitted the power to a gear and chain system, attached to a short post positioned directly behind each reflector, which further reduced the rotation to one revolution per six hours. A pipe connected to an adjustable rotating pin on the large gear transmitted the motion to the bottom of the reflector. A timeclock controlled the operation of the tracking system, which rotated the bottom of the reflector forward from 0900 to 1200 h and backward to the starting position from 1300 to 1600 h. Figure 3 shows the amount of movement needed to follow the sun on January 21 at Brookings, South Dakota (44^o 18' 30" latitude, 96^o 47' 30" longitude). Since the sun's horizontal motion was not tracked, the concentrator was designed to be 1.83 m longer than the collector. The extra length allowed concentrated insolation to be focused on the entire north side of the collector during four hours before and after solar noon.

Collector-Storage Unit

The collector-storage unit, which (c-w) constructed into three sections, was 9.76 m long and 1.22 m wide with the sides tilted at 60^o with the horizontal, Figure 4. The horizontal distance separating it from the reflector was 1.02 m. To support the weight of the rocks in the TES unit, the 7.6 cm ~~plenum~~ platform was constructed with .91 and 2.66 mm steel on the bottom and top, respectively, and with 7.6 cm x 9.02 kg/m channel iron supports. Fifteen centimeters of fiberglass insulation were placed inside the plenum platform to provide an approximate thermal resistance, R, of 2.3 m^2-C/W. Low-iron glass was ordered but did not arrive until the research was completed. Consequently, tempered window glass (.86 m x 1.93 m x 3.2 mm) was used to cover ~~The glass framework, consisting of aluminum wrap-around millwork, was attached to angle iron supports at the top and bottom of the collector, Figure 4.~~ the absorber plate which consisted of 1.52 mm sheet steel painted with a lacquer-based, black, absorber finish (absorptivity = .95). Baffles were attached to the absorber to create additional air turbulence for better heat transfer, Figure 9. Fiberglass insulation (7.6 cm thick) was placed directly beneath the top cover, which was constructed of

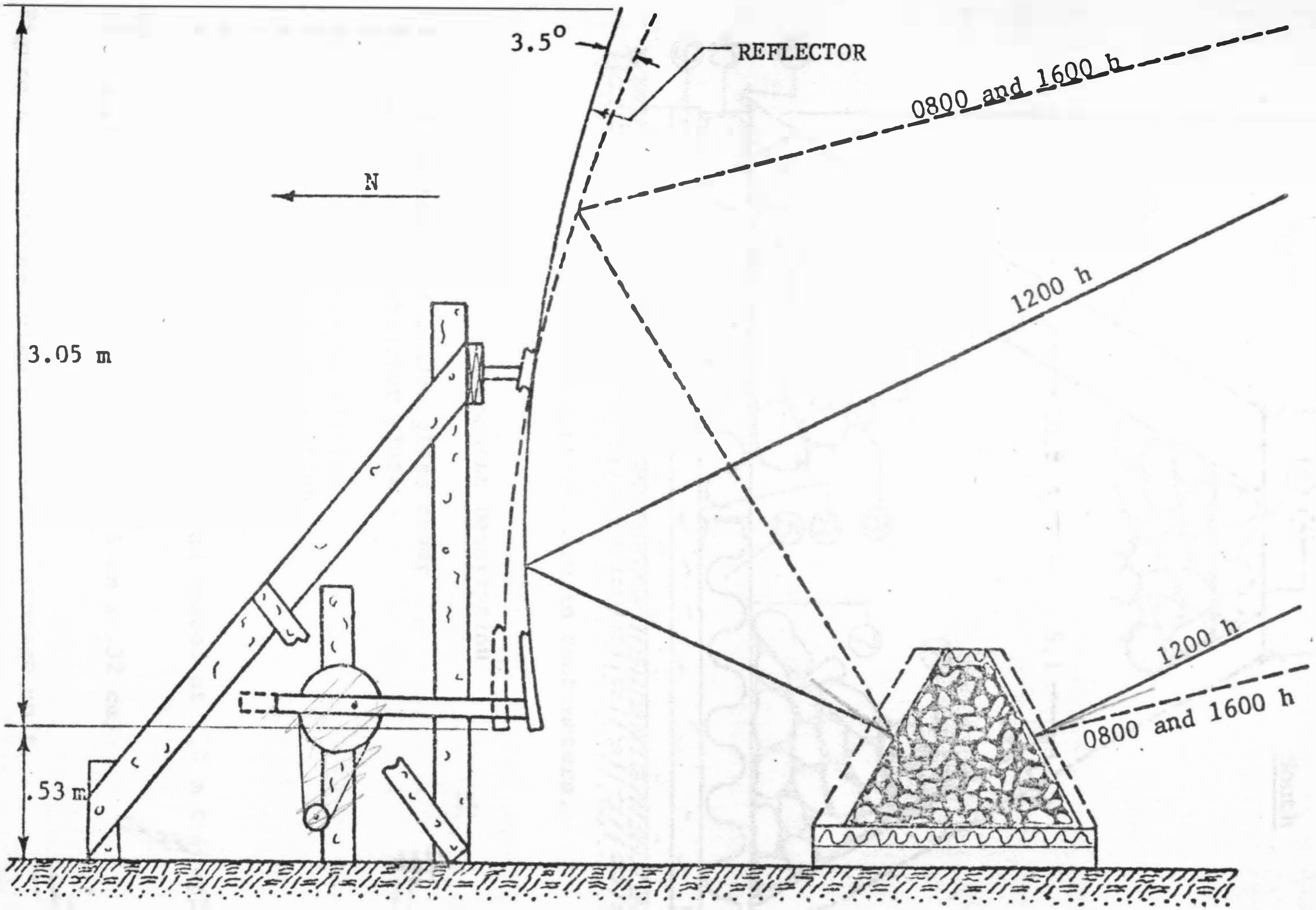
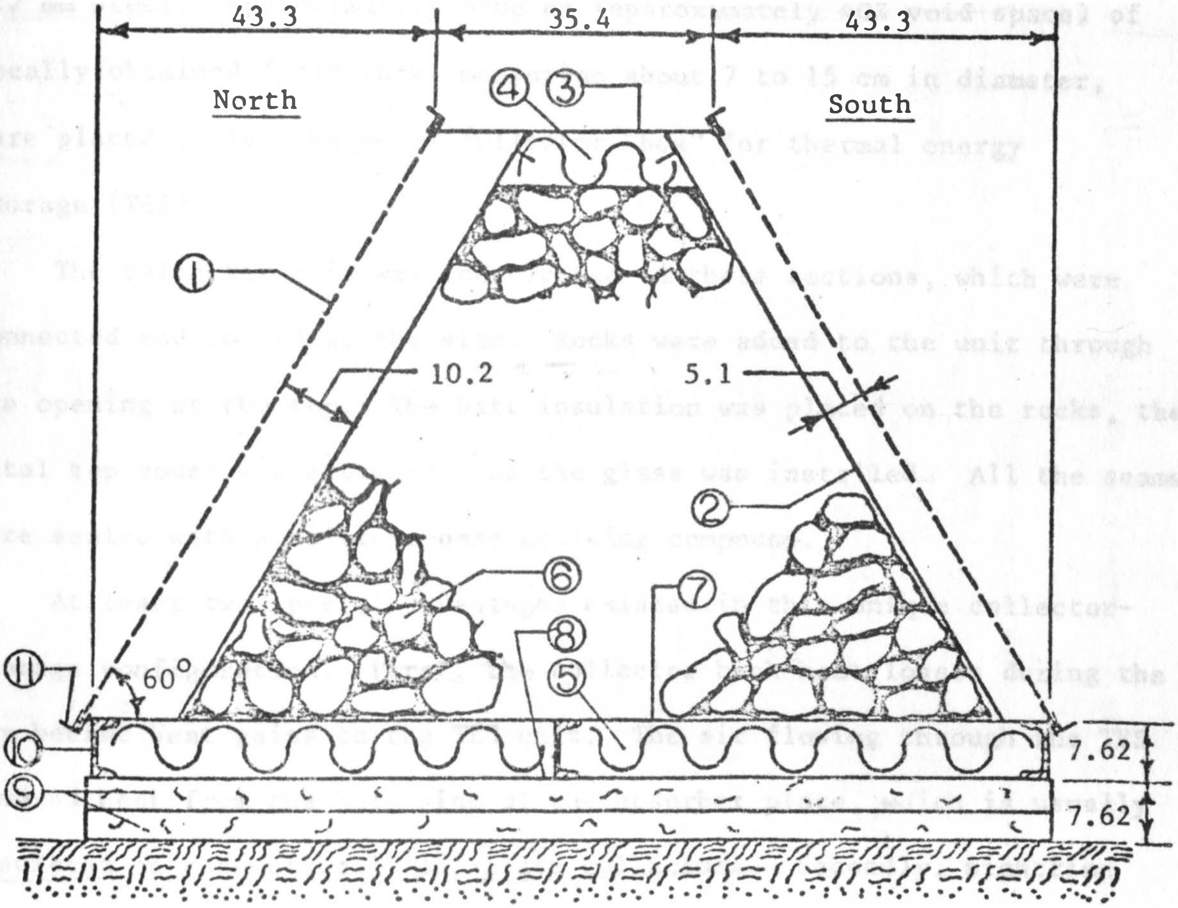


Figure 3. Profile of the solar energy-intensifier system, January 21.



Note: All dimensions are in centimeters.

Component Description

1. 3.2 mm tempered window glass cover
2. 1.52 mm steel absorber plate
3. 2.66 mm steel
4. 7.6 cm fiberglass insulation
5. 15.2 cm fiberglass insulation
6. 7 to 15 cm field rocks
7. 2.66 mm steel
8. .91 mm steel
9. 5 cm x 10 cm boards laid flat and spaced at 1.2 m to support collector above the ground.
10. 7.6 cm x 9.02 kg/m channel iron
11. angle iron support (2.5 cm x 2.5 cm x .32 cm)

Figure 4. Sectional view of collector-storage unit.

2.7 mm steel. Approximately 6700 kg (approximately 40% void space) of locally obtained field rock, measuring about 7 to 15 cm in diameter, were placed inside the metal collector "box" for thermal energy storage (TES).

The collector unit was constructed in three sections, which were connected end to end at the site. Rocks were added to the unit through the opening at the top. The batt insulation was placed on the rocks, the metal top cover was attached, and the glass was installed. All the seams were sealed with a silicone-base caulking compound.

At least two special advantages existed in this unique collector-storage configuration. First, the collector back heat losses during the day became heat gains to the TES unit. The air flowing through the TES removed heat from the back side of the absorber plate, which is usually insulated on conventional flat-plate collectors. Secondly, nighttime heat losses from the TES through the absorber were collected by the air between the plate and the glass cover and recirculated back into the storage unit. Continuous movement of ventilating air through the collectors allowed it to regain some of the energy that would otherwise have been lost. As the air removed heat from the absorber plate, its surface was cooled which reduced the radiation heat loss from the storage. Figures 5 and 6 illustrate the airflow paths.

The collector unit was designed for a farrowing house with an exhaust-type ventilation system. The TES unit was placed in the pathway of air moving into the building. Since winter ventilation rates are relatively low, only a small additional pressure drop would be imposed on the fans normally required for ventilation.

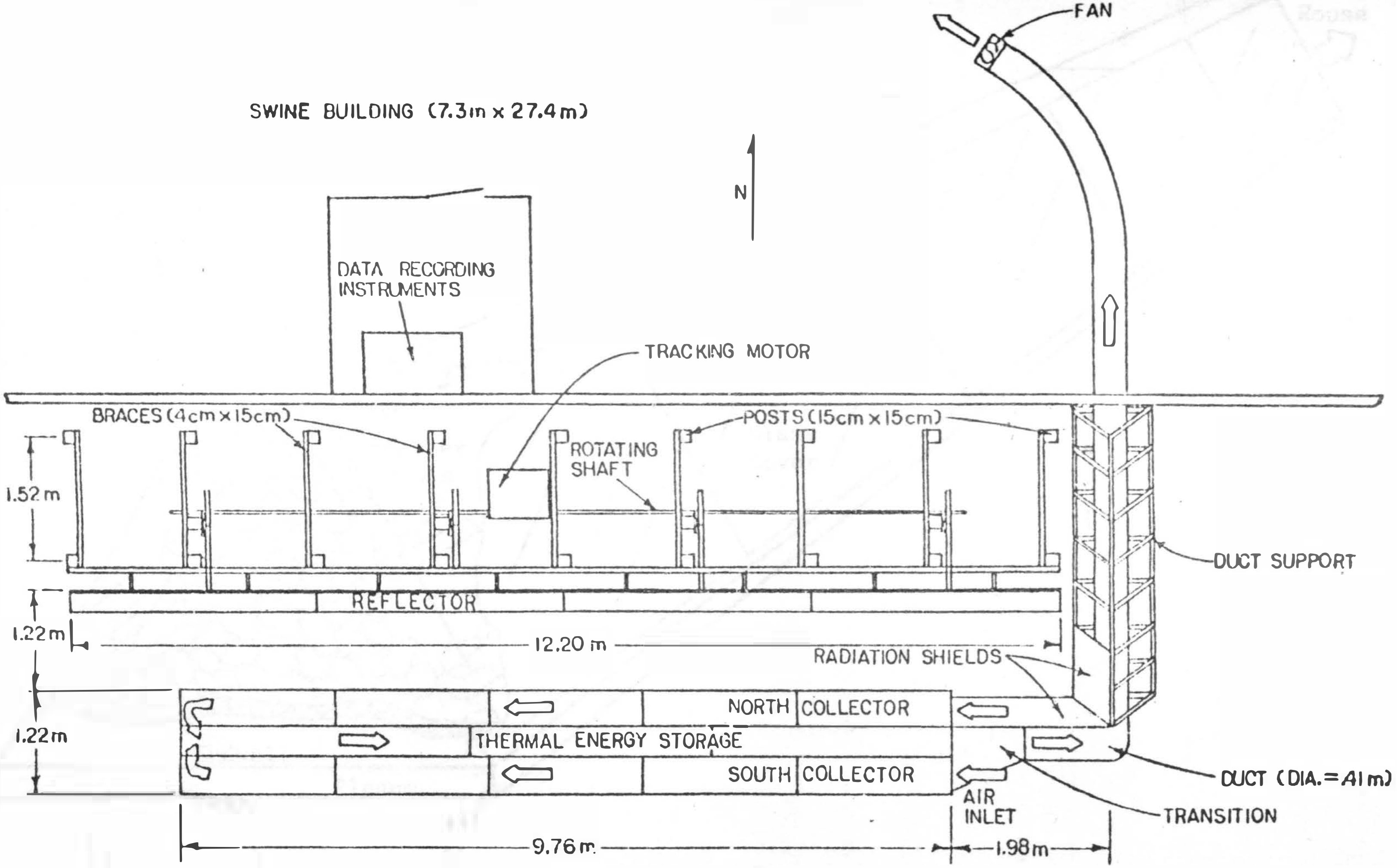


Figure 5. Plan view of research facility: Test No. 1 and 2, January 14 to February 28, 1979.

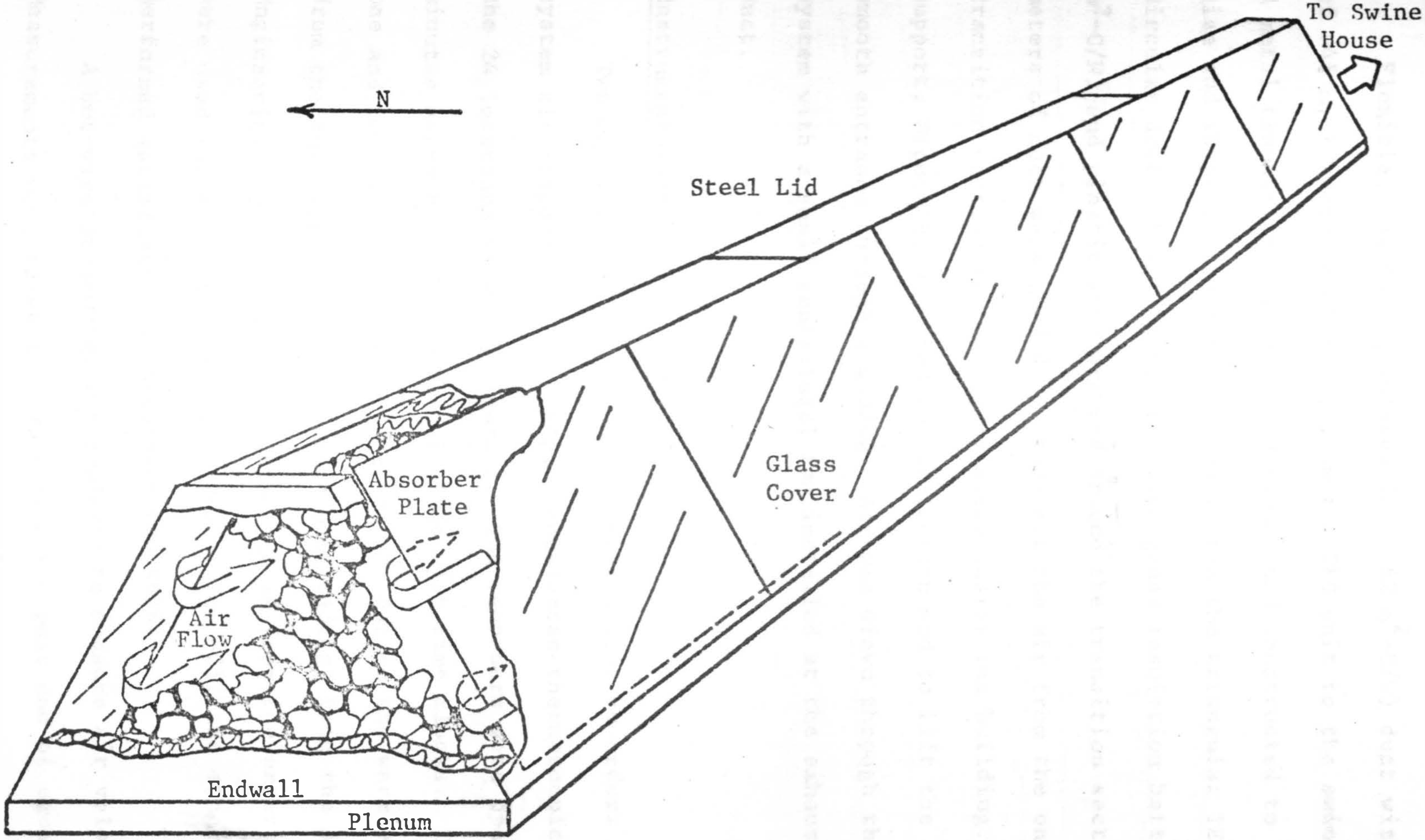


Figure 6. Collector-storage unit, showing airflow paths.

Ductwork and Fan

Flexible, plastic, insulated (R = .62 m^2-C/W) duct with a diameter of .41 m, transported the air from the TES unit to the ~~swine~~ building. A metal transition section was designed and constructed to convert the size and shape of the air passageway from the triangular TES unit to the circular duct. Eight-centimeter fiberglass insulation batts (R = 1.9 m^2-C/W) and plastic were wrapped around the transition section. Eleven meters of duct were needed to transport the air from the one meter transition section to ~~the~~ center alley inside the building. A duct support, Figure 8, was used for protection and to lift the duct for smooth entrance through a window. Air was drawn through the solar system with a small centrifugal fan installed at the exhaust end of the duct.

Instrumentation

Two multi-point, strip chart, potentiometer recorders monitored system air temperatures with copper-constantan thermocouples placed at the 24 locations shown in Figure 7. The recorders were operated for 15 minutes every hour and were controlled with time clocks. Thermocouples one and two gave faulty ambient readings, due to the warm ventilation air from the building. Ambient temperature readings from the Agricultural Engineering weather station (located one km from the experimental site) were used for the data analysis. Except for #21, the other thermocouples performed satisfactorily throughout the test.

A hot-wire anemometer was employed to measure air velocities. Measurements were taken at 1.93 m from the west end of each collector,

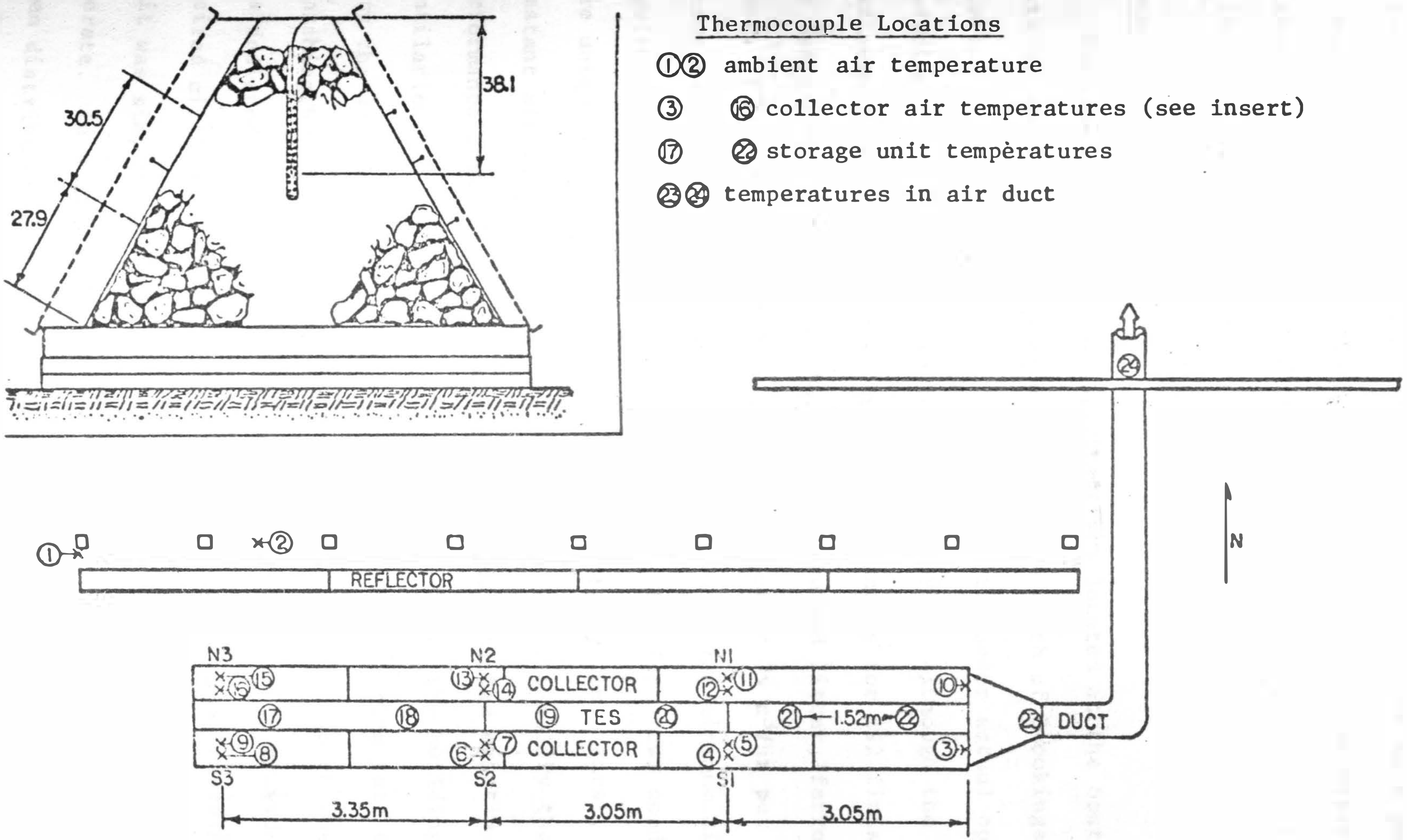


Figure 7. Thermocouple locations. Collector-storage cross-section, upper left. Dimensions in cm.

at the seam of the transition section and the duct, and at a position on the duct, located 2.44 m before the fan. An Eppley pyranometer was used to measure the radiation striking a horizontal surface on the roof of the Agricultural Engineering building.

Procedure

The swine house heating experiment was located at the South Dakota State University Swine Research Farm, one km north of Brookings, South Dakota. The solar system, Figure 8, was tested under actual operating conditions from January 13 to February 28, 1979. Although the confinement barn used in the study had a capacity for 192 finishing hogs, the system had been designed for a twenty sow and litter, farrowing house. Since the Midwest Plan Service recommends 34 m^3/hr per sow and litter for minimum, continuous ventilation rate, the minimum airflow required by the system would be 680 m^3/hr. Therefore, two conditions were unique to the experimental testing of the system. First, the constant airflow provided by a fan was required to simplify the performance analysis. In a practical application, the existing ventilation fans would draw the preheated air into the building and thus vary the airflow rate frequently. Also, the ventilation rate of the finishing building was much greater than the rate for which the system was designed. Therefore, a smaller fan was required to provide the desired airflow. Secondly, the warm air from the experimental solar unit was simply blown into the environment as a space heater would operate. In a practical application, however, the warm air would have been distributed to the existing ventilation inlets of the building to obtain the desired airflow patterns.

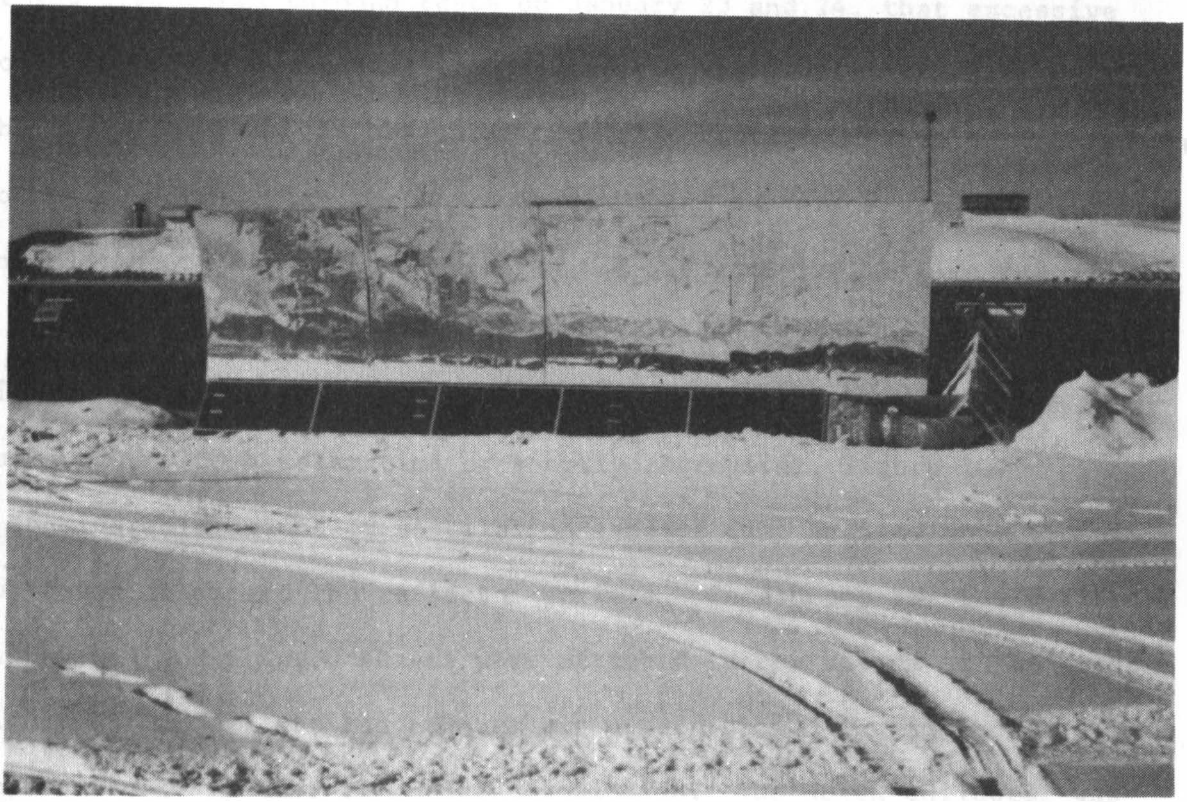


Figure 8. Field testing of the SEI-TES system for swine building heating: January 14 to February 28, 1979.

A delay in the return of the hot-wire anemometer probes, sent to be recalibrated, prevented airflow measurements until the first week of February. It was then discovered that the total airflow rate (260 m^3/hr) through the system was less than the minimum, winter ventilation rate. A larger fan was then installed on February 10 and produced an airflow rate of 709 m^3/hr. The ratio of north collector airflow to total airflow was .617. Since a smaller amount of solar energy was received by the south side, the north collector had been designed with a larger airflow channel and, consequently, produced the larger airflow rate.

A portable, hand-held, thermocouple recorder was employed to verify the collector temperatures recorded with the regular instrumentation. It was discovered through tests on January 23 and 24, that excessive collector temperatures had been recorded. The exposed thermocouples on the collector had been absorbing the solar radiation, causing the sensors to become warmer than the air. This problem was alleviated by shielding the thermocouples with duct tape on the glass covers, Figure 9.

The reflector and collector surfaces accumulated frost during the night. The early morning sun, however, would completely melt the frost buildup by 0900 h solar time or shortly thereafter, Figure 10. A considerable amount of ventilation exhaust dust settled onto the north collector glass and the reflector surface. On January 29, the reflector was washed and plywood sheets were attached to the bottom of the posts, Figure 11, to deflect the exhaust air upward behind the reflector. This substantially reduced the dust accumulation. The north collector was washed three times and the south collector once during the six week test. To use this solar system, a livestock building could be designed with the exhaust fans located on the north side of the building to eliminate the problem entirely.

Settling of the rocks in the TES unit caused the absorber plate to bulge outward. The north seam between the second and third sections of the collector, which had been sealed with caulking compound broke apart as a result of the pressure. The break was noticed on February 23, which indicated that the short circuit in the airflow path had probably occurred late in the test period.

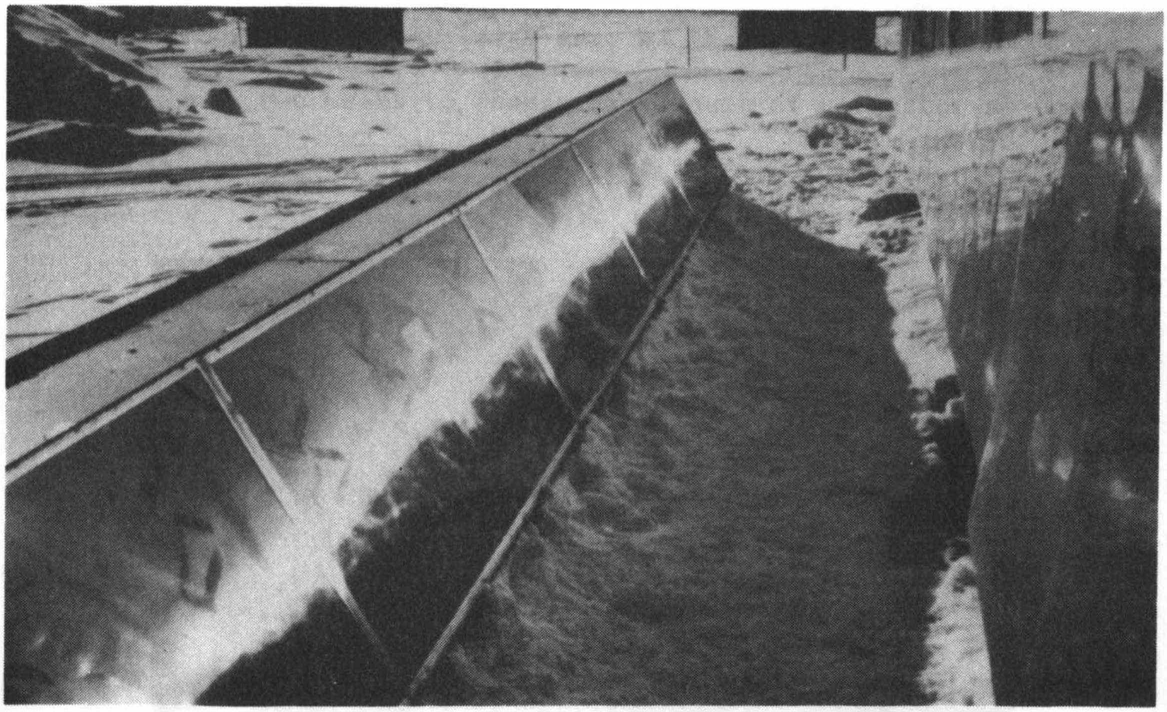


Figure 9. Concentrated band of solar radiation focused on the north collector by the concentrator. Note the glass cover framework, metal top cover, and collector baffles.

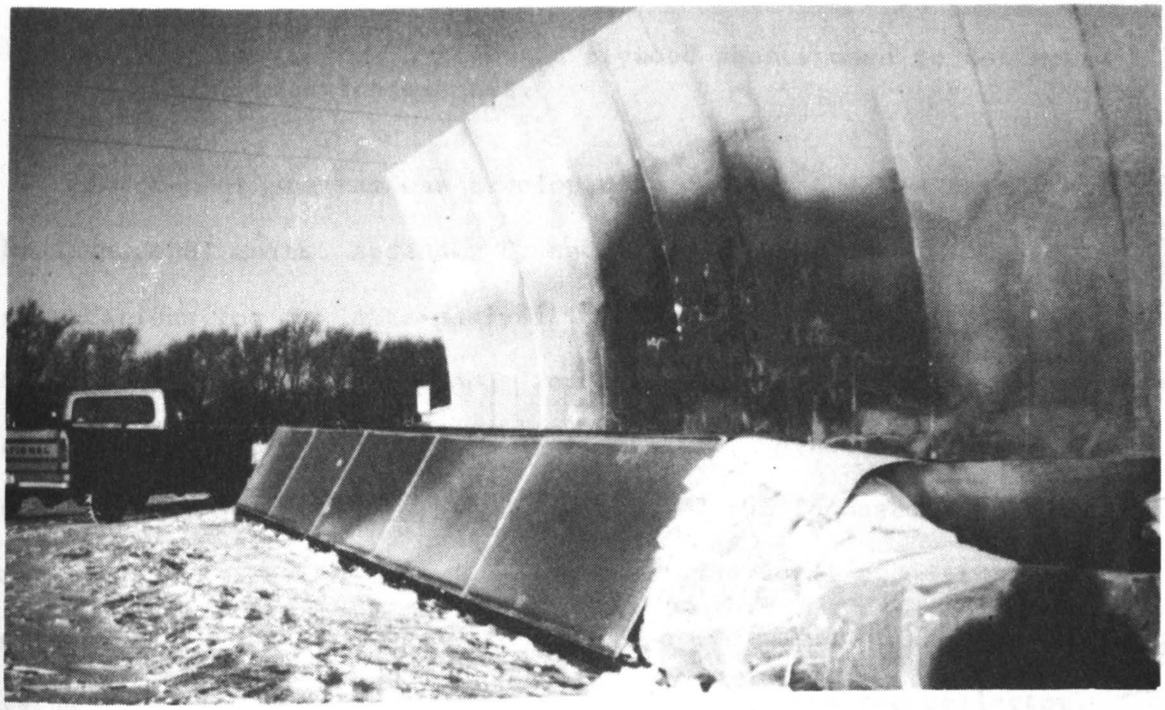


Figure 10. Frost accumulation on reflector and collector surfaces. Melting usually was completed at approximately 0900 h.

The offset pin on the large gear of the tracking mechanism was adjusted every two weeks to change the amount of reflector movement as the diurnal variation of the sun's profile angle changed.

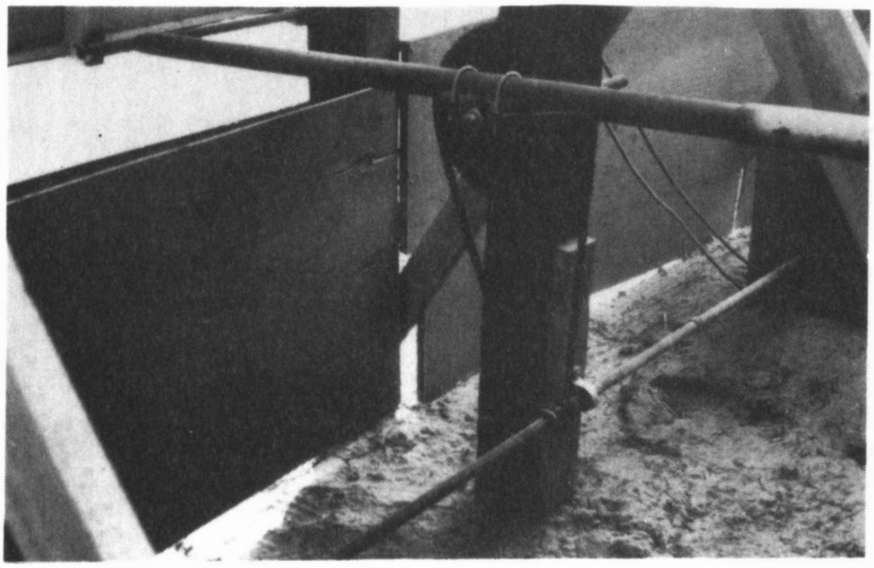


Figure 11. Tracking mechanism and plywood sheets used to deflect ventilation exhaust.

A computer program was developed to convert the raw data from English to SI units, Appendix E, and to perform the necessary computations for the data analysis. Temperature rises, incident radiation values, instantaneous and cumulative efficiencies, heat flows, and appropriate computer plots were obtained. Since the concentrator was longer than the collector, a portion of the focused strip of radiation did not fall on the collector. The total radiation and efficiency values were based on the effective length of the reflector (9.54 m), or that which concentrated radiation onto the collector. Several hours of missing data, Appendix F, occurred due to instrument failure and to the inability of one recorder to measure temperatures below -17.8 C. Therefore, the various overall performance parameters were not based on an equal number of days. A step-wise, multiple, regression analysis was used to obtain system performance, prediction equations.

RESULTS AND DISCUSSION

The specific characteristics and overall performance of the solar energy intensifier-thermal energy storage (SEI-TES), swine house heating experiment are presented. The discussion of the experimental results is organized under the following topic headings: (1) Thermal Performance for Test No. 1, (2) Thermal Performance for Test No. 2, (3) Statistical Analysis, and (4) Economic Performance. Since the airflow rate used in Test No. 1 was lower than the minimum winter ventilation rate, the results from Test No. 2 were analyzed more extensively.

Thermal Performance for Test No. 1

An airflow rate of 260.0 m^3/hr was used during Test No. 1, with north and south collector airflow rates of 160.4 and 99.6 m^3/hr, respectively. The temperature rises of the collector fluid at six locations, which are labeled S1, S2, S3, N1, N2, and N3 in Figure 7, were influenced by time of day. The maximum, collector temperature rises during a virtually cloudless day, February 2, were 89 and 61 C for the north and south collectors, respectively, Figure 12. The occurrence of early morning cloudiness on January 28, Figure 13, prevented the collector fluid from reaching the temperatures that were possible on a totally clear day. The maximum, collector air temperature usually occurred at 1300 or 1400 h. During a period of 11 days, the average, hourly, collector temperature rises were considerably lower in the morning than in the afternoon, Figure 14, which produced a skew to the left in the curve. This was partially due to the heat required to warm the collector mass to its equilibrium operating temperature and to the

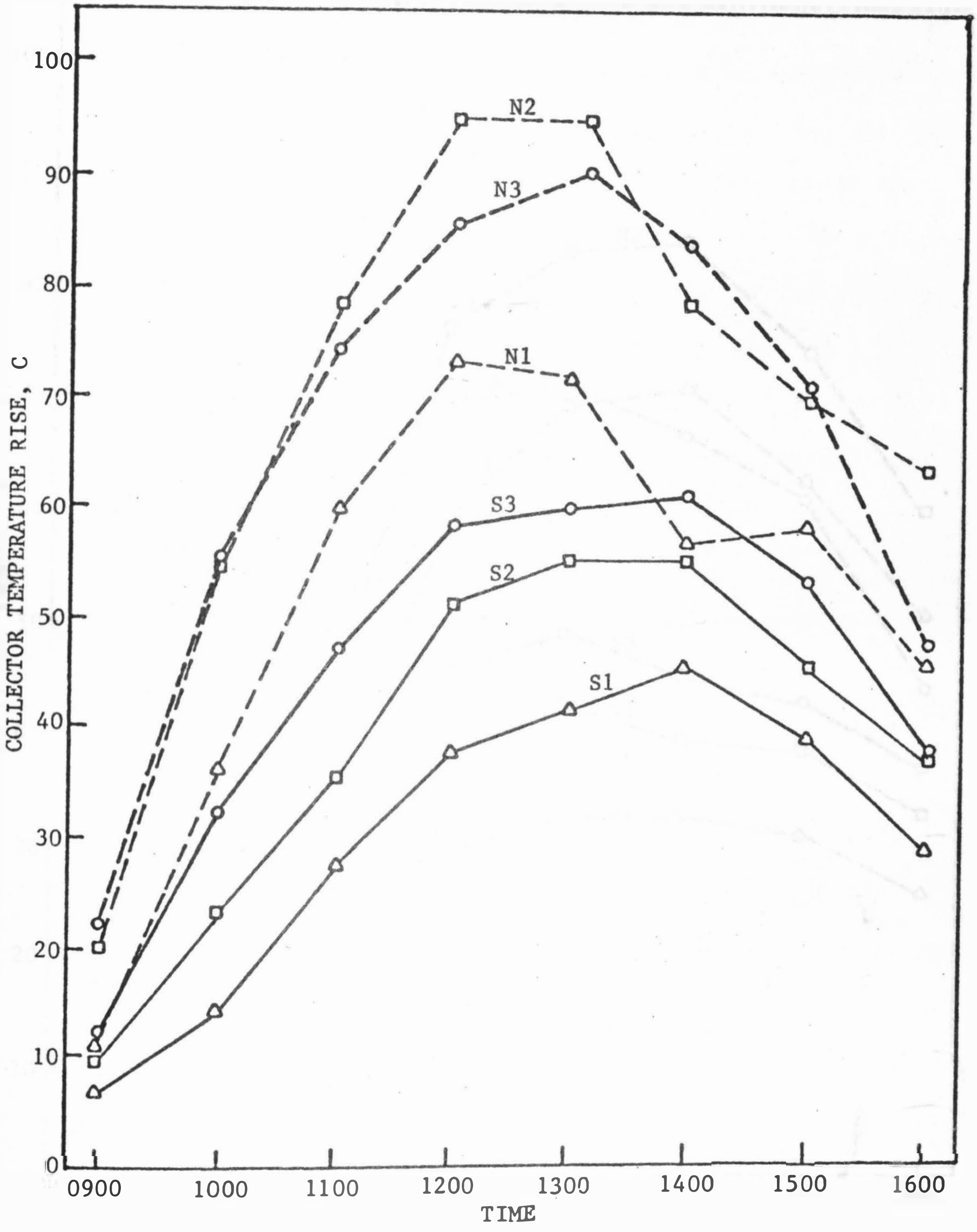


Figure 12. Collector air temperature rise as influenced by time of day, February 2, 1979.

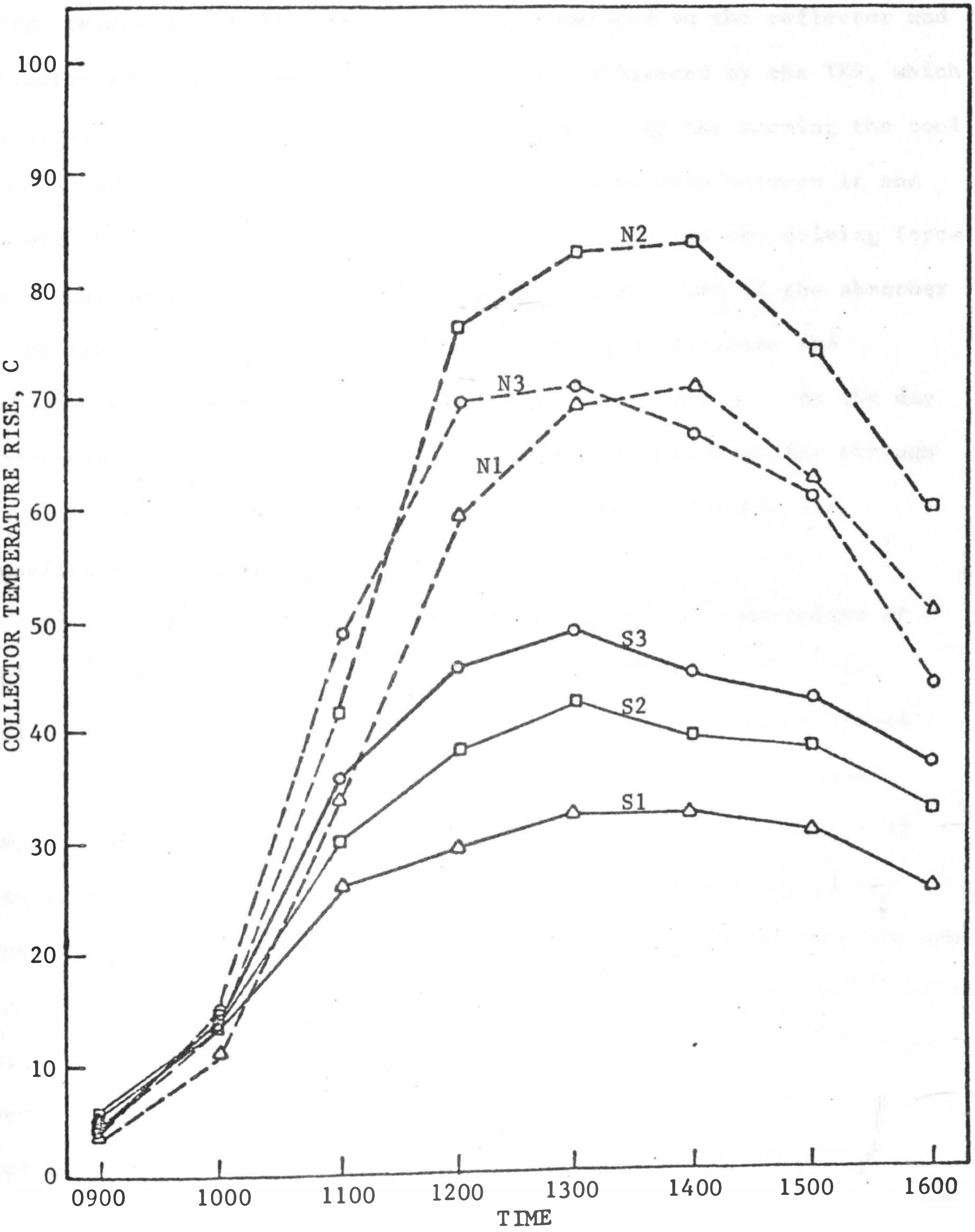


Figure 13. Collector air temperature rise as influenced by time of day, January 28, 1979.

energy required to melt the frost that accumulated on the reflector and collector surfaces, Figure 10. It was also influenced by the TES, which was located directly behind the absorber plate. In the morning the cool storage medium provided a large temperature difference between it and the absorber plate. This temperature differential was the driving force for a substantial amount of heat transfer from the back of the absorber to the TES. Consequently, less heat was available to raise the temperature of the air as it passed through the collector. As the day progressed with rising storage temperatures, the heat transfer through the back of the absorber plate decreased, and the collector air temperature increased.

Particularly during the afternoon, the collector temperature at position N3 was frequently less than the temperature at N2. This indicated that a net loss of heat from the air occurred as it flowed through the collector from N2 to N3. An inspection of the storage temperatures, during these hours, revealed cooler temperatures at N3 than at N2. At position N2, storage temperatures behind the plate frequently became equal to or warmer than the collector air temperatures. Concurrently, at position N3, the storage temperature became much cooler than the collector temperature. This indicated that considerably more thermal energy flowed through the back of the absorber plate during the last third as compared to the middle third of the collector length.

Ambient and storage temperatures are plotted from 0900 h on January 28 and February 2 to 0800 h of the succeeding day, Figures 15 and 16. The 24-hour periods cut across two calender days, as it was desirable to observe system response following particular days of solar energy input.

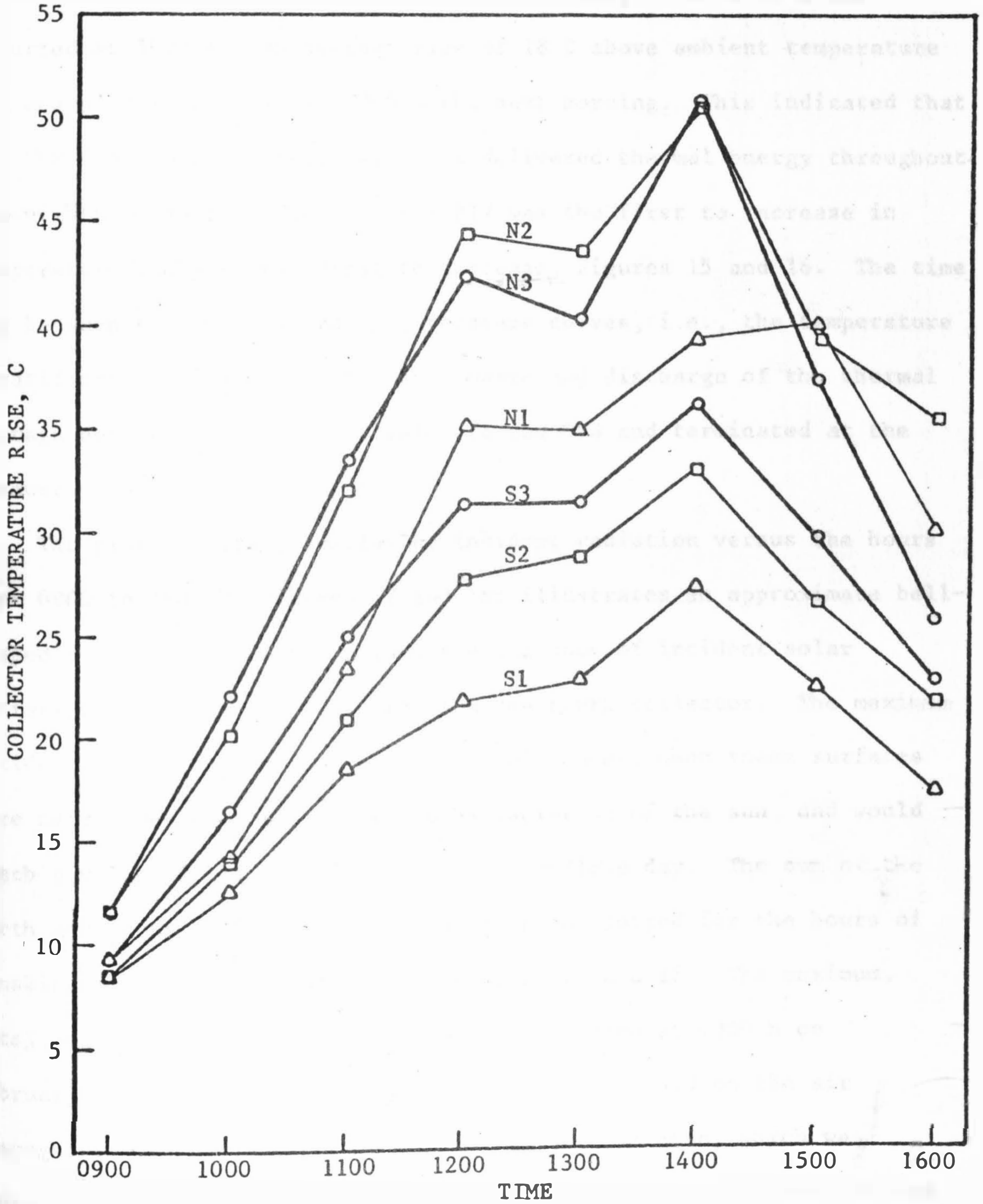


Figure 14. Average collector temperature rise as influenced by the time of day. Eleven days during period from January 25 to February 9, 1979.

The maximum storage temperature rise on February 2 was 57.3 C and occurred at 1600 h. An average rise of 18 C above ambient temperature was measured in the TES at 0800 h the next morning. This indicated that the TES functioned properly since it delivered thermal energy throughout the nighttime hours. Thermocouple #17 was the first to increase in temperature and also the first to decrease, Figures 15 and 16. The time lag between the three storage temperature curves, i.e., the temperature stratification, indicated that the charge and discharge of the thermal storage unit began at the air inlet to the TES and terminated at the exhaust.

The plot of total, available, incident radiation versus the hours from 0900 to 1600 h, Figures 17 and 18, illustrates an approximate bell-shaped curve. The plotted values are the sums of incident solar radiation normal to the reflector and the south collector. The maximum incident radiation occurred at around solar noon, when these surfaces were nearly perpendicular to the beam radiation of the sun, and would reach a value of 115 to 120 MJ/hr on a cloudless day. The sum of the north and south collector heat gains is also plotted for the hours of sunshine during the same two days, Figures 17 and 18. The maximum, total, collector heat gain of 25.7 MJ/hr occurred at 1300 h on February 2. The values of heat collection were based on the air temperature measurements at S3 and N3. Since the heat, which was transferred from the backside of the absorber did not flow past N3 and S3, the values were less than the total amount of collected energy. No attempt was made to delineate the quantity of heat collected from the backside of the absorber.

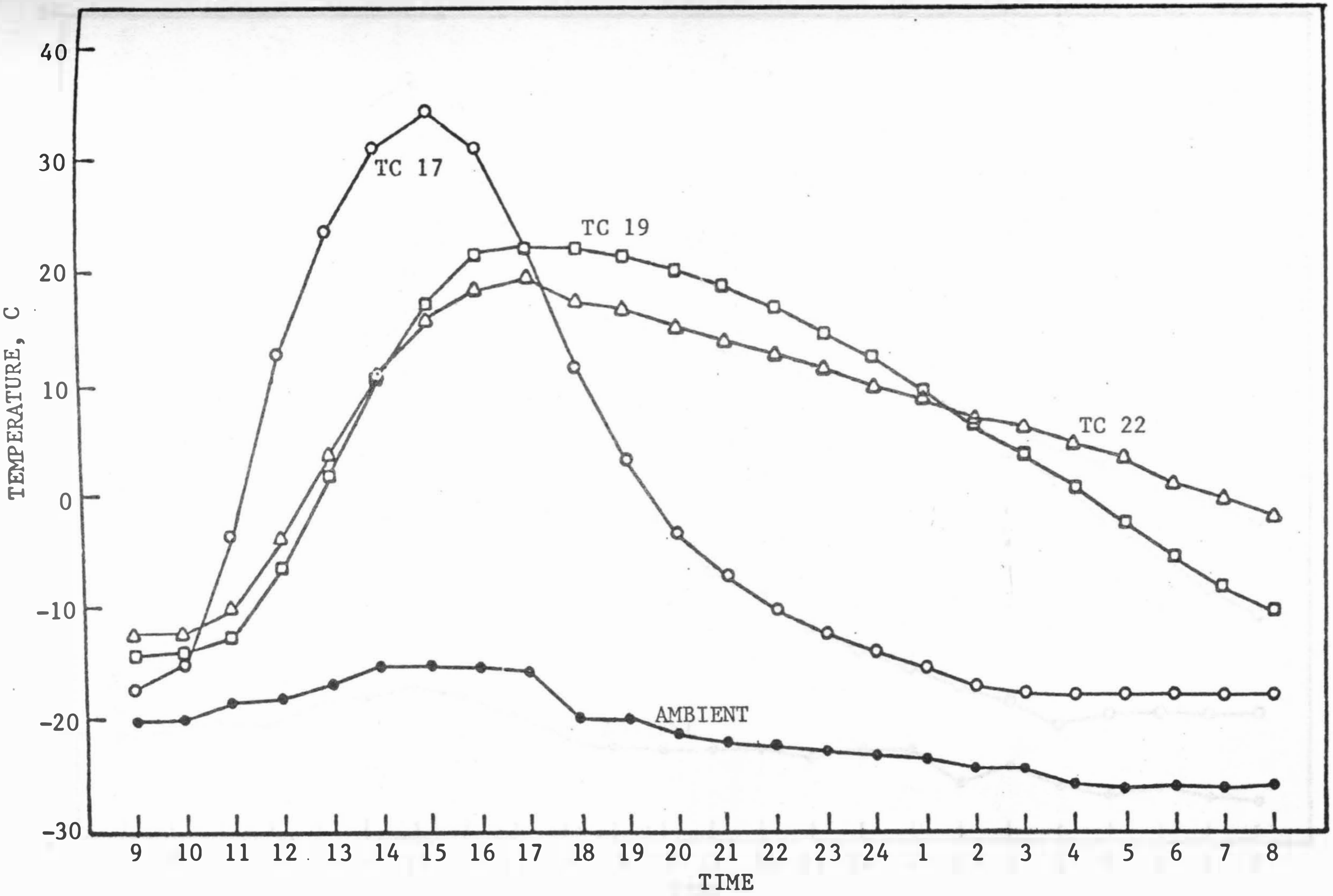


Figure 15. Storage and ambient temperatures for a 24-hour period beginning on January 28 at 0900 h.

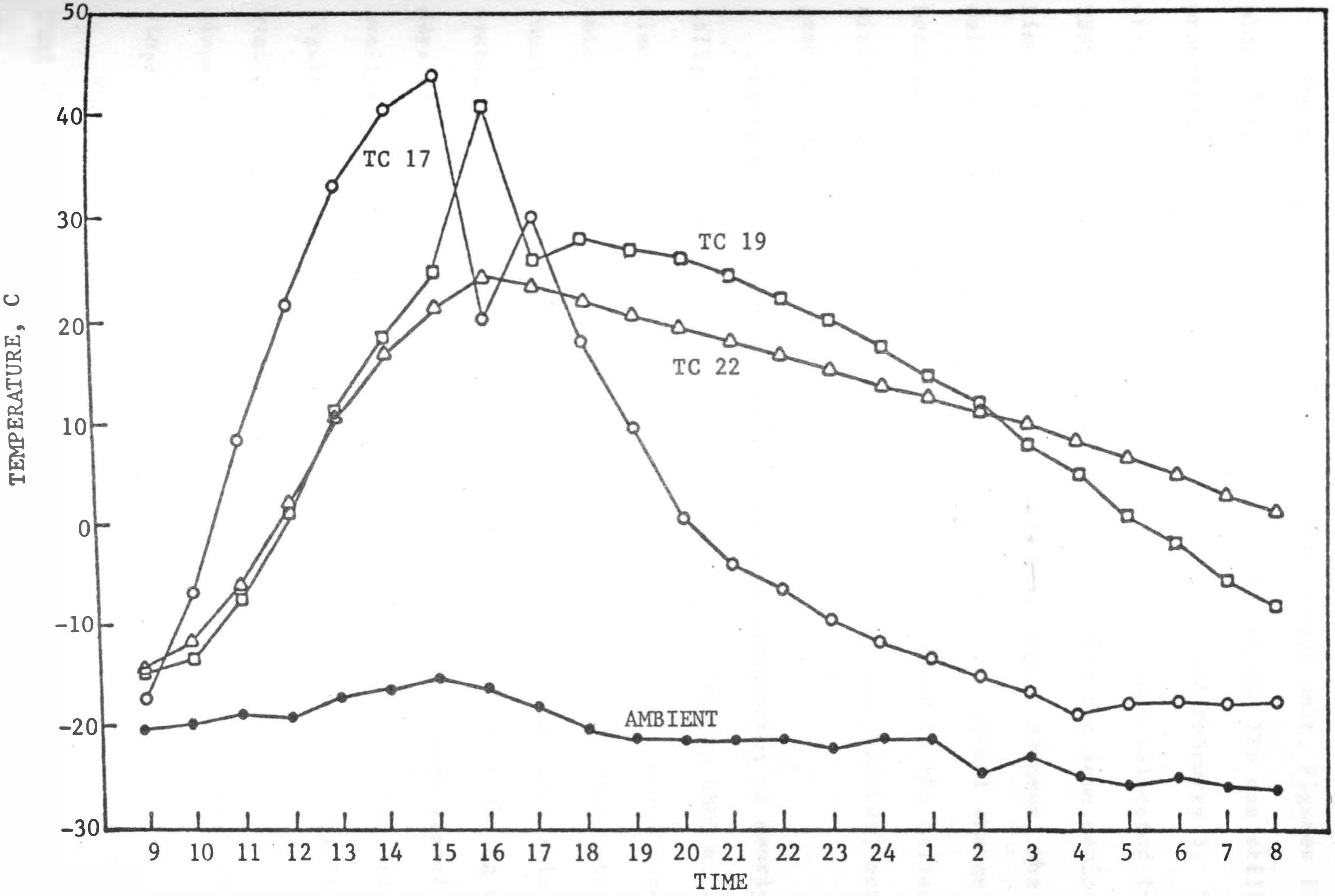


Figure 16. Storage and ambient temperatures for a 24-hour period beginning on February 2 at 0900 h.

The hourly heat collection from the storage unit, Figures 17 and 18, plotted over a 24-hour time period, showed that the TES was still providing over 6 MJ/hr at 0800 h on January 29 and February 3. The difference of total collector heat gain and the heat collected from the TES, i.e., the storage rate, is also plotted over the same period of time. Negative values indicate storage discharge. However, the calculated values are only a rough estimate of the actual charge rate because some of the thermal energy was recirculated in the collector airflow, because heat transferred directly from the absorber, and because general heat losses were not measured.

Daily heat gains were obtained through integration of hourly heat collection rates over 24-hour time periods from 0900 to 0800 h. This time span was used because the collection of heat from the TES continued into the early hours of the following day. Figure 19 illustrates the cumulative, incident, solar radiation energy which was available to the system and the cumulative energy delivered from the unit during the 27 days of the test period. A total of 17.47 GJ of incident radiation were available and 3.4 GJ of thermal energy were delivered during Test No. 1. Figure 20 is a graph of cumulative useful heat versus the cumulative, available, incident radiation for the same 27 days of the test. The slope at any point on the curve indicates system efficiency. The average slope, i.e., efficiency, for Test No. 1 was .195.

The daily thermal efficiencies, based on heat collected from 0900 to 0800 h, versus daily totals of incident radiation are illustrated in Figure 21. Daily efficiencies ranged from a low of 4.6% to a high of 29%. A highly significant, third degree, polynomial curve, fitted by the

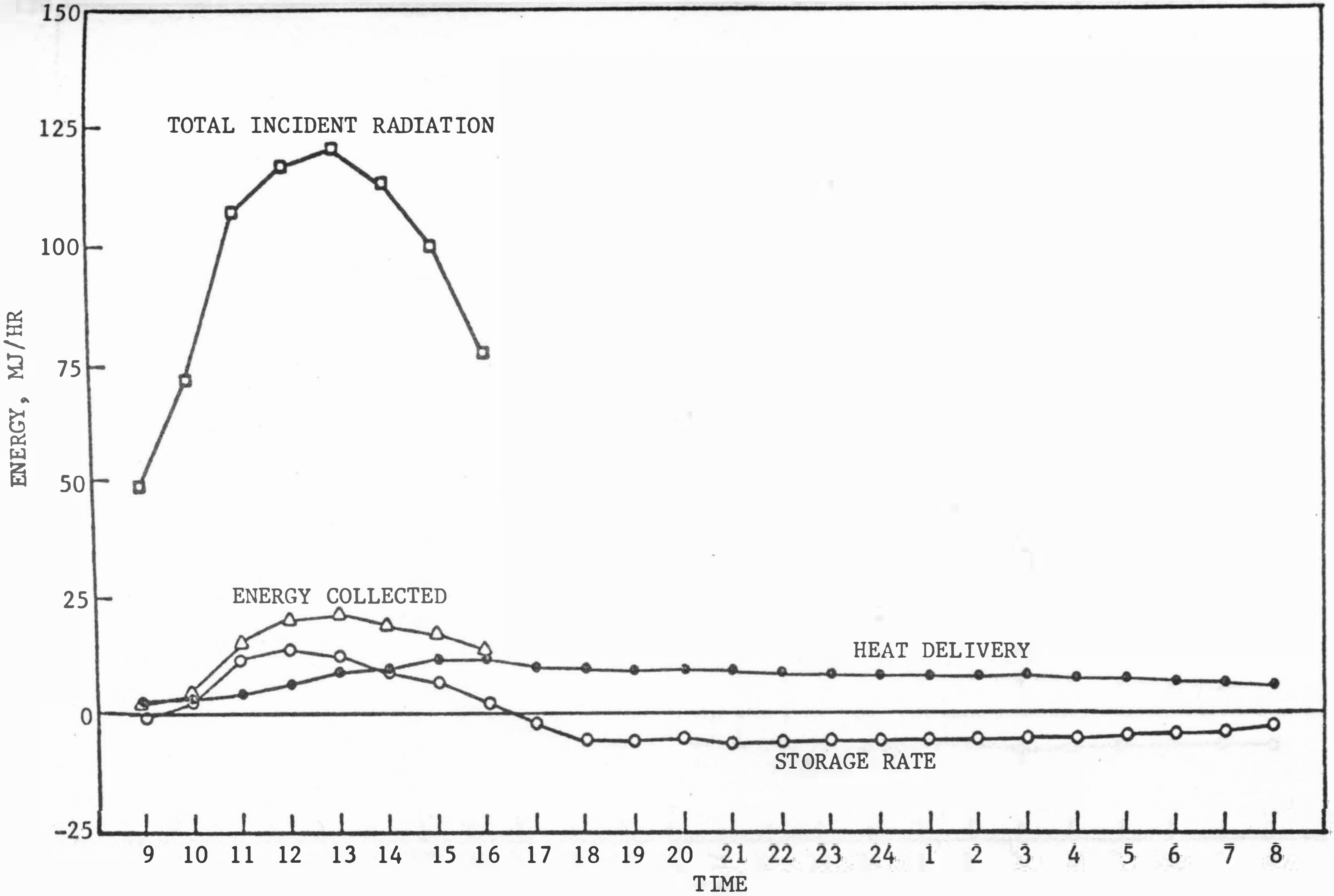


Figure 17. Available, collected, delivered, and stored energy versus the time of day, January 28.

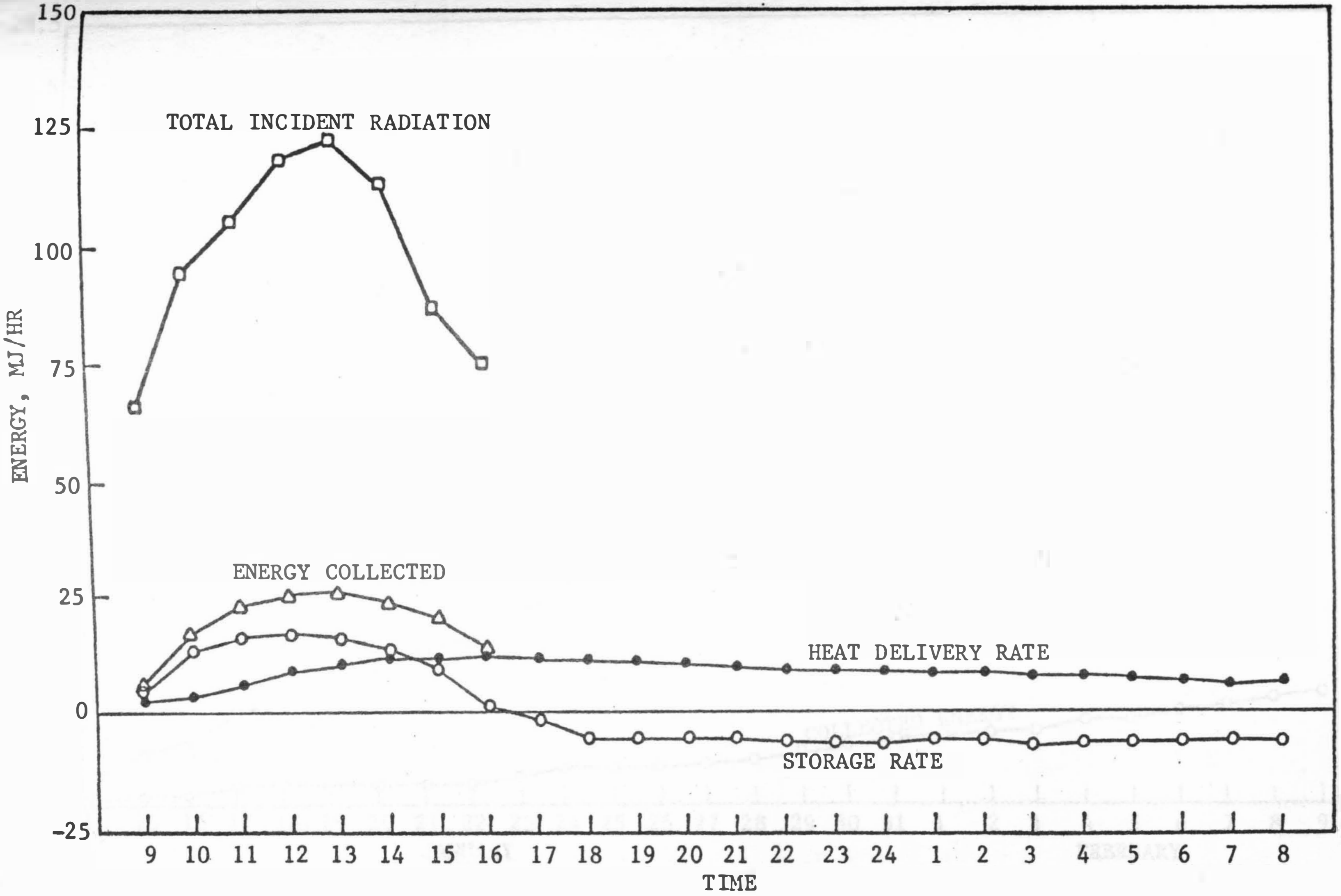


Figure 18. Available, collected, delivered and stored energy versus the time of day, February 2.

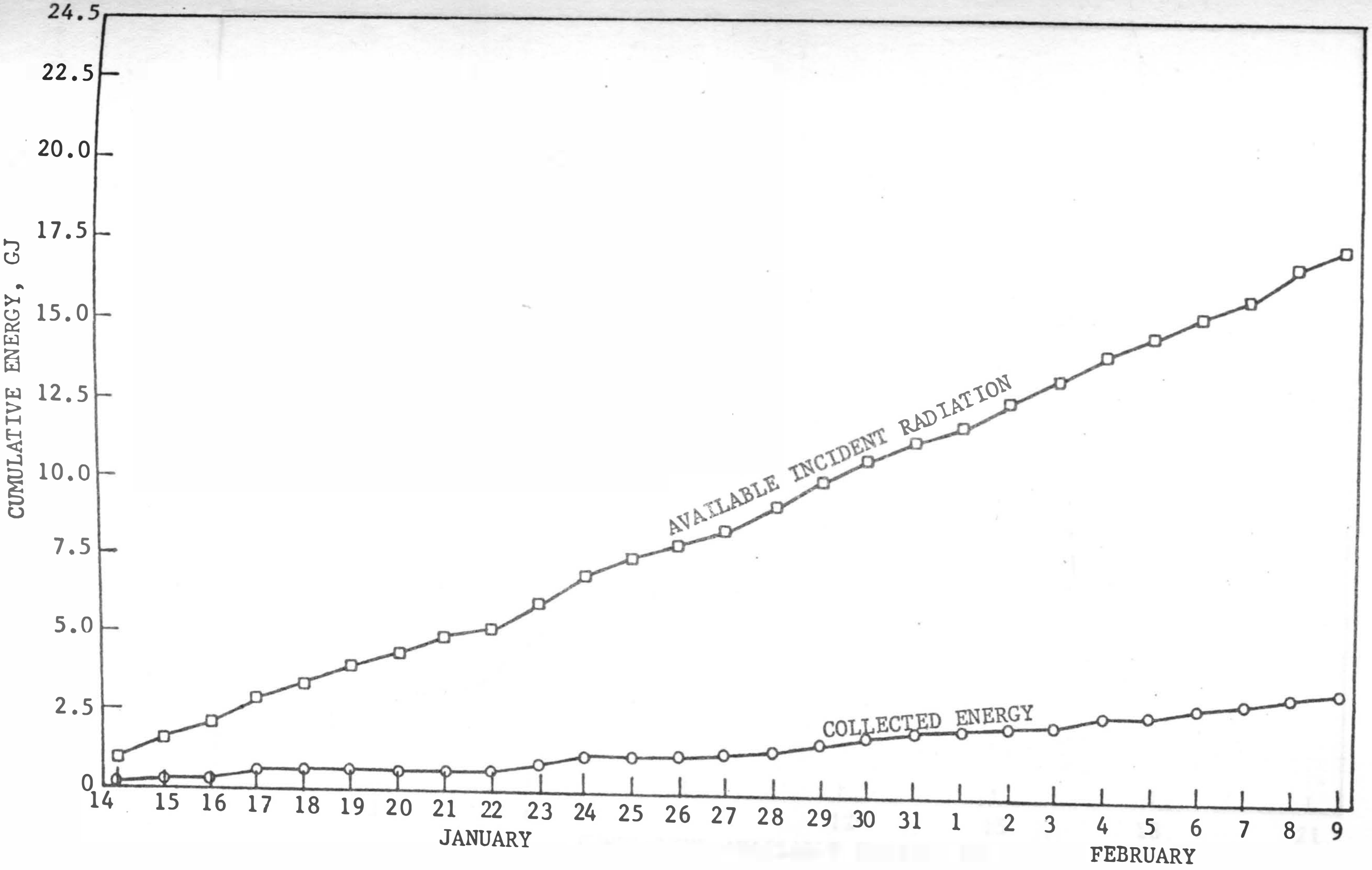


Figure 19. Cumulative, available radiation normal to reflector and south collector and cumulative collected thermal energy, Test No. 1.

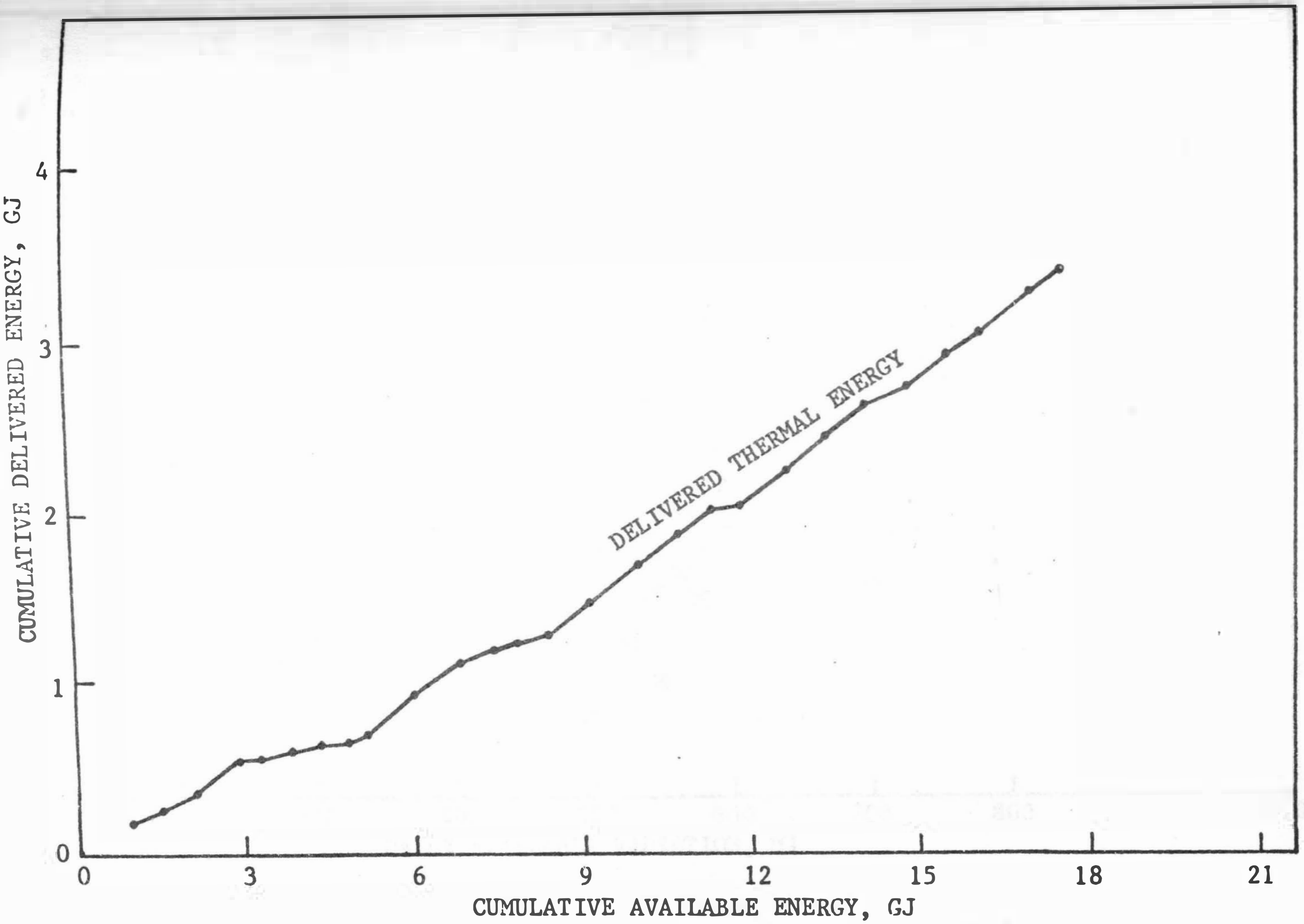


Figure 20. Cumulative delivered thermal energy versus cumulative available solar energy, Test No. 1.

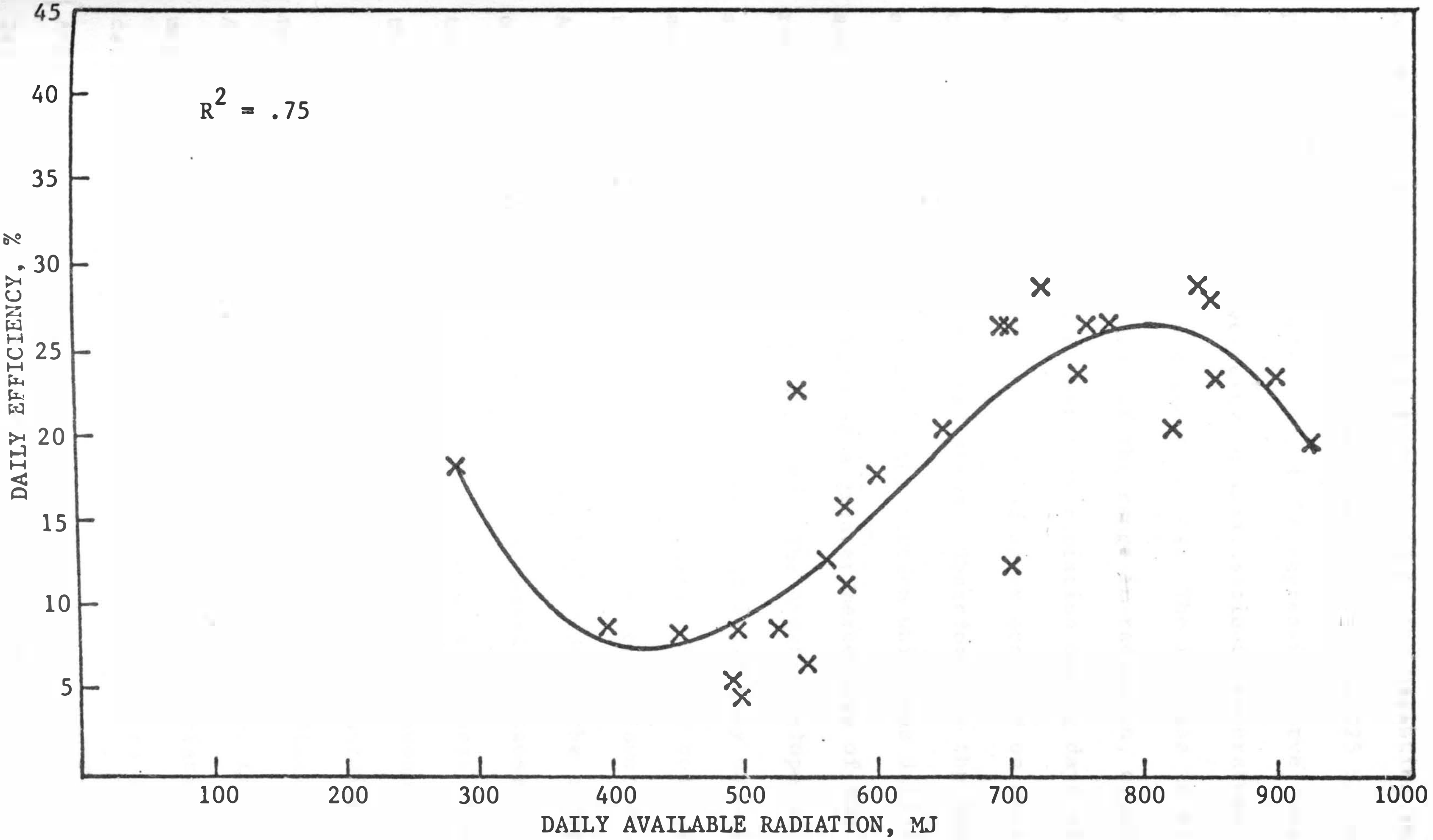


Figure 21. Daily efficiency as influenced by daily available radiation, January 14 to February 9, 1979.

method of least squares explained 75.1% of the variation in daily efficiency for the range in radiation from 285 to 925 MJ (Appendix A-1). The scatter of the points, around the regression curve, was due to factors such as wind velocity, diurnal ambient temperature changes, cloudy weather, and measurement errors. The increase in efficiency values, for the major part of the range in radiation, occurred because of the low fraction of direct beam radiation during days with low, total, solar radiation. Little or no cloud cover occurred on days with large totals of available solar radiation. Therefore, as the amount of daily available radiation increased, the portion which was diffuse decreased, and the reflector concentrated a greater percentage of the total radiation onto the north collector. The negative slope at the right side of the curve indicates a decrease in efficiency as daily radiation amounts increase on totally cloudless days. Higher collector temperatures would increase heat losses and cause lower efficiency. A similar phenomenon occurred at the left side of the curve as the amount of radiation on totally cloudy days increased and caused higher air temperatures in the south collector. Because of these changes in slope, the third-degree, polynomial regression appears reasonable.

An improved coefficient of determination was obtained in predicting the daily delivered heat as a function of daily radiation, Figure 22. A highly significant, third order, polymonial curve, fitted by the method of least squares, explained 87.6% of the variation in daily delivered heat for the range of radiation from 285 to 925 MJ (Appendix A-2). The quantities of daily delivered heat ranged from 27.4 to 243.4 MJ. The shape of the regression curve was similar to the estimate of daily efficiency in Figure 22.

Thermal Performance for Test No. 2

A volumetric airflow rate of 709 m^3/hr was used during Test No. 2, with north and south collector airflow rates of 437 and 271 m^3/hr, respectively. The installation of the larger fan was the only alteration of the system from Test No. 1.

Maximum temperature rises of 40.8 and 28.3 C were recorded in the north and south collectors on the somewhat cloudy day of February 19, Figure 23. Three consecutive cloudless days occurred on February 23, 24 and 25, Figures 24, 25 and 26. Maximum temperature rises of 67.5 and 41.4 C were reached in the north and south collectors, respectively. The maximum, average, north and south collector temperatures for a period of 13 days were 31.6 and 23.1 C and occurred at 1400 h, Figure 27. The bell-shaped temperature variation of the air in the collector was skewed to the left as in Test No. 1. The system warm-up period in the morning again caused the longer left tail of the curve.

Ambient and storage temperature curves are plotted versus the 24-hour, heat delivery period for February 19, 23, 24 and 25, Figures 28 and 29. The maximum, storage temperature rise of 45 C, above an ambient air temperature of -10 C, occurred at 1600 h on February 24. On the somewhat cloudy day of February 19, storage temperature rises decreased to zero at 0600 h the following morning. During the three, consecutive, clear days, however, positive temperature differences in the TES were maintained until collection of energy began the next day. As described in the results of Test No. 1, the heating and cooling front

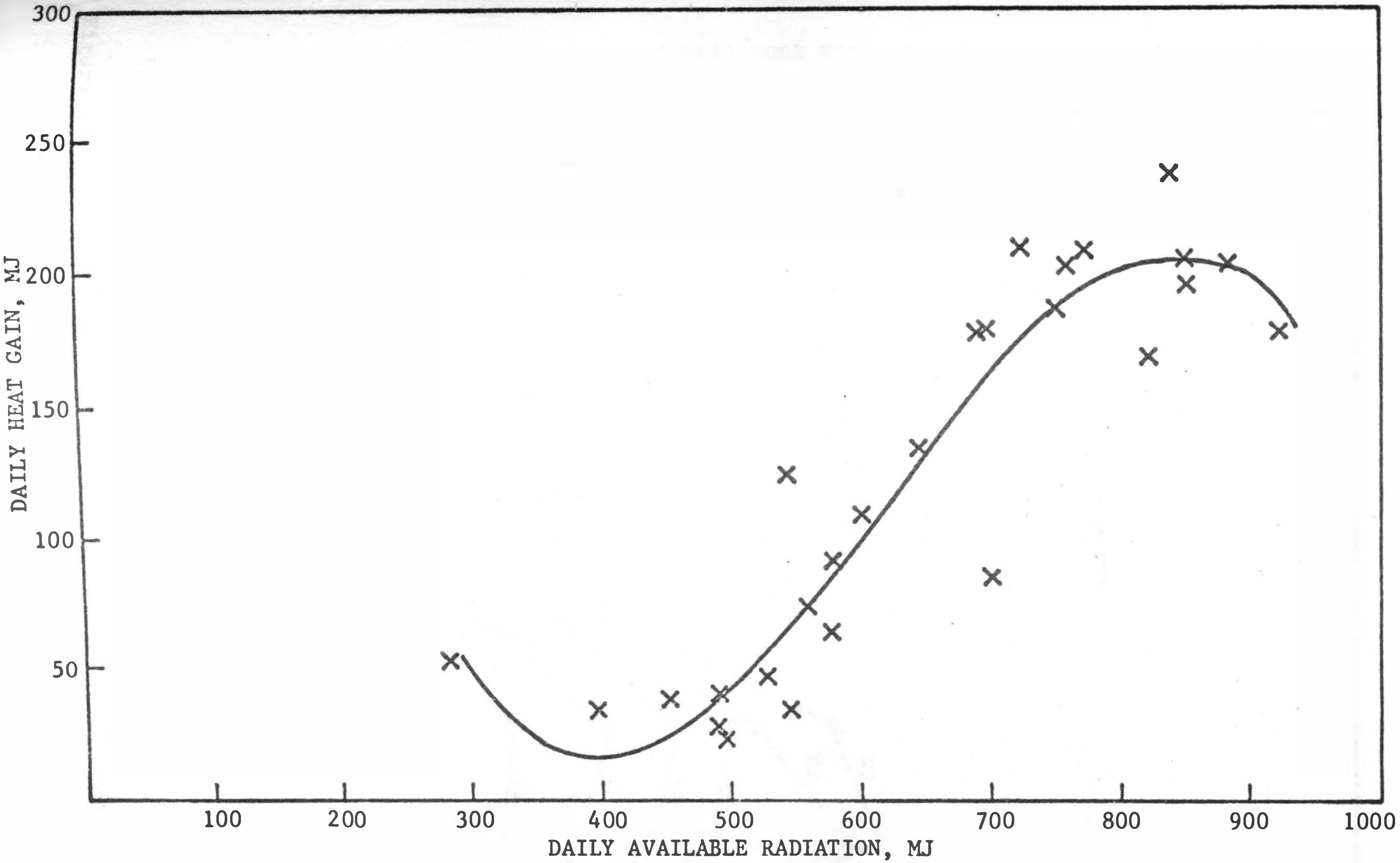


Figure 22. Daily heat gain as influenced by daily available radiation, January 14 to February 9, 1979.

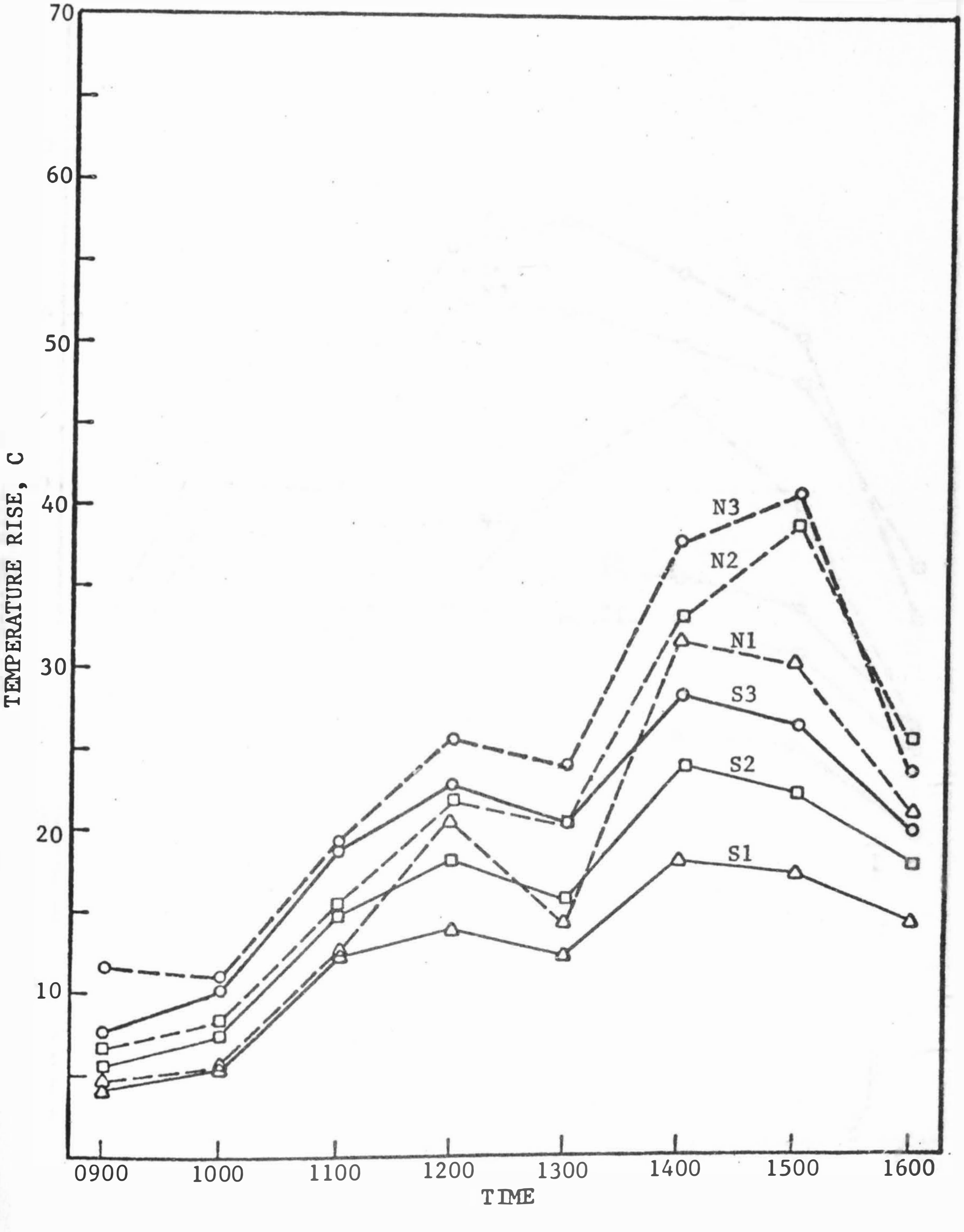


Figure 23. Collector temperature rise as influenced by time of day, February 19, 1979.

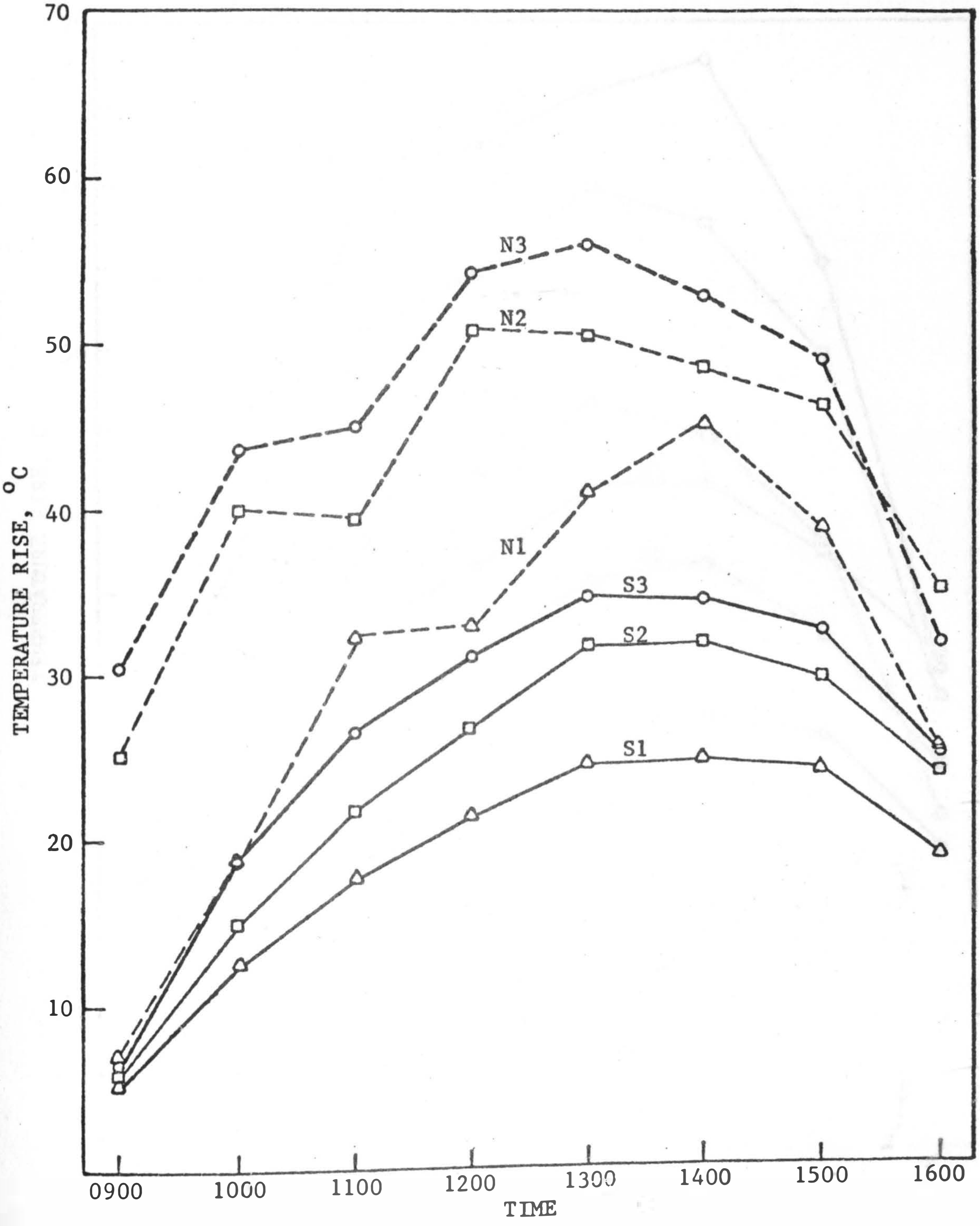


Figure 24. Collector temperature rise as influenced by time of day, February 23, 1979.

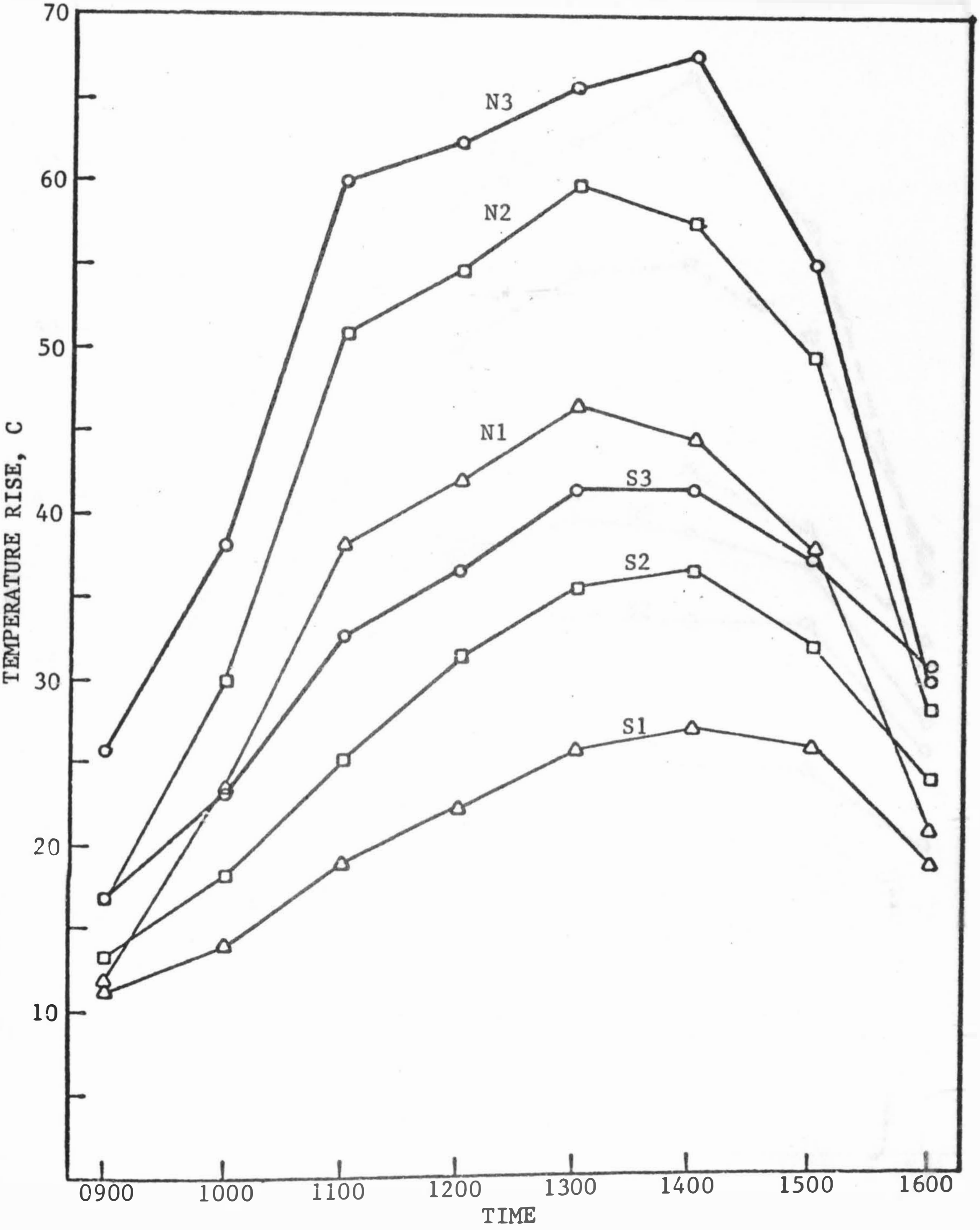


Figure 25. Collector temperature rise as influenced by time of day, February 24, 1979.

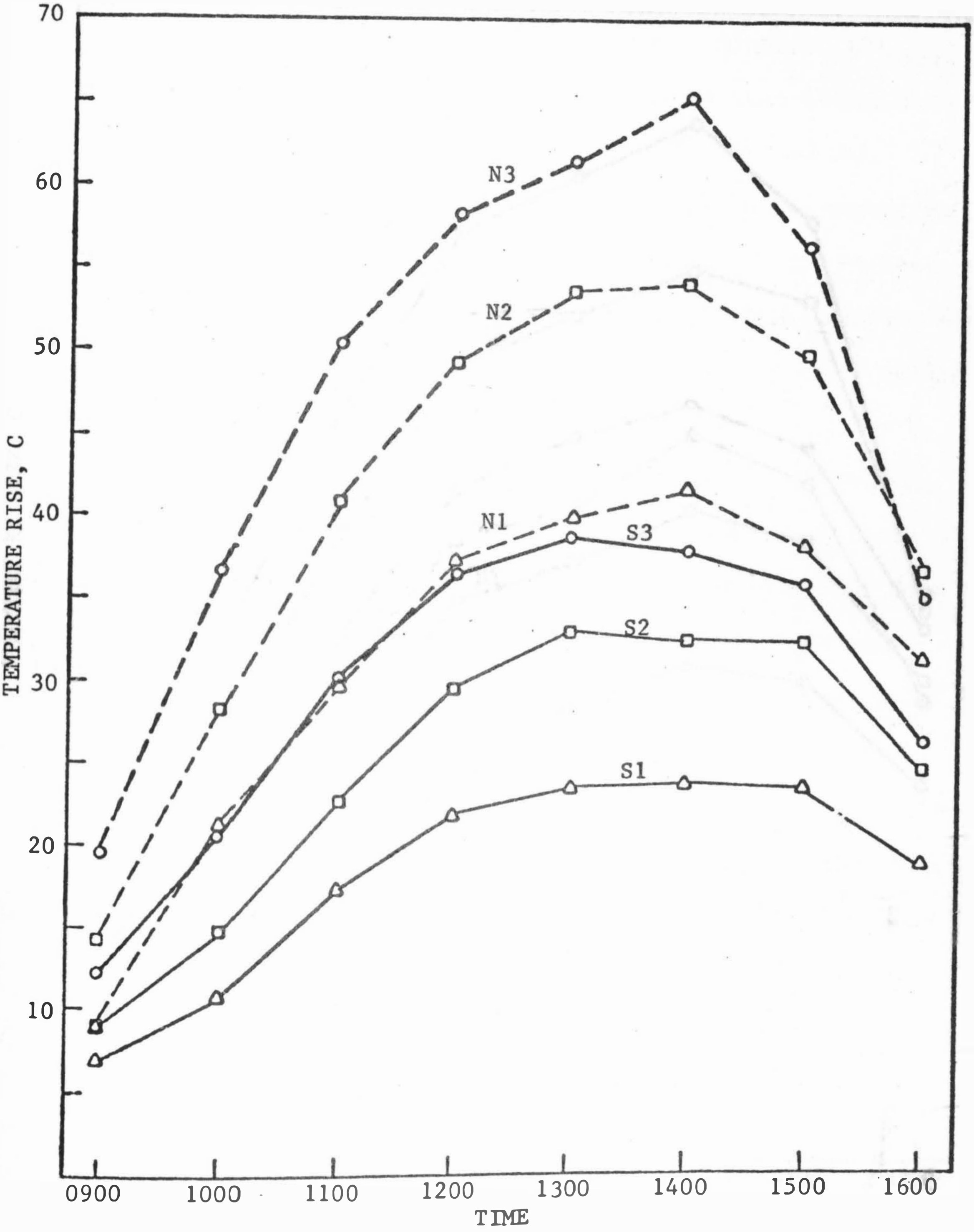


Figure 26. Collector temperature rise as influenced by time of day, February 25, 1979.

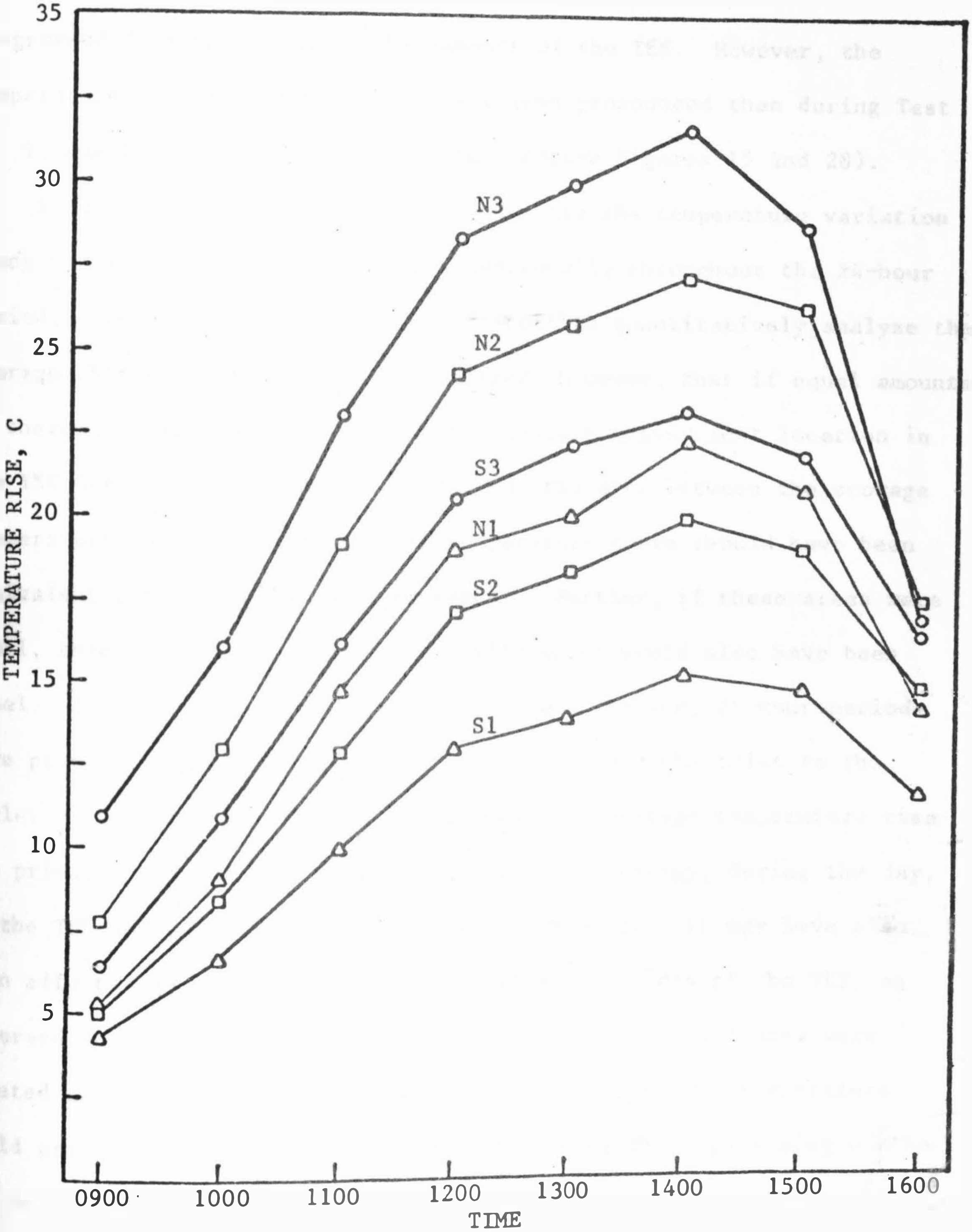


Figure 27. Average collector temperature as influenced by the time of day for 13 days during Test No. 2.

progressed from the inlet to the exhaust of the TES. However, the temperature stratification was clearly less pronounced than during Test No. 1, due to the higher airflow rate (Compare Figures 15 and 28).

Since thermocouple #21 failed, and since the temperature variation along the length of the TES changed continually throughout the 24-hour period, Figures 28 and 29, it was difficult to quantitatively analyze the storage characteristics. It was realized, however, that if equal amounts of thermal energy flowed past each temperature measurement location in the TES during several days of operation, the area between the storage temperature curves and the ambient temperature curve should have been equivalent for each point of measurement. Further, if these areas were equal, then the average temperature differences would also have been equal. The average storage temperature rises for ten, 24-hour periods were plotted, and showed an increase in value from the inlet to the outlet of the TES, Figure 30. The increase in average temperature rise was primarily caused by the addition of thermal energy, during the day, to the TES and from the back of the absorber plate. It may have also been affected by the increased airflow along the sides of the TES, as observed in smoke tests at the inlet. Since the thermocouples were located at the center of the TES, the true, average, air temperature would probably have not been recorded until more thorough mixing of the air occurred as it flowed toward the exhaust. The slight decrease in average temperature rise from #22 to #23 was a result of heat loss from the transition section.

The incident radiation values and the storage charge rate were calculated, as in Test No. 1, and had similar characteristics, Figure 31.

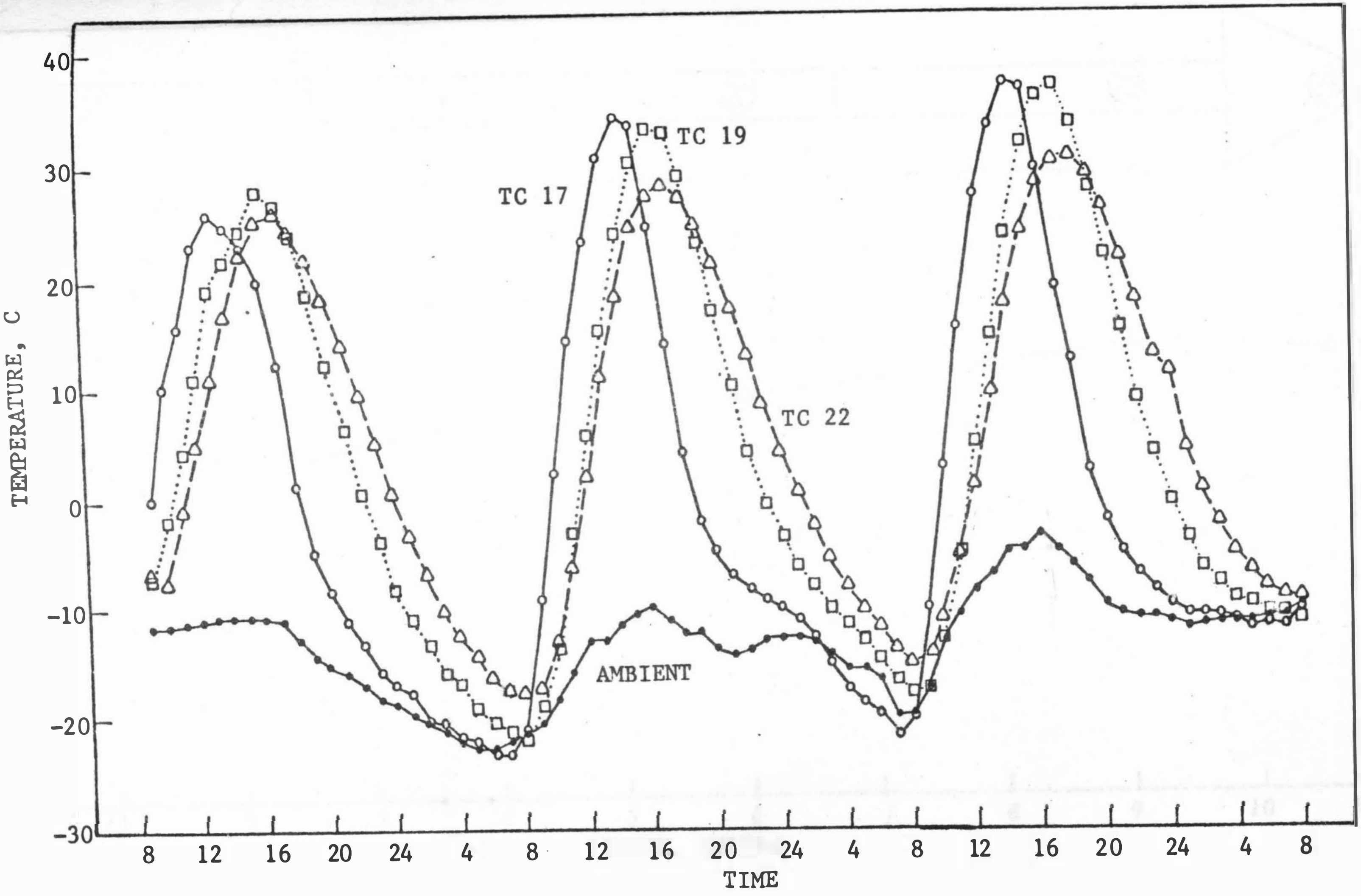


Figure 29. Storage and ambient temperatures, February 23, 24 and 25, 1979.

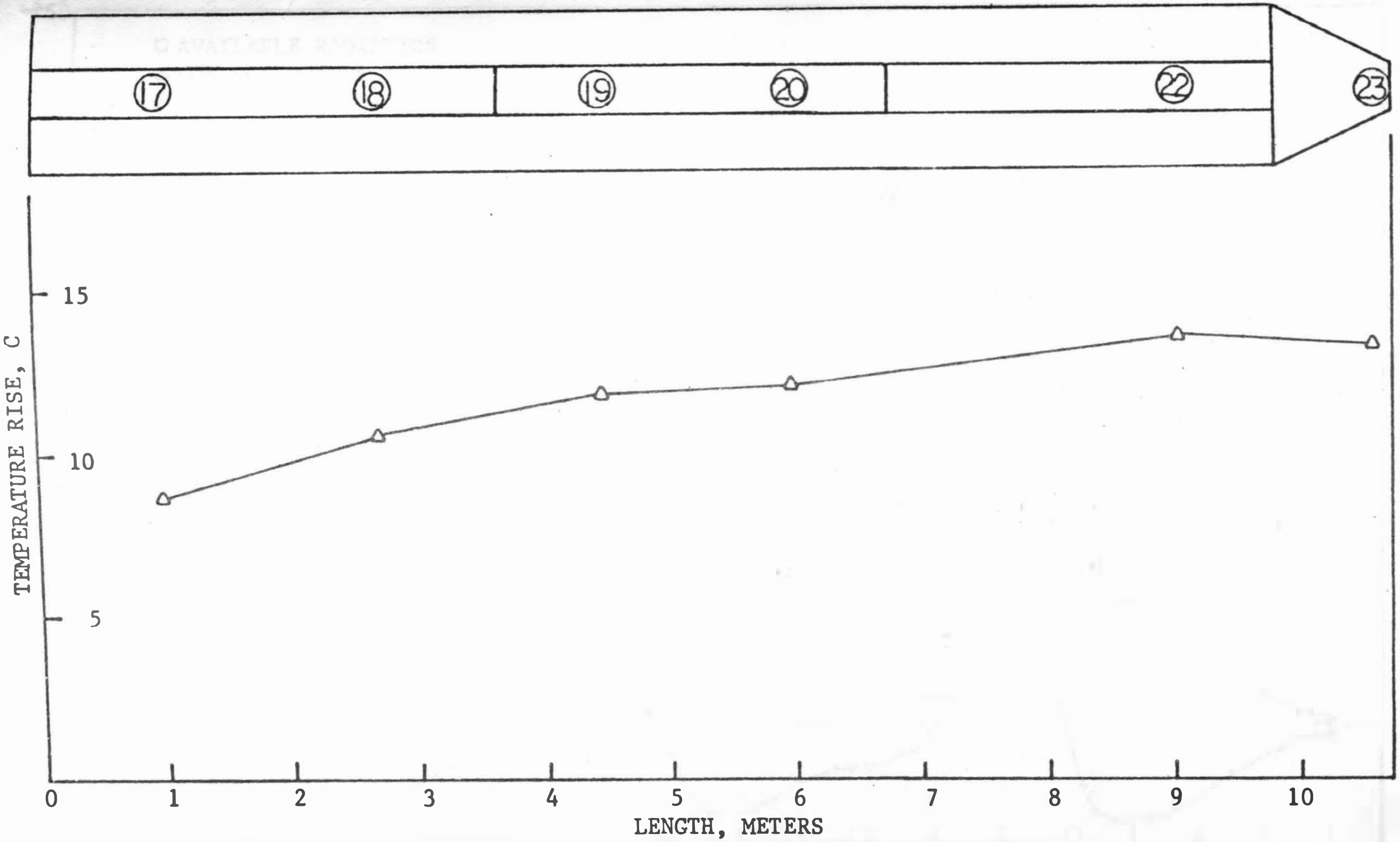


Figure 30. Average storage temperatures as influenced by the position along the length of the TES, ten 24-hour periods from 0900 to 0800 h.

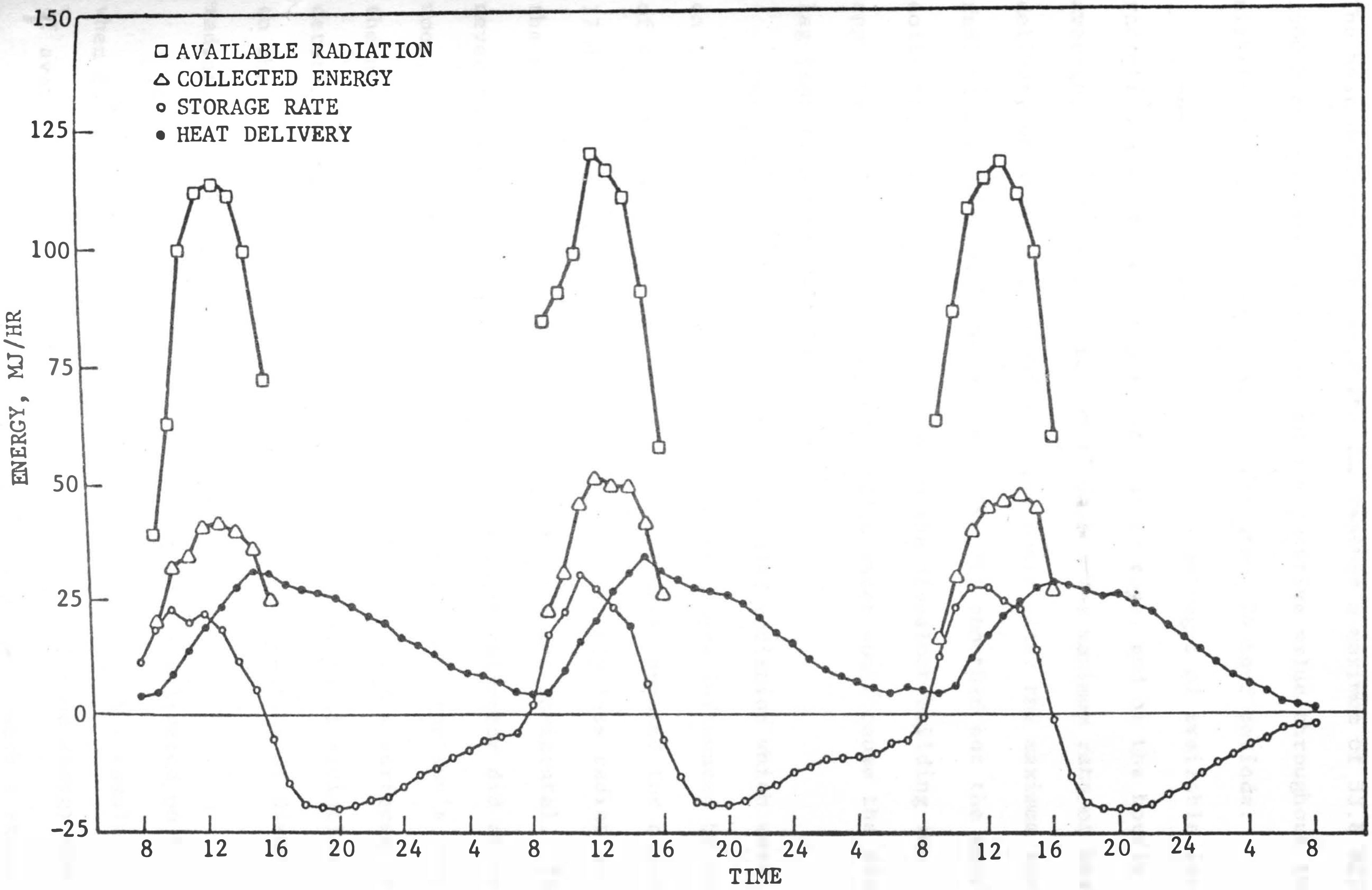


Figure 31. Available, collected, stored and delivered energy for three consecutive cloudless days: February 23, 24 and 25, 1979.

The heat delivery rate from the TES reached a maximum of 33.8 MJ/hr at 1500 h on February 24 and retained a positive value throughout the nighttime hours for the three, illustrated, 24-hour periods.

Figure 32 is a graph of the hourly averages of available incident radiation and ambient temperature for 17 days, and of the hourly, average, heat delivery rate for 15 days. The maximum rate of heat delivery occurred approximately three hours after the maximum incident radiation available to the system. The TES smoothed out the energy collection rate and provided heat to the livestock building for approximately 16 hours. Higher airflow rates would cause the storage lag time to become shorter.

The portions of the direct, beam solar radiation which were incident on the south collector and the concentrator were influenced by the time of day, Figure 33. These hourly averages were computed for a period of 17 days. The concentrator received significantly less radiation than the south collector which was tilted 60° from the horizontal. The SEI never faced directly at the sun, as the south collector did at solar noon, because it tilted slightly downward to focus the sun's rays onto the north collector. The hourly cosine factor of the surfaces is determined from Figure 33 by dividing the quantity of radiation incident on the receiving surface by the corresponding quantity of direct radiation.

The maximum, daily heat gain of 416 MJ was delivered on February 16 when 845 MJ of incident radiation were available. The cumulative totals of available, incident, solar radiation and collected energy are presented in Figure 34. The portions of the curves with a steep slope

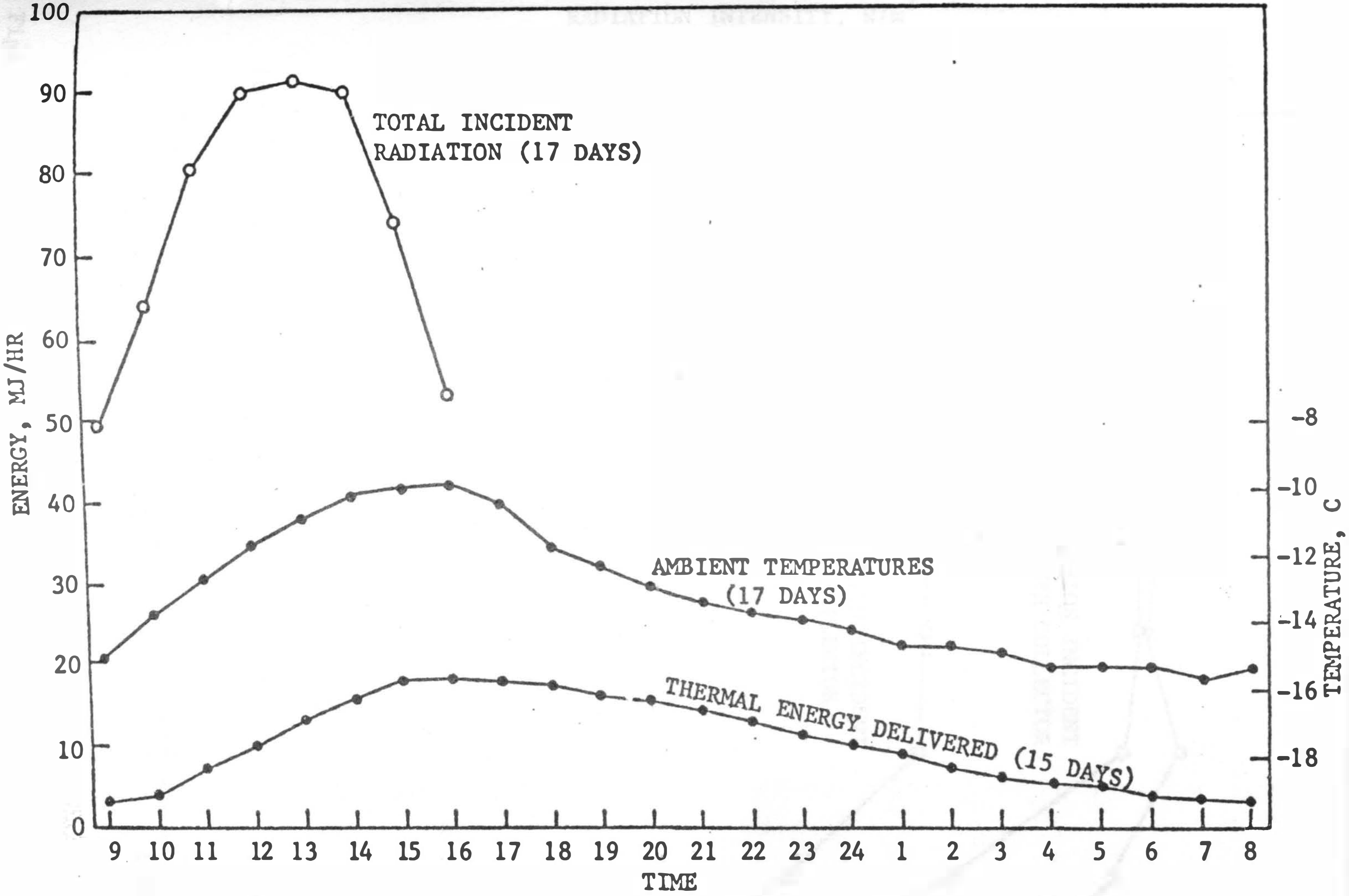


Figure 32. Hourly average available and delivered energy, and hourly average ambient temperatures, Test No. 2.

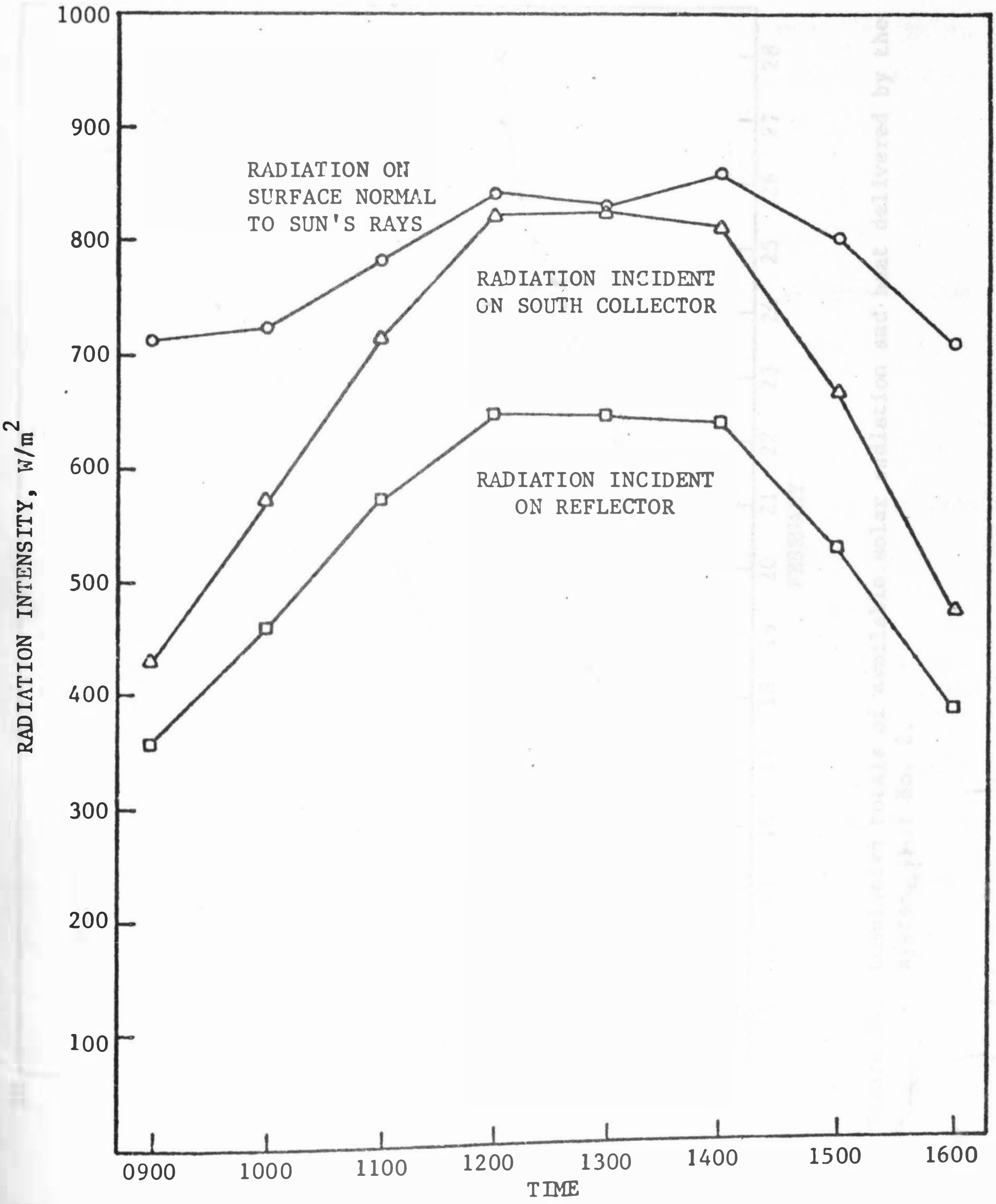


Figure 33. Hourly average of incident radiation on the reflector, south collector, and a surface normal to the sun's rays. 17 days.

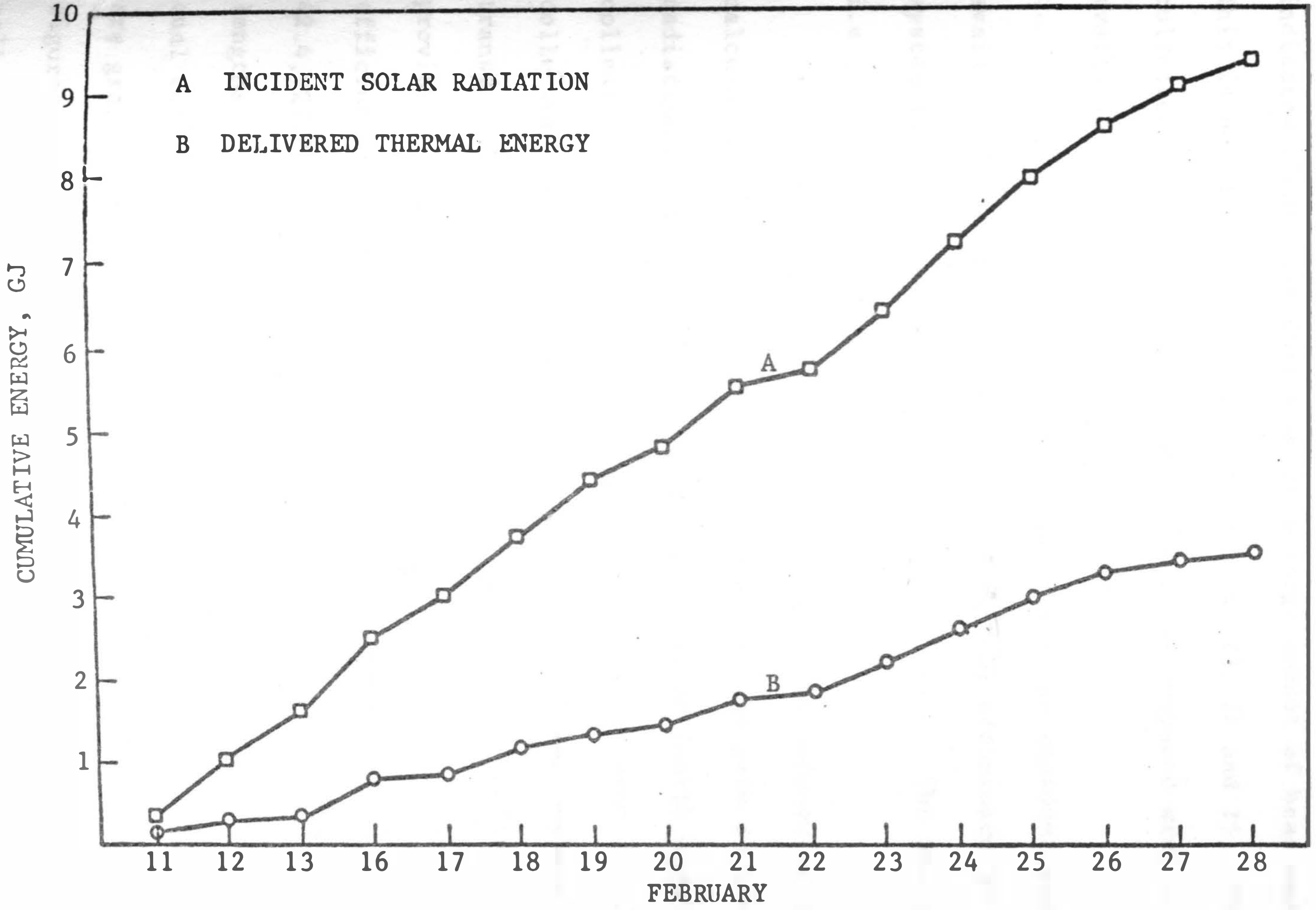


Figure 34. Cumulative totals of available solar radiation and heat delivered by the system, Test No. 2.

indicated clear days during which a large amount of heat was collected. This is noted especially for February 16, 23, 24 and 25. The total heat collected during the 16 days was 3.50 GJ as compared with 9.38 GJ of available solar radiation.

The cumulative energy collected versus the incident radiation available is shown in Figure 35. The thermal efficiency of the SEI-TES system is determined from the slope of the curve. The average slope, i.e., efficiency, was .373 for Test No. 2.

The instantaneous collector efficiency, as defined on page 33, was calculated as the ratio of hourly collector heat gain to hourly incident radiation on the respective length of reflector (north side) or collector (south side). This ratio does not represent the "true" collector efficiency for the SEI-TES because of the occurrence of heat transfer through the absorber plate. However, the calculations did provide some useful information. The average instantaneous collector efficiencies during 11 days from 0900 to 1600 h were 57.1, 36.6, 28.0, 42.4, 27.8 and 20.7% for the S1, S2, S3, N1, N2, and N3 collector lengths, respectively. The average instantaneous efficiency for the dual collector system was 22.6%. The hourly, instantaneous efficiencies are graphed for February 19 and 23, Figures 36 and 37. It can be seen in Figures 36 and 37 that as the length of collector increased, the heat collection efficiency decreased. The portion of length near the collector exhaust contributed little to the net heat gain of the collector fluid. The inlet section of the collector, however, collected heat at much higher efficiency. Efficiencies of 100% or greater were calculated for the S1 length during the late afternoon hours. These high

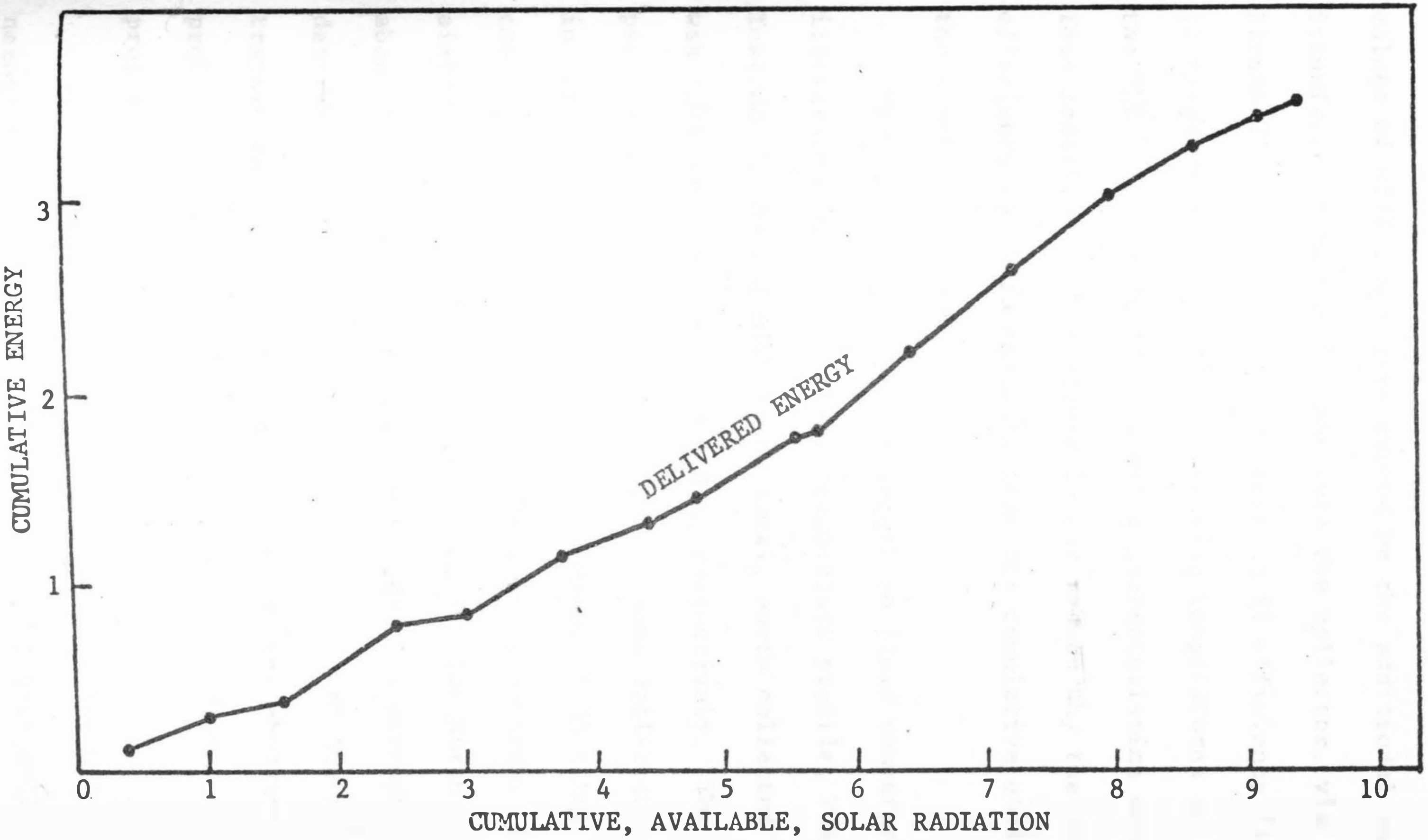


Figure 35. Cumulative, delivered energy versus cumulative available solar radiation, Test No. 2.

values of efficiency were caused by the additional energy that was transferred from the TES and into the collector, via the absorber plate. Figure 37 shows a steady increase in S1 efficiency from 1100 to 1600 h corresponding to steadily increasing temperatures at the exhaust end of the TES. Figure 36 shows similar characteristics on a day with somewhat less radiation. This effect is one reason why the instantaneous efficiency was less reliable than the cumulative efficiency in analyzing the system's performance.

The effect of collector length on fluid temperature rise is illustrated in the collector temperature profile, Figure 38. During Test No. 2, 68 and 87% of the total, north collector temperature rise was achieved after 3.0 and 6.0 m, respectively. The corresponding percentages were 65 and 84% for the south collector. The temperatures in the north collector were approximately 1.35 times higher than corresponding temperatures in the south collector. Due to the higher airflow in the north collector, however, the north side heat gain was about 2.2 times that of the south side. No attempt was made to determine the quantities of heat loss through the glass covers or of heat transferred to the TES from the back of the absorber plate, but it was probable that both factors significantly influenced the shape of the profile.

To obtain a more appropriate value of the SEI-TES efficiency, it was necessary to integrate the hourly, useful heat collection and incident radiation over time periods of 24 hours from 0900 to 0800 h. The daily thermal efficiencies versus the daily totals of incident radiation for 16 days are illustrated in Figure 39. The daily efficiencies ranged from

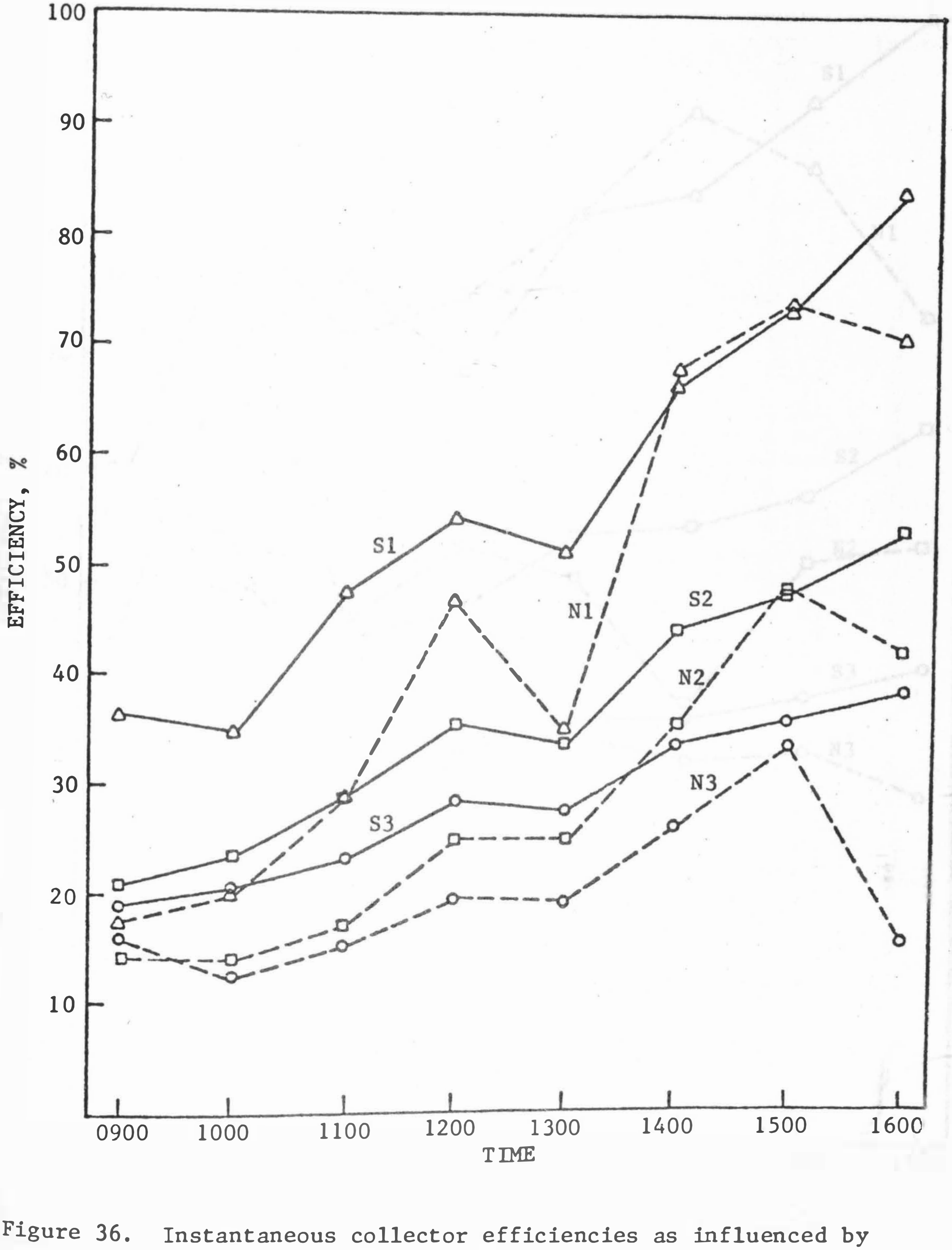


Figure 36. Instantaneous collector efficiencies as influenced by time of day, February 19, 1979.

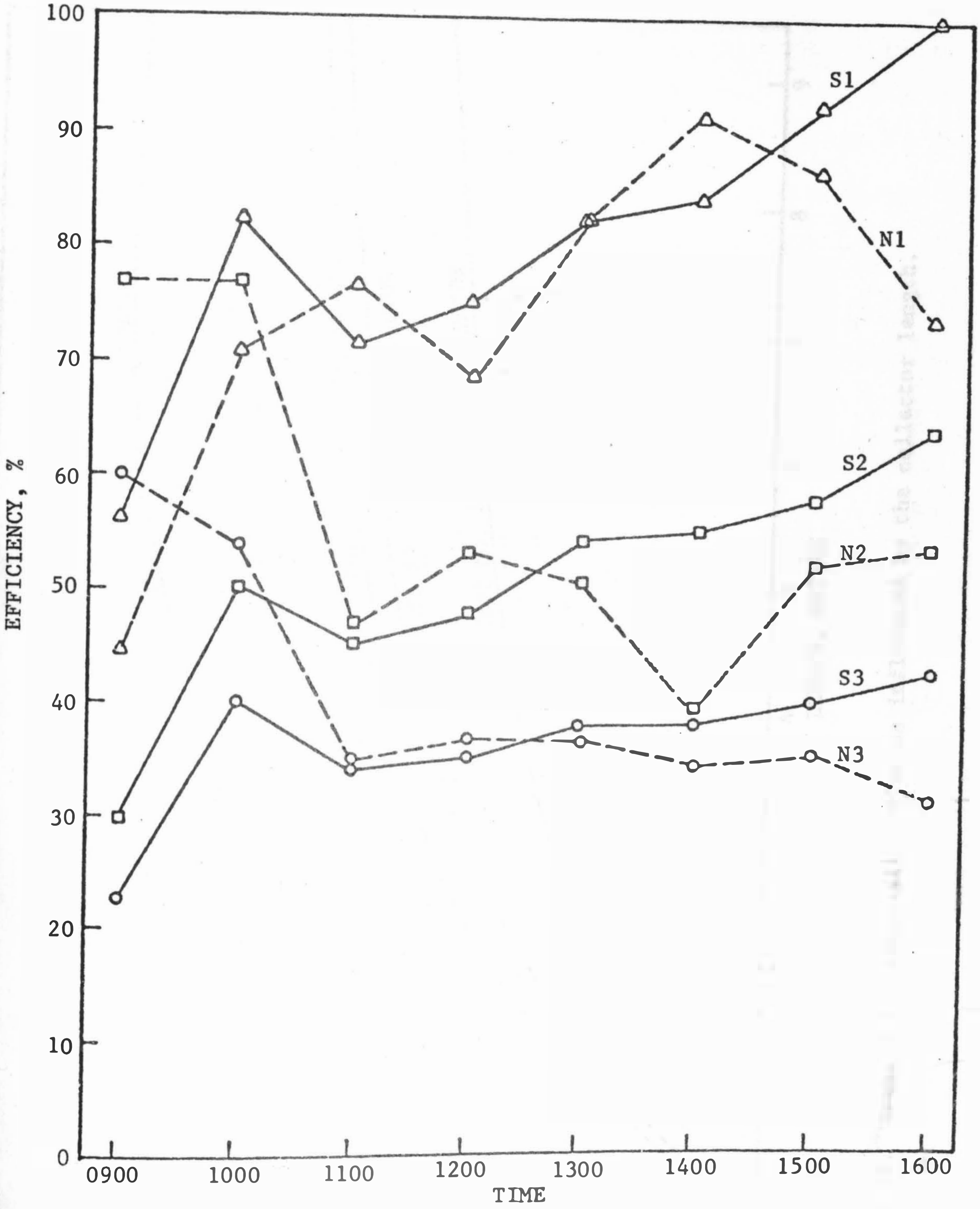


Figure 37. Instantaneous collector efficiencies as influenced by time of day, February 23, 1979.

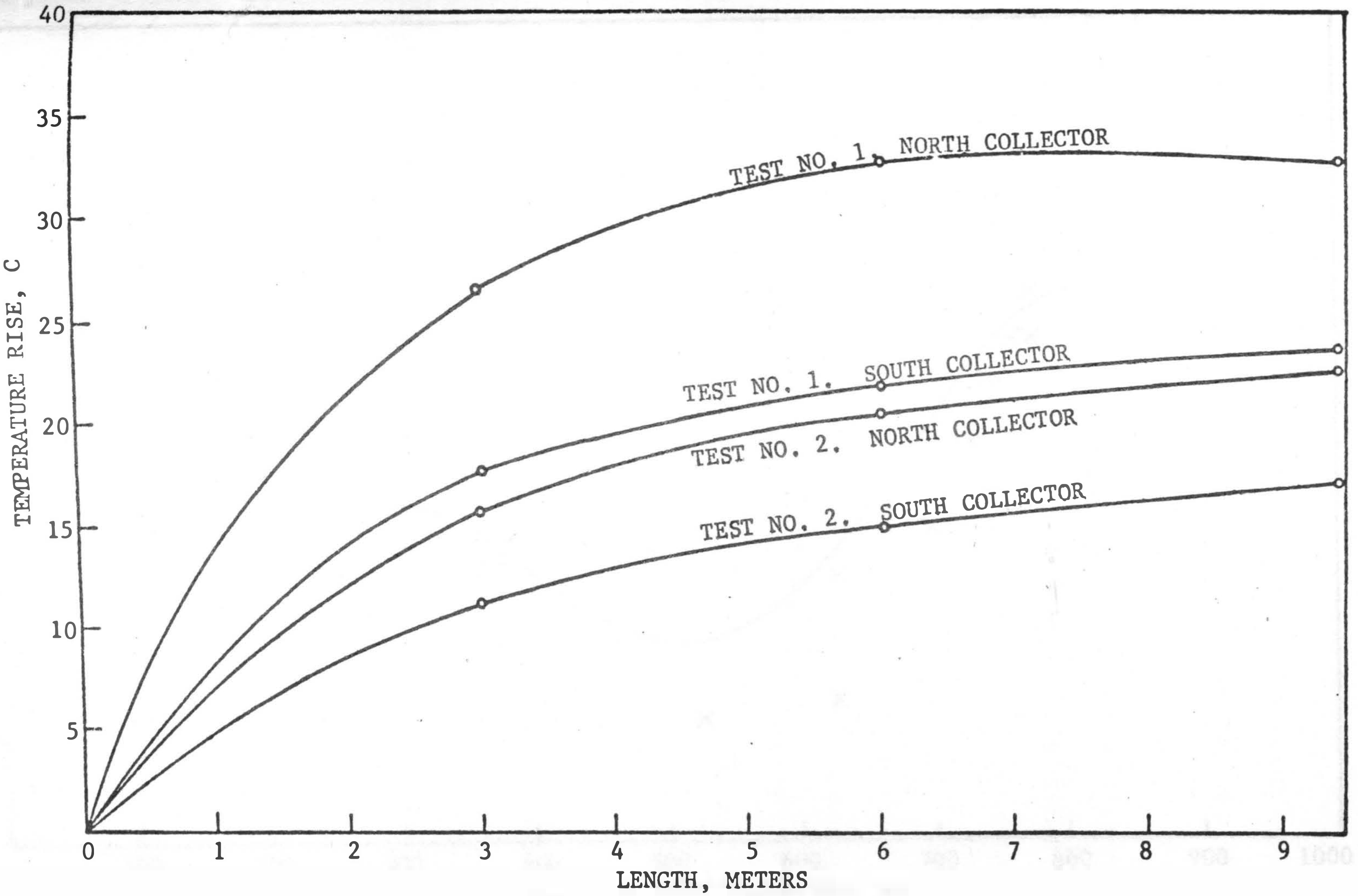


Figure 38. Average air temperature rise as influenced by the collector length.

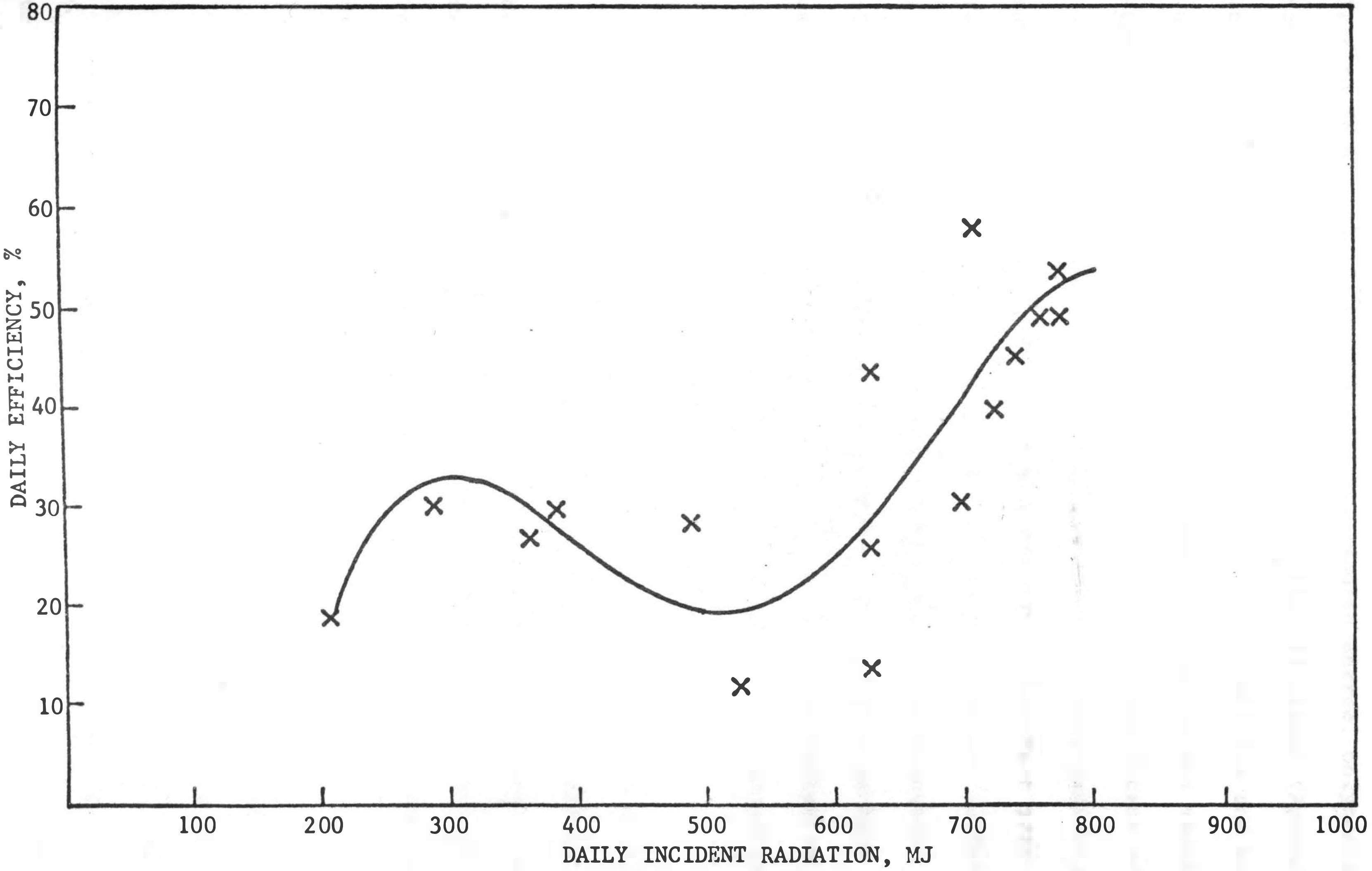


Figure 39. Daily efficiency versus daily radiation for 16 days during Test No. 2.

11.8 to 58.4%. The highly significant, fourth degree, polynomial curve accounted for 68.4% of the variation in daily efficiency (Appendix A-3). It was noted from weather conditions that wind velocities and hourly variation in ambient temperature accounted for some of the variation, but statistical analysis was not used to verify other significant effects.

The daily delivered heat versus the daily incident radiation for the same 16 days are illustrated in Figure 40. The daily heat gain ranged from 62 to 416 MJ and the daily radiation ranged from 209 to 845 MJ. A highly significant, fourth degree, polynomial curve accounted for 85.4% of the variation in daily heat (Appendix A-4). This is perhaps a more useful relationship, as compared to efficiency versus radiation, since it accounted for an additional 17% of the variation in the dependent variable.

Statistical Analysis

Multiple, step-wise, regression analyses were used to develop linear, significant prediction equations for the hourly rate of collector heat gain and instantaneous efficiency as functions of hourly incident radiation. The sample sizes were 108 and 111 hours for Test No. 1 and Test No. 2, respectively. The following regression equations were significant at the .01 level:

Test No. 1	R^2	Test No. 2	R^2
$Q_s = -1.61 + 5.8I_s$	.686	$Q_s = -1.48 + 7.9I_s$	.688
$Q_n = -9.65 + 10.8I_n$	.711	$Q_n = -10.76 + 18.0I_n$	.611
$EFF_s = -1.2 + 20.9I_s$	.416	$EFF_s = 12.8 + 23.0I_s$	.283
$EFF_n = -7.4 + 11.6I_n$	.568	$EFF_n = -1.8 + 16.0I_n$	.346

where: I = incident radiation striking the south (s), or north (n) collector, kW/m^2

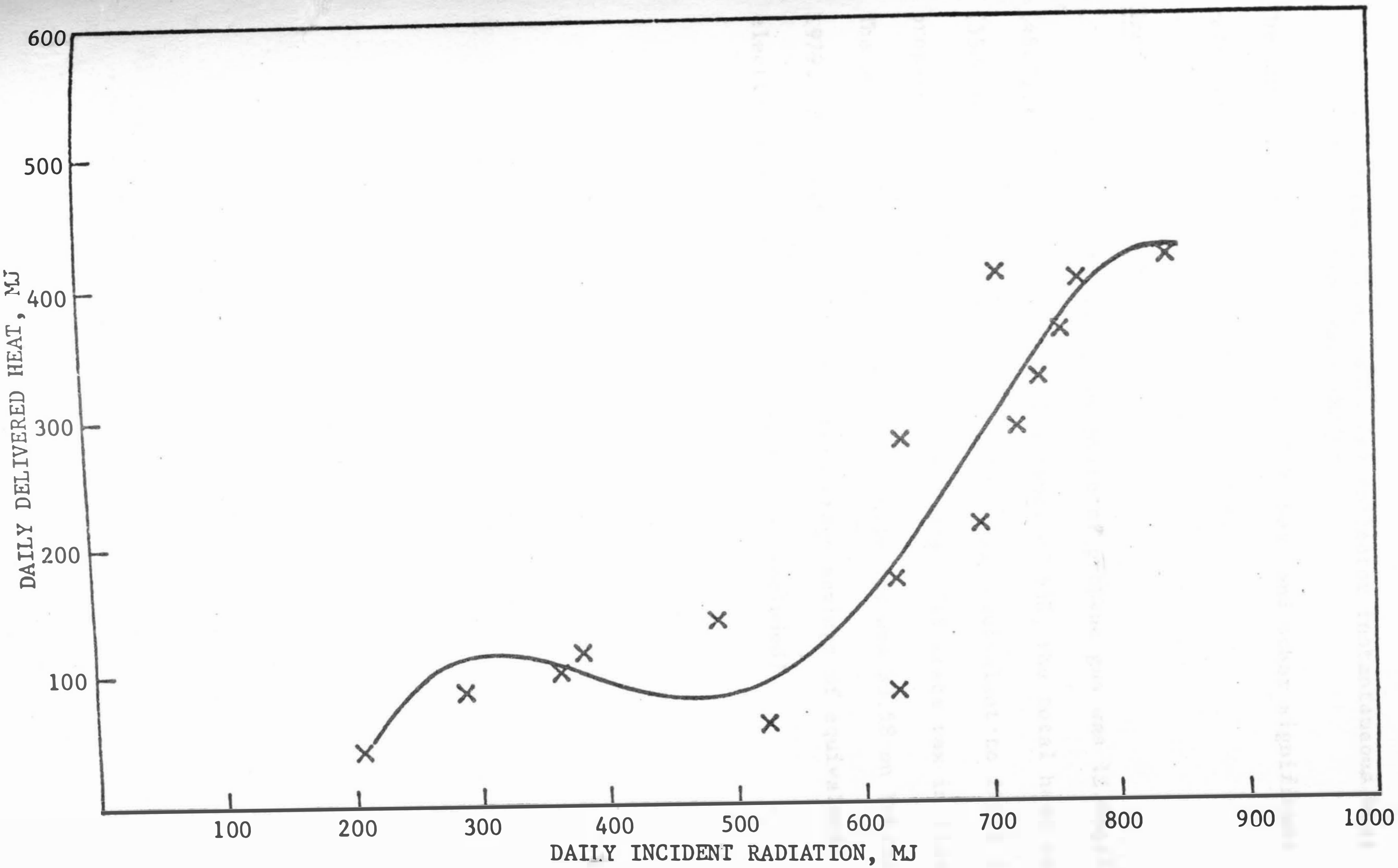


Figure 40. Daily delivered heat versus daily available radiation for 16 days during Test No. 2

Q = north (n) or south (s) collector instantaneous heat collection rate, MJ/hr.

The analysis of variance tables for these and other significant relationships are listed in Appendix A.

Economic Performance

On November 19, 1979, the price of propane gas was 12.68¢/liter (48¢/gal). At an LP heater efficiency of 65%, the total heat collected (3500 MJ) during 16 days of Test No. 2 was equivalent to 228.8 liters of propane or an average savings of $1.88/day (4% state tax included). The maximum propane savings for a single day was $3.58 on February 16, 1979. At a rate of .90¢/MJ, the average savings of equivalent electrical energy was $2.05/day (4% tax included).

CONCLUSIONS

The following conclusions were reached as a result of this study:

1. Air temperatures reached maximums of 89 and 61 C for the north and south collectors during Test No. 1 and 67.5 and 41.4 C for the north and south collectors during Test No. 2.
2. Approximately 67 and 85% of the collector temperature rise was achieved with the first 33 and 63% of the collector lengths, respectively.
3. Maximum storage temperature rises were 57.3 and 45.0 C during Test No. 1 and Test No. 2, respectively, and occurred at approximately 1600 hours.
4. Transient temperature differentials existed along the collector which caused a considerable amount of direct heat transfer from the absorber to the thermal energy storage.
5. The rate of heat delivery from the TES peaked at approximately three hours after the maximum incident radiation.
6. Totals of 3.4 and 3.5 GJ of energy were collected for cumulative efficiencies of 19.5 and 37.3% during Test No. 1 and Test No. 2, respectively. The nearly twofold increase in thermal efficiency resulted from increasing the total airflow by a factor of 2.73. The airflow in Test No. 1 was less than the minimum winter ventilation rate for a 20-sow farrowing house.
7. Daily efficiencies ranged from 4.6 to 29% for Test No. 1 and from 11.8 to 58.4% for Test No. 2. Highly significant, third and fourth degree polynomial, prediction equations, which accounted for 75.1

and 68.4% of the variations, were developed to estimate the daily efficiency as a function of daily incident radiation.

8. Daily heat gains ranged from 27.4 to 243.4 MJ for Test No. 1 and from 62 to 416 for Test No. 2. Highly significant, third and fourth degree polynomial, prediction equations, which accounted for 87.6 and 85.4% of the variations, were developed to estimate the daily heat gain as a function of daily incident radiation.
9. At the current price of 12.68¢ per liter of propane, an average savings of $1.88/day (sales tax included) was obtained during the second test. The savings of equivalent electrical energy was $2.05/day (sales tax included).
10. The performance of the SEI-TES system would further improve with higher minimum ventilation rates.

SUMMARY

Agricultural processes provide excellent opportunities for continuous airflow, low-temperature applications for solar energy. Advantages of an agricultural solar system are obtained by concentrating the solar radiation, by storing the collected thermal energy, and by providing the capability for several applications. Some field data and performance information have been collected on multiple-use solar energy intensifier systems. To develop and improve the performance of this type of system, a new and unique storage-collector configuration was incorporated into the design of a solar energy intensifier-thermal energy storage unit. Research was conducted at the South Dakota State University Swine Research Farm to evaluate the system performance characteristics for preheating swine house ventilation air.

Temperature, airflow, and radiation data were measured and recorded from January 14 to February 28, 1979. On February 10, the airflow rate was increased to the design, minimum, winter ventilation rate. The data were reduced and analyzed to obtain temperature rises, heat gains, and efficiencies for both airflow rates, and comparisons of the results were observed. Statistical analyses were utilized to develop significant relationships to predict performance characteristics from climatic conditions.

The equivalent energy savings during the second test were 14.3 liters of propane or 60.8 kWh of electricity per day as compared with 8.22 liters of propane or 35 kWh of electricity per day for the first test. The cumulative efficiency increased from 19.5 to 37.3% with the increase in airflow despite the disadvantage of receiving 60.4 MJ less radiation per day and thereby utilizing the intensifier a decreased amount.

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the evaluation of the solar energy intensifier-thermal energy storage system, this author offers the following suggestions for further improvement in the design and construction of the system.

1. The last portion of collector length contributed little or nothing to the collector temperature rise. Therefore, it is necessary to decrease the length of the airflow path.
2. It is illustrated in Figure 33 that the radiation incident on the concentrator was much less than on a surface perpendicular to the sun's rays. The difference was caused by the fact that the reflector must face somewhat below the angle of the sun's rays to focus onto the collector. It is, therefore, suggested to optimize the distance between the reflector and the collector.
3. Since the back of the absorber plate is at the same temperature as the front, an increased airflow across the backside would further increase the removal rate of thermal energy.
4. Additional support is needed to prevent the settling of the rocks from bulging the absorber plate.
5. Insulation of the top edge of the collector is recommended to decrease heat losses by convection and conduction.

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APPENDIXES

APPENDIX A

ANALYSIS OF VARIANCE TABLES

Table A-1. Analysis of Variance for the Daily Efficiencies (E_d) of Test No. 1. Independent Variable = Daily Incident Radiation (S).

Estimate: $E_d = 144-.77684(S)+1.3900445(10)^{-3}S^2-7.525976655(10)^{-7}S^3$

$R^2 = .750$ n = 27 days Energy in MJ

Source	DF	SS	MS	F
Due to S	3	1296.0	432.0	23.1 **
Error	23	430.9	18.7	
Total	26	1726.9		

** Significant at the 1% level.

Table A-2. Analysis of Variance of Daily Delivered Heat (H_d) of Test No. 2. Independent Variable = Daily Incident Radiation (S).

Estimate: $H_d = 747-4.363033(S)+8.0756(10)^{-3}(S)^2-4.331266(10)^{-6}(S)^3$

$R^2 = .876$ n = 27 days Energy in MJ

Source	DF	SS	MS	F
Due to S	3	129661	43220	54.15 **
Error	23	18357	798	
Total	26	148018		

** Significant at the 1% level

Table A-3. Analysis of Variance for Daily Efficiencies (E_d) of Test No. 2. Independent Variable = Daily Incident Radiation (S).

$$E_d = -271.6+2.8177(S)-9.167576(10)^{-3}(S)^2+1.221512(10)^{-5}(S)^3 -5.655695(10)^{-9}(S)^4$$

Estimate: see above

$R^2 = .684$ n = 16 days Energy in MJ

Source	DF	SS	MS	F
Due to S	4	2077	519	5.95 **
Error	11	959	87	
Total	15	3036		

** Significant at the 1% level.

Table A-4. Analysis of Variance for Daily Delivered Heat (H_d) of Test No. 2. Independent Variable = Daily Incident Radiation (S).

Estimate: $H_d = -1542.3+15.29614(S)-4.99443(10)^{-2}(S)^2+6.728463(10)^{-5}(S)^3 -3.116862(10)^{-8}(S)^4$

$R^2 = .854$ n = 16 days Energy in MJ

Source	DF	SS	MS	F
Due to S	4	246159	61540	16.12 **
Error	11	42006	3819	
Total	15	288165		

** Significant at the 1% level.

Table A-5. Analysis of Variance for Instantaneous North Collector Efficiences (E_i) for Test No. 2. Independent Variable = Incident Radiation*(I_n) in W/m^2.

Estimate: $E_i = -1.78 + .016483(I_n)$ $R^2 = .346$ $n = 111$

Source	DF	SS	MS	F
Due to I_n	1	7685	7685	57.7 **
Error	109	14520	133	
Total	110	22205		

* Based on glass transmissivity = .80, plate absorptivity = .95, concentrator reflectivity = .87, beam/total radiation = .80 and $A_r/A_c = 3.53$.

**Significant at the 1% level

Table A-6. Analysis of Variance of Instantaneous South Collector Efficiencies (E_i) for Test No. 2. Independent Variable = Incident Radiation (I_s) in W/m^2.

Estimate: $E_i = 12.82 + .023(I_s)$ $R^2 = .283$ $n = 111$

Source	DF	SS	MS	F
Due to I_s	1	4062	4062	43 **
Error	109	10273	94	
Total	110	14335		

** Significant at the 1% level

Table A-7. Analysis of Variance of the Instantaneous Heat Gain (Q_n) in MJ/hr from the North Collector for Test No. 2. Independent Variable = Incident Radiation*, (I_n) in W/m^2.

Estimate: $Q_n = -10.764 + 0.18(I_n)$ $R^2 = .611$ n = 111

Source	DF	SS	MS	F
Due to I_n	1	697	697	170.9 **
Error	109	444	4	
Total	110	1142		

* Based on glass transmissivity = .80, plate absorptivity = .95, concentrator reflectivity = .87, beam/total radiation = .80 and $A_r/A_c = 3.53$.

** Significant at the 1% level

Table A-8. Analysis of Variance of the Instantaneous Heat Gain (Q_s) in MJ/hr from the South Collector for Test No. 2. Independent Variable = Incident Radiation (I_s) in W/m^2.

Estimate: $Q_s = -1.4795 + .00792(I_s)$ $R^2 = .688$ n = 111

Source	DF	SS	MS	F
Due to I_s	1	38.6	38.6	240.7 **
Error	109	17.5	.2	
Total	110	56.1		

** Significant at the 1% level

Table A-9. Analysis of Variance for Instantaneous Efficiency (E_i) of the North Collector for Test No. 2 Using a Power Regression. Dependent Variable = $\ln(E_i)$. Independent Variable = $\ln((T_c-T_a)/I_n)$. I_n = Instantaneous Absorbed Radiation.* T_c = Average Collector Temperature. T_a = Ambient Temperature.

Estimate: $E_i = 1152.9((T_c-T_a)/I_n)^{.879}$ $R^2 = .958$ n = 111

Source	DF	SS	MS	F
Regression	1	60.9	60.9	2445 **
Error	108	2.7	.025	
Total	109	63.6		

* See Table A-7.

** Significant at the 1% level

Table A-10. Analysis of Variance for Instantaneous Efficiency, E_i, of the South Collector for Test No. 2 Using a Power Regression. Dependent Variable = $\ln(E_i)$. Independent Variable = $\ln((T_c-T_a)/I_s)$. I_s = Instantaneous Absorbed Radiation. T_a = Ambient Temperature.

Estimate: $E_i = 906.9((T_c-T_a)/I_s)^{.834}$ $R^2 = .964$ n = 111

Source	DF	SS	MS	F
Regression	1	20.4	20.4	2928 **
Error	109	.76	.007	
Total	110	21.1		

** Significant at the 1% level

APPENDIX B

MATERIAL COSTS
OF THE EXPERIMENTAL SOLAR SYSTEM

Table B-1. Costs of the Reflector Materials

Quantity	Description	Unit Cost, $	Total Cost, $
37.18 m^2	King-Lux aluminum	22.048/m^2	819.76
7	Cold rolled sheet steel (1.22 m x 3.049 m x 1.2 mm)	22.32	156.26
3	Cold rolled sheet steel (1.22 m x 3.149 m x 1.2 mm)	24.11	72.33
4	Tubing (20 cm x 5 cm x 3.2 mm x 6.1 m)	67.75	271.00
2	Extra strength pipe (5 cm x 53.3 cm)	38.61	77.21
6	Angle iron (3.18 cm x 3.18 cm x 6.4 mm x 6.1 m)	11.51	69.05
2	Angle iron (3.18 cm x 3.18 cm x 4.8 mm x 6.1 m)	8.88	17.76
9	Wooden posts (5 cm x 25.4 cm x 6.1 m)	51.00	459.00
	Brace boards:		
9	(5 cm x 15.2 cm x 3.05 m)	6.15	56.35
2	(5 cm x 25.4 cm x 3.05 m)	8.25	16.50
3	(5 cm x 25.4 cm x 6.1 m)	16.50	49.50
2	(5 cm x 10.2 cm x 6.1 m)	5.93	11.86
9	(5 cm x 10 cm x 1.52 m)	1.49	13.41
4	(5 cm x 10 cm x 3.66 m)	3.56	14.24
	White paint		2.95
	Nails		3.08
	Adhesive		2.00

Table B-1. Continued.

Quantity	Description	Unit Cost, $	Total Cost, $
	Mounting brackets:		
1	Angle iron (3.18 cm x 3.18 cm x 6.4 mm x 6.1 m)	11.52	11.52
1	Extra Strength Pipe (.61 mm x 7.6 mm)	10.12	10.12
8	Bolts	.53	4.24
8	Muffler Clamps (6.3 cm)	.57	4.56

Total reflector costs----2142.70

Table B-2. Costs of the Collector Materials

Quantity	Description	Unit Cost, $	Total Cost, $
2	Hot rolled sheet steel (1.22 x 6.10 m x 1.52 mm)	4.97	9.93
2	Hot rolled sheet steel (1.22 x 3.05 m x 2.66 mm)	42.07	84.14
1	Hot rolled sheet steel (1.22 x 3.66 m x 2.66 mm)	64.89	64.89
1	Hot rolled sheet steel (1.22 x 2.44 m x 1.21 mm)	18.03	18.03
4	Hot rolled sheet steel (1.22 x 3.05 m x 1.52 mm)	23.27	93.08
2	Hot rolled sheet steel (1.22 x 3.66 m x 1.52 mm)	27.92	55.84
2	Hot rolled sheet steel (1.22 x 3.05 m x .91 mm)	18.03	36.06
1	Hot rolled sheet steel (1.22 x 3.66 m x .91 mm)	21.04	21.04
3	Hot rolled sheet steel (.35 x 3.25 m x 2.66 mm)	13.06	39.18
	Cutting charges:		
12	Angle iron (2.5 x 2.5 x .32 cm x 6.1 m)		57.60
1	Hot rolled flat iron (.96 cm x 2.5 cm x 6.1 m)	6.31	6.31
5	Structural channel iron (7.6 cm x 9.02 kg/m x 6.1 m)	20.71	103.53
	Labor		9.50
	Freight		40.34

Table B-2. Continued.

Quantity	Description	Unit Cost, $	Total Cost, $
8	Tempered glass (.864 x 1.93 m x 3.18 mm)	28.50	228.00
2	Salvage tempered glass (.864 x 1.93 m x 4.76 m)	14.25	28.50
	Alumax millwork wrap around		24.24
	Silicone base caulking compound		32.00
1	Clear rubber caulk	5.29	5.29
17	Utility boards (5.1 x 10.2 cm x 2.44 m)	1.84	31.28
.17 m^3	Gravel pad	141.15/m^3	24.00
100	Stove bolts (.476 x 1.91 cm)		
110 kg	Welding rod	.23/kg	25.00
1.1 liter	Black absorber paint	4.49 liter	4.94
2.97 m^2	Fiberglass insulation (8.9 cm)	2.13 m^2	6.32
11.9 m^2	Fiberglass insulation (15.2 cm)	3.58 m^2	42.60
	Delivery of field rock		10.00
	O_2 and acetylene		30.00

Total collector costs----1131.54

Table B-3. Cost of Duct Materials

Quantity	Description	Unit Cost, $	Total Cost, $
1	Steel (1.22 x 3.05 m x .91 mm)	18.03	18.03
2	Norflex duct (40.6 cm x 3.05 m)	31.20	62.40
2	Salvage flexible duct (40.6 cm x 2.44 m)	12.50	25.00
	Fiberglass insulation (60 x 8.9 cm)		9.48
3	Lumber (5.1 cm x 10.2 cm x 4.27 m)	3.22	9.66
24	Lumber (2.5 cm x 10.2 cm x .92 m)	.76	18.24
2	Perforated straps	.79	1.58
1	Wire roll (15.2 m)	.35	.35
20	Lag screws	.024	.47
3	Spray paint	1.57	4.71
1	Roll of duct tape	3.30	3.30

Total duct cost----153.22

Table B-4. Cost of Tracking Mechanism

Quantity	Description	Unit Cost, $	Total Cost, $
1	10-watt synchronous motor	53.15	53.15
4	Pillow blocks	6.13	24.52
8	2 bolt flange bearings	2.23	17.84
4	13 tooth sprockets	5.548	22.19
4	78 tooth sprockets	22.396	89.58
1	60:1 gear reducer		100.35
8	#40 riveted chain	6.20/m	75.60
14.63 m	Hot rolled shafting (2.54 cm)	2.20/m	32.19
2 pkg's	Chain links	1.22	2.44
11.3 m	Pipe (5.40 cm x 0.08 cm)	2.92/m	32.04
2.85 m	Threaded rod	.82/m	2.33
1	Time clock	50.00	50.00
4	Wooden posts (12.7 cm x 15.2 cm x 2.44 m)	15.20	60.80
1	Extension cord wire	33.82	33.82
1	Heat lamp	1.36	1.36
12	Set screws	.10	1.20
1	3-wire receptacle	.93	.93
2	Box connector	.12	.24
1	3-wire male plug	.81	.81
18	Bolts (35.6 cm x 1.27 cm)	.16	2.97
1	Flat washer (1.27 cm)	.61	.61

Table B-4. Continued.

Quantity	Description	Unit Cost, $	Total Cost, $
18	Hex nuts (1.6 cm)	.15	2.76
1	Roll of lock washers	1.86	1.86
1.22 m	Black pipe (2.54 cm)	2.00/m	2.44
.81 m	Channel iron (7.6 cm x 2.3 kg)	3.80/m	3.08
16	Lag screws (.64 x 6.35 cm)	.09	1.44
4	Bolts (1.27 x 12.20 cm)	.18	.72
.38 m	Black pipe (1.27 cm)	1.35/m	.51

Total tracking mechanism cost----617.78

Table B-5. Other Material Costs

Quantity	Description	Unit Cost, $	Total Cost, $
2	Plywood CDX (1.22 m x 2.44 cm x .95 cm)	10.40	20.80
1	Fan	50.00	50.00
	Miscellaneous items		26.40

Total----97.20

APPENDIX C

REFLECTOR SURFACE SPECIFICATIONS

Table C-1. Reflector Sheet Specifications

Supplier	Kingston Industries
Product Name	Kinglux Aluminum Solar Reflector Sheet
Material	High-purity aluminum
Thickness	.3 mm
Structure	Non-clad
Total Reflectance	87.6%
Specular to Total Reflectance Ratio	.963
Coating	Anodic film oxide (.2 micron thick)
Weatherability	No deterioration after 180,000 langleys exposure
Abrasion Resistance	56 g/micron
Adhesive	Goodyear Pliobond Adhesive

APPENDIX D

DAILY AMOUNTS OF AVAILABLE SOLAR RADIATION AND DELIVERED THERMAL ENERGY

Table D-1. Test No. 1: 24-hour periods from 0900 to 0800 hours.

Day	Incident Radiation (MJ)	Heat Delivered (MJ)	Daily Efficiency (%)
1/14/79	925	184	19.9
1/15/79	580	65	11.2
1/16/79	579	93	16.0
1/17/79	821	170	20.7
1/18/79	396	35	8.8
1/19/79	547	36	6.5
1/20/79	494	23	4.6
1/21/79	489	42	8.5
1/22/79	285	52	18.2
1/23/79	885	211	23.8
1/24/79	853	201	23.6
1/25/79	566	73	12.9
1/26/79	453	37	8.2
1/27/79	526	46	8.8
1/28/79	752	187	24.9
1/29/79	850	238	28.0
1/30/79	698	185	26.5
1/31/79	645	132	20.5
2/1/79	489	27	5.6
2/2/79	774	208	26.8
2/3/79	759	203	26.8
2/4/79	692	184	26.6
2/5/79	702	86	12.2
2/6/79	724	210	29.0
2/7/79	601	108	17.9
2/8/79	839	243	29.0
2/9/79	543	124	22.9
Totals	17467	3403	19.5 (overall)

Table D-2. Test No. 2: 24-hour periods from 0900 to 0800 hours.

Day	Incident Radiation (MJ)	Heat Delivered (MJ)	Daily Efficiency (%)
2/11/79	382	113	29.5
2/12/79	626	161	25.8
2/13/79	627	84	13.4
2/16/79	845	416	49.2
2/17/79	525	62	11.8
2/18/79	722	285	39.5
2/19/79	693	209	30.2
2/20/79	367	99	27.0
2/21/79	742	336	45.2
2/22/79	209	39	18.6
2/23/79	709	414	58.4
2/24/79	770	412	53.5
2/25/79	760	373	49.1
2/26/79	633	275	43.5
2/27/79	486	136	28.1
2/28/79	287	86	29.9
Totals	9383	3500	37.3 (overall)

APPENDIX E

SI TO ENGLISH CONVERSIONS

SI to English Conversions

To convert from	To	Multiply by
liter	gal	.26417
m	ft	3.281
m^2	ft^2	10.758
m^3	ft^3	35.2876
cm	in	2.54
m^3/hr	ft^3/min	.5885
kW	Btu/hr	3414.426
MJ	MBtu	1055.06
kg	lb	.45359237
C	F	F=1.8(C+32)
m^2-C/W	hr-ft^2-F/Btu	5.675355
kJ/kg	Btu/lb	.429923

APPENDIX F

SOLAR RADIATION AND TEMPERATURE DATA

TABLE F. INCIDENT SOLAR RADIATION MEASURED ON A HORIZONTAL SURFACE AND AIR TEMPERATURES MONITORED AT LOCATIONS IN FIGURE 7

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
11	1		-11.1	-11.4	-11.4	-11.4	-11.7	-11.7	-11.7	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.4	-11.1	-11.1	-10.8	-10.0	-10.0	-9.7
11	2		-11.1	-11.7	-11.4	-11.7	-11.9	-11.9	-11.9	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.4	-11.4	-10.3	-10.3	-10.3
11	3		-11.1	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-11.9	-11.9	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-10.6	-10.8	-10.6
11	4		-11.7	-11.7	-11.7	-11.7	-12.2	-12.2	-12.2	-11.7	-11.7	-11.9	-11.9	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.1	-11.1	-10.8
11	5		-12.2	-12.2	-12.2	-11.7	-12.2	-12.2	-12.2	-12.2	-12.2	-11.9	-11.9	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.1	-11.4	-10.8
11	6		-12.2	-12.2	-12.2	-11.7	-11.9	-11.9	-11.9	-12.5	-12.5	-11.9	-12.2	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.4	-11.4	-10.8
11	7	0.02	-11.7	-11.9	-11.9	-11.7	-12.2	-12.2	-12.2	-12.2	-12.2	-11.9	-11.9	-11.9	-11.9	-11.7	-11.7	-11.7	-11.7	-11.4	-11.4	-11.4
11	8	0.04	-11.7	-12.2	-12.2	-11.7	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-12.2	-11.9	-12.2	-11.9	-11.9	-11.9	-11.9	-11.4	-11.4	-11.1
11	9	0.17	-11.7	-11.9	-11.9	-11.7	-11.9	-11.9	-11.9	-12.2	-12.2	-11.4	-11.4	-10.8	-10.8	-11.7	-11.9	-11.7	-11.7	-11.7	-11.7	-11.1
11	10	0.33	-11.7	-9.4	-8.9	-8.9	-8.1	-7.2	-7.2	-10.3	-10.0	-9.7	-9.7	-8.3	-8.3	-9.7	-10.8	-11.1	-11.4	-10.8	-10.6	-10.0
11	11	0.41	-11.7	-7.2	-5.6	-5.6	-5.0	-3.6	-3.3	-8.9	-8.3	-7.8	-7.5	-6.1	-6.1	-7.5	-8.9	-10.3	-10.3	-10.0	-9.4	-8.6
11	12	0.51	-11.1	-5.6	-3.9	-3.3	-5.3	-1.1	-0.6	-7.5	-7.2	-5.8	-5.6	-3.9	-3.6	-5.6	-6.9	-8.9	-8.9	-8.6	-8.1	-7.2
11	13	0.38	-11.1	-6.1	-4.2	-4.4	-3.3	-2.2	-1.7	-7.8	-7.2	-6.7	-6.1	-4.4	-4.4	-4.2	-4.7	-6.9	-7.2	-7.2	-6.7	-6.1
11	14	0.26	-11.1	-7.2	-6.1	-5.6	-4.7	-3.9	-3.9	-8.9	-8.3	-7.5	-7.2	-6.1	-6.1	-4.4	-3.9	-5.6	-5.8	-6.1	-6.1	-5.8
11	15	0.17	-11.7	-7.8	-6.4	-6.1	-5.6	-5.6	-5.0	-9.4	-8.9	-8.3	-8.1	-7.2	-7.2	-6.1	-4.2	-4.7	-5.3	-5.8	-6.1	-5.6
11	16	0.10	-12.2	-9.2	-8.6	-8.1	-8.1	-8.1	-8.1	-10.6	-10.0	-9.7	-9.4	-9.2	-9.2	-7.8	-5.0	-4.7	-5.0	-5.6	-6.4	-5.8
11	17	0.04	-12.8	-10.6	-9.7	-10.0	-10.0	-10.0	-10.0	-11.4	-11.1	-11.1	-10.6	-10.8	-10.8	-9.7	-6.7	-5.6	-5.6	-5.6	-6.7	-6.7
11	18	0.02	-13.9	-11.7	-11.4	-11.1	-11.7	-11.7	-11.7	-12.5	-11.9	-12.2	-11.9	-12.2	-12.2	-11.1	-8.3	-6.7	-5.4	-6.1	-7.2	-7.2
11	19		-13.9	-11.9	-11.4	-11.7	-11.9	-12.2	-12.2	-12.2	-12.2									-6.7	-7.8	-7.8
11	20		-14.4	-12.2	-11.7	-11.9	-12.2	-12.2	-12.2	-12.5	-12.5									-7.8	-8.3	-8.3
11	21		-15.0	-12.8	-12.8	-12.8	-13.3	-13.3	-13.3	-12.8	-12.8									-8.6	-9.2	-9.2
11	22		-15.6	-13.6	-13.6	-13.3	-13.6	-13.6	-13.6	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-13.3	-12.8	-11.7	-11.1	-9.4	-9.7	-10.0
11	23		-15.6	-15.0	-15.0	-13.9	-15.0	-15.0	-14.2	-15.0	-15.0									-10.6	-10.8	-10.6
11	24		-16.7	-14.7	-14.4	-14.4	-15.0	-15.0	-15.0	-14.7	-14.7									-11.4	-11.4	-11.4
12	1		-17.2	-15.0	-15.0	-15.0	-15.6	-15.6	-15.6	-15.3	-15.3									-12.2	-12.2	-12.2
12	2		-17.8	-15.8	-15.6	-15.8	-16.4	-16.4	-16.4	-16.4	-16.4	-16.1	-16.1	-16.1	-16.1	-15.8	-15.0	-14.2	-13.9	-12.8	-12.8	-12.8
12	3		-17.8	-16.9	-16.9	-16.9	-17.2	-17.2	-17.2	-16.9	-16.9									-13.6	-13.6	-13.6
12	4		-20.6																	-14.4	-14.4	-14.7
12	5		-22.2																	-15.0	-15.6	-15.6
12	6		-23.3													-22.2	-19.7	-17.2	-17.2	-16.1	-16.7	-16.7
12	7	0.02	-23.3																	-17.2	-17.5	-17.8
12	8	0.10	-23.3				-17.8	-17.8	-17.8			-22.8	-21.7	-22.2	-21.4	-23.1	-22.5	-20.0	-20.0	-18.1	-18.9	-18.3
12	9	0.27	-21.7	-17.8	-17.8	-17.8	-18.1	-18.1	-16.4	-17.8	-17.8	-17.5	-19.2	-15.6	-17.2	-20.0	-21.7	-20.6	-20.3	-17.8	-17.8	-17.8
12	10	0.44	-18.9	-11.7	-9.4	-8.1	-7.2	-3.6	-3.1	-10.8	-13.6	-2.8	-10.0	5.6	-4.4	-8.3	-16.1	-18.3	-17.8	-16.7	-14.4	-13.3
12	11	0.64	-16.7	-6.9	-3.9	-1.7	-0.6	3.9	5.0	1.1	-8.3	8.9	-2.8	18.3	4.4	-0.6	-10.0	-13.9	-13.3	-13.9	-9.4	-8.6
12	12	0.67	-16.7	-6.7	-3.3	-1.7	-0.3	3.1	4.4	-5.3	-8.1	0.6	-3.1	7.8	0.6	2.2	-3.3	-8.9	-8.3	-10.0	-6.4	-6.1
12	13	0.55	-16.7	-4.7	-1.7	0.0	1.7	4.4	5.3	-1.7	-5.0	2.2	-3.3	8.3	0.6	0.6	0.0	-4.4	-4.4	-6.7	-4.4	-3.9
12	14	0.56	-15.6	-6.9	-3.6	-2.5	-1.4	0.0	0.6	-7.8	-7.8	-5.6	-5.0	-2.8	-3.3	1.1	2.8	-0.6	-0.6	-3.3	-2.5	-2.5
12	15	0.45	-13.9	-6.7	-3.9	-3.3	-2.5	-1.9	-1.1	-8.3	-7.8	-7.2	-6.1	-5.0	-5.0	-2.8	1.7	1.1	1.1	-1.9	-2.2	-1.7
12	16	0.28	-13.9	-8.1	-6.4	-6.1	-5.6	-5.6	-5.3	-10.0	-8.9	-8.9	-8.3	-7.8	-7.8	-5.6	0.6	1.7	1.7	-0.6	-1.9	-1.7
12	17	0.11	-14.4	-10.0	-8.3	-8.6	-8.6	-8.9	-8.9	-11.1	-10.8	-10.6	-10.0	-10.6	-10.6	-8.3	-2.8	0.0	0.6	-0.6	-2.2	-2.5
12	18	0.02	-14.4	-11.4	-10.3	-10.8	-10.8	-11.7	-11.7	-12.5	-11.7	-12.2	-12.2	-12.8	-12.8	-11.1	-6.1	-2.2	-1.7	-1.1	-3.3	-3.6
12	19		-14.4	-11.7	-11.1	-11.4	-11.9	-12.2	-12.2	-12.8	-12.2	-12.8	-12.8	-13.3	-13.3	-12.2	-8.9	-4.4	-3.9	-2.5	-3.9	-4.7
12	20		-15.0	-12.8	-12.2	-12.5	-12.8	-13.3	-13.3	-13.6	-13.1	-13.9	-13.3	-13.9	-13.9	-13.3	-11.1	-7.2	-6.1	-3.9	-5.3	-5.6
12	21		-15.0	-13.3	-13.3	-13.6	-13.9	-14.2	-14.2	-14.2	-13.9	-13.3	-13.3	-14.4	-14.4	-13.9	-12.2	-9.4	-8.3	-5.6	-6.7	-7.2
12	22		-15.0	-13.6	-13.3	-13.9	-14.2	-14.4	-14.4	-14.2	-13.9	-14.4	-14.4	-14.4	-14.4	-14.4	-13.3	-11.1	-10.6	-7.5	-8.1	-8.3
12	23		-14.4	-14.2	-13.9	-14.2	-14.7	-14.7	-14.7	-14.4	-14.4	-14.4	-14.4	-14.4	-14.4	-14.4	-13.9	-12.2	-11.7	-9.2	-9.4	-9.7
12	24		-15.6	-14.4	-14.4	-14.4	-15.0	-15.0	-15.0	-15.3	-15.3	-15.0	-15.0	-15.0	-15.0	-14.4	-14.4	-13.3	-12.8	-10.6	-10.6	-10.8

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
13	1		-15.6	-15.6	-15.6	-15.0	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-15.6	-14.4	-13.9	-13.9	-11.[illegible]	-11.9	-11.9
13	2		-16.7	-16.1	-16.1	-15.6	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-15.6	-15.0	-14.4	-14.4	-12.8	-12.8	-12.8
13	3		-17.8	-17.8	-17.8	-17.8	-18.1	-18.1	-18.1	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-17.2	-15.6	-15.0	-15.0	-13.9	-13.9	-13.9
13	4		-18.3	-17.8	-17.8	-17.2	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-17.8	-16.7	-15.6	-15.6	-14.4	-14.7	-14.4
13	5		-18.9		-18.6	-18.9						-18.9	-18.9	-18.9	-18.9	-18.3	-17.2	-16.1	-16.1	-15.3	-15.3	-15.3
13	6		-19.4									-20.0	-20.0	-20.0	-20.0	-19.4	-18.3	-17.2	-17.2	-15.8	-16.1	-16.1
13	7	0.02	-20.0									-20.6	-20.6	-20.6	-20.6	-20.0	-19.4	-18.3	-17.8	-16.7	-16.7	-16.7
13	8	0.07	-18.9	-18.3	-18.1	-18.1	-18.1	-17.8	-17.8	-18.9	-18.9	-18.9	-18.9	-18.9	-18.3	-19.4	-19.4	-18.3	-18.3	-17.2	-17.2	-16.7
13	9	0.29	-17.2	-13.1	-11.7	-11.7	-10.8	-8.9	-8.9	-9.7	-13.6	-4.4	-10.6	-1.7	-5.6	-12.8	-17.8	-17.8	-17.8	-16.1	-15.3	-14.7
13	10	0.41	-16.7	-12.2	-11.1	-10.8	-10.0	-8.3	-8.3	-12.8	-12.8	-11.7	-11.7	-9.4	-10.0	-7.8	-12.8	-15.6	-15.0	-14.2	-12.8	-12.2
13	11	0.62	-13.9	-6.1	-3.3	-3.1	-1.1	1.1	1.7	-4.7	-7.2	0.0	-3.9	5.6	0.0	-3.3	-8.3	-11.7	-11.1	-11.7	-8.9	-8.1
13	12	0.63	-12.8	-5.0	-2.2	-1.9	-0.6	1.4	1.9	-6.7	-6.1	-4.4	-3.9	-1.7	-1.7	-1.1	-3.9	-8.3	-7.8	-8.6	-6.7	-6.1
13	13	0.63	-11.1	-2.8	0.0	0.0	1.9	3.9	4.4	-3.9	-3.9	-1.1	-0.6	2.2	1.7	0.0	-0.6	-4.4	-4.4	-5.6	-4.2	-3.6
13	14	0.64	-9.4	-1.9	1.4	1.7	3.1	4.4	5.0	-3.9	-3.3	-1.7	-1.1	-2.8	-2.2	0.6	1.7	-1.1	-1.7	-3.1	-2.2	-1.7
13	15	0.38	-9.4	-1.7	1.4	1.4	2.8	3.6	4.4	-3.1	-2.8	-1.1	-0.6	1.1	0.6	0.0	1.7	0.6	0.0	-1.1	-0.8	0.0
13	16	0.31	-9.4	-4.4	-2.8	-2.8	-2.2	-2.2	-1.7	-6.1	-5.6	-5.6	-5.0	-5.0	-5.0	-2.2	1.1	1.1	1.1	0.0	-1.1	-0.3
13	17	0.13	-9.4	-6.1	-4.4	-5.0	-4.4	-4.4	-4.4	-6.9	-6.7	-6.7	-6.1	-6.7	-6.7	-4.4	-0.6	0.6	0.6	0.3	-1.1	-1.1
13	18	0.02	-9.4	-6.9	-6.1	-6.7	-6.7	-6.9	-6.9	-7.8	-7.2	-7.8	-7.2	-8.3	-8.3	-7.2	-3.3	-0.6	-0.6	0.0	-1.7	-1.7
13	19		-9.4	-7.2	-6.7	-6.7	-7.2	-7.2	-7.2	-7.8	-7.5	-8.3	-8.3	-8.3	-8.9	-7.8	-5.0	-2.8	-2.2	-0.8	-2.2	-2.2
13	20		-8.9	-7.2	-7.2	-7.2	-7.8	-7.8	-7.8	-7.8	-7.5	-7.8	-7.8	-8.3	-8.3	-8.3	-6.7	-3.9	-3.3	-1.9	-2.8	-2.8
13	21		-8.9	-7.2	-6.7	-7.5	-7.8	-7.8	-7.8	-7.8	-7.8	-8.3	-8.3	-8.3	-8.3	-7.8	-7.2	-5.6	-5.0	-3.1	-3.9	-3.9
13	22		-8.3	-7.2	-7.2	-7.2	-7.8	-8.1	-8.1	-7.2	-7.2	-7.8	-7.8	-8.3	-8.3	-8.3	-7.8	-6.7	-6.1	-4.4	-4.4	-4.4
13	23		-7.8	-7.5	-7.5	-7.2	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-8.3	-8.3	-7.8	-7.2	-5.0	-5.3	-5.0
13	24		-7.2	-7.2	-7.2	-7.2	-7.5	-7.5	-7.5	-7.2	-7.2	-7.8	-7.8	-7.2	-7.2	-8.3	-8.3	-7.8	-7.8	-5.8	-5.8	-5.6
14	1		-6.7	-6.7	-6.7	-6.9	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.8	-7.8	-7.8	-7.8	-6.1	-6.1	-6.1
14	2		-6.7									-7.2	-7.2	-7.2	-7.2	-7.8	-7.8	-7.8	-7.8			
14	3		-6.7									-6.7	-6.7	-6.7	-6.7	-6.7	-7.2	-7.2	-7.2			
14	4		-6.1									-7.2	-7.2	-7.2	-7.2	-7.2	-7.8	-7.8	-7.8			
14	5		-6.1									-6.9	-6.9	-6.9	-6.9	-7.2	-7.2	-7.2	-7.5			
14	6		-6.1									-6.7	-6.7	-6.7	-6.7	-7.2	-7.2	-7.5	-7.5			
14	7	0.02	-6.1									-6.7	-6.7	-6.7	-6.7	-7.2	-7.2	-7.2	-7.2			
14	8	0.04	-6.1									-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-7.2			
14	9	0.20	-5.0									-5.6	-5.6	-5.0	-5.0	-5.6	-6.1	-6.1	-6.7			
14	10	0.23	-4.4									-4.4	-3.9	-2.8	-2.8	-4.4	-5.0	-5.6	-5.6			
14	11	0.42	-3.9									-2.2	-1.7	0.0	0.0	-1.7	-3.3	-4.4	-4.4			
14	12	0.40	-3.3									-0.6	0.0	1.7	2.2	1.1	-1.1	-2.8	-2.8			
14	13	0.34	-3.9									0.6	1.1	2.2	2.8	2.2	1.1	-1.1	-1.7			
14	14	0.49	-3.9									1.7	2.2	4.4	4.4	3.3	2.8	0.6	0.0			
14	15	0.34	-3.9	0.6	-0.6	2.2	3.3	3.9	4.2	-1.1	-0.6	-0.6	0.6	1.1	1.1	2.8	3.9	1.7	1.7	1.1	1.1	1.7
14	16	0.20	-2.8	-1.1	0.0	0.6	1.1	1.1	1.1	-2.8	-1.9	-1.7	-1.1	-1.1	-1.1	0.6	3.3	2.2	2.2	1.7	1.1	1.7
14	17	0.07	-6.1	-2.8	-1.7	-1.7	-1.7	-1.7	-1.4	-6.7	-3.3	-3.9	-3.3	-3.3	-3.3	-1.1	2.2	2.2	2.2	1.7	0.6	1.1
14	18	0.02	-6.1	-3.9	-2.8	-3.3	-3.3	-3.6	-3.6	-4.7	-4.2	-4.4	-4.4	-5.0	-5.0	-3.3	0.6	1.7	1.7	1.7	0.3	0.3
14	19		-6.7	-4.4	-3.9	-3.9	-3.9	-4.4	-4.4	-5.0	-4.7	-5.6	-5.0	-5.6	-5.6	-4.4	-1.7	0.6	0.6	1.1	0.0	0.0
14	20		-6.7	-5.0	-4.4	-4.7	-5.0	-5.6	-5.0	-5.0	-5.0	-6.1	-6.1	-6.1	-6.1	-5.6	-3.3	-1.1	-1.1	0.3	-0.6	-0.8
14	21		-6.7	-5.0	-5.0	-5.0	-5.6	-5.6	-5.6	-5.3	-5.3	-6.1	-6.1	-6.1	-6.1	-6.1	-4.4	-2.8	-2.2	-0.6	-1.1	-1.4
14	22		-10.0	-7.2	-6.7	-6.7	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-6.7	-5.6	-3.9	-3.3	-1.7	-2.2	-2.5
14	23		-11.1	-8.9	-8.6	-8.3	-8.9	-8.9	-8.9	-8.9	-8.9	-9.4	-10.0	-9.4	-9.4	-8.3	-6.7	-5.0	-4.4	-2.8	-3.3	-3.6
14	24		-12.2	-9.4	-9.4	-9.4	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-10.0	-11.1	-8.9	-6.7	-6.7	-3.9	-4.4	-5.0

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY HR (FEB 79)		PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
15	1		-13.9	-11.1	-10.6	-10.8	-11.4	-11.4	-11.4	-11.4	-11.1	-11.7	-11.7	-11.9	-11.9	-12.2	-10.0	-8.3	-8.3	-5.0	-5.6	-6.1
15	2		-15.0	-12.2	-12.2	-11.9	-12.2	-12.2	-12.2	-12.2	-12.2	-13.3	-12.8	-13.3	-13.3	-13.3	-11.7	-10.0	-9.4	-6.1	-6.7	-7.2
15	3		-15.6	-13.3	-13.3	-12.8	-13.6	-13.6	-13.6	-13.3	-13.3	-13.9	-13.9	-14.4	-13.9	-14.4	-13.3	-11.1	-10.6	-7.5	-7.8	-8.1
15	4		-16.1	-13.9	-13.9	-13.9	-14.4	-14.4	-14.4	-13.3	-13.3	-14.4	-14.4	-15.0	-15.0	-14.4	-13.3	-11.1	-10.6	-8.9	-8.9	-9.4
15	5		-16.1	-13.9	-14.4	-13.9	-14.4	-14.4	-14.4	-14.4	-13.9	-14.4	-14.4	-15.0	-15.0	-15.0	-13.9	-12.2	-11.7	-10.0	10.0	-10.0
15	6		-16.7	-14.4	-15.0	-15.0	-15.6	-15.6	-15.6	-14.4	-14.4	-15.0	-15.0	-15.6	-15.6	-15.6	-14.4	-13.3	-12.8	-10.6	-11.1	-11.1
15	7	0.02	-17.2	-16.4	-16.4	-16.1	-16.7	-16.7	-16.9	-16.1	-16.1	-16.7	-16.7	-17.2	-17.2	-16.7	-15.6	-14.4	-13.9	-11.7	-11.9	-12.2
15	8	0.03	-17.8	-16.7	-16.7	-16.7	-17.2	-17.2	-17.2	-16.7	-16.7	-17.2	-17.2	-17.8	-17.8	-17.2	-16.1	-15.0	-15.0	-12.8	-12.9	-12.8
15	9	0.14	-18.9	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-17.2	-17.2	-17.2	-17.2	-17.8	-16.7	-16.1	-15.6	-13.3	-13.6	-13.3
15	10	0.30	-18.9	-15.0	-14.4	-13.9	-13.9	-12.8	-13.3	-15.6	-15.6	-16.1	-16.1	-16.1	-16.1	-16.7	-16.7	-16.1	-16.1	-13.6	-13.6	-13.3
15	11	0.40	-19.4	-15.0	-14.4	-13.3	-13.9	-12.2	-12.5	-15.6	-15.6	-15.6	-15.6	-15.0	-15.0	-15.6	-15.6	-15.6	-15.6	-13.3	-13.3	-12.8
15	12	0.46	-20.0	-12.8	-12.2	-11.7	-11.4	-9.4	-10.0	-14.4	-13.9	-15.0	-14.4	-13.9	-13.9	-14.4	-14.4	-15.0	-15.0	-13.1	-12.5	-12.2
15	13	0.63	-20.0	-10.0	-9.4	-8.6	-8.3	-6.1	-6.7	-12.2	-12.2	-12.2	-11.7	-10.0	-10.6	-12.2	-12.8	-13.9	-13.3	-12.2	-11.7	-10.8
15	14	0.68	-20.6	-7.2	-6.1	-3.9	-3.3	0.0	0.0	-6.1	-10.0	-2.8	-7.2	3.9	-4.4	-6.1	-8.9	-11.1	-10.6	-9.4	-7.8	-7.2
15	15	0.58	-21.7	-10.0	-8.1	-5.6	-6.1	-3.3	-3.3	-8.3	-10.8	-5.6	-9.4	0.0	-7.2	-6.1	-6.1	-7.8	-7.8	-7.2	-5.8	-5.6
15	16	0.34	-21.7	-15.0	-13.3	-12.2	-12.5	-12.2	-12.2	-15.0	-13.9	-13.9	-12.2	-12.8	-12.8	-10.0	-6.1	-6.7	-6.1	-6.1	-6.7	-6.7
15	17	0.15	-23.9	-17.2	-16.7	-15.6	-16.1	-16.7	-16.7	-17.8	-17.2	-17.8	-16.1	-17.8	-17.8	-15.6	-8.9	-6.7	-6.1	-6.1	-7.2	-7.2
15	18	0.02	-25.0									-21.1	-20.6	-21.7	-21.7	-20.0	-13.3	-8.9	-8.3	-7.2	-8.3	-9.4
15	19		-26.1									-22.8	-22.2	-23.9	-23.9	-22.8	-17.8	-11.7	-11.1	-8.3	-10.0	-11.1
15	20		-26.7									-24.4	-23.9	-25.0	-25.0	-25.0	-20.6	-15.6	-14.4	-10.6	-11.7	-12.8
15	21		-27.8									-25.0	-25.0	-25.6	-26.1	-26.1	-23.3	-18.9	-17.8	-12.8	-13.6	-14.7
15	22		-28.3									-26.1	-26.1	-27.2	-27.2	-26.7	-25.0	-21.1	-20.6	-15.8	-16.1	-16.4
15	23		-28.9									-26.7	-26.7	-27.2	-27.8	-27.8	-26.1	-23.9	-22.8			
15	24		-28.9									-27.2	-27.8	-27.8	-28.3	-28.3	-27.8	-25.6	-24.4			
16	1		-30.0									-28.3	-28.3	-28.9	-28.9	-28.9	-28.3	-26.7	-26.1			
16	2		-30.0									-28.9	-28.9	-29.4	-29.4	-30.0	-28.9	-27.8	-27.2			
16	3		-30.6									-29.4	-30.0	-30.0	-30.0	-30.0	-29.4	-28.3	-27.8			
16	4		-31.1									-30.6	-30.6	-30.0	-31.1	-30.6	-30.6	-29.4	-29.4			
16	5		-31.1									-31.1	-31.1	-31.1	-31.1	-31.7	-30.6	-30.0	-30.0			
16	6		-31.7									-32.2	-32.2	-32.2	-32.2	-32.2	-31.7	-30.6	-30.6			
16	7	0.02	-32.2									-32.2	-32.2	-32.2	-32.2	-32.2	-31.7	-31.1	-31.1			
16	8	0.09	-32.2									-30.6	-30.6	-30.0	-30.6	-31.1	-32.2	-31.7	-31.7			
16	9	0.42	-30.0									-24.4	-21.1	-22.8	-20.6	-25.0	-29.4	-30.6	-30.6			
16	10	0.58	-27.8									-9.4	-5.0	-8.3	-1.1	-16.1	-23.3	-27.2	-26.1			
16	11	0.78	-26.1	-12.8	-9.4	-6.7	-6.1	-0.6	1.1	-6.7	-2.8	0.6	3.9	0.6	10.6	-4.4	-15.0	-20.6	-19.4		-14.4	-15.3
16	12	0.88	-24.4	-5.0	0.6	6.7	6.7	10.0	14.4	18.9	19.4	37.8	31.1	35.0	46.1	10.6	-2.8	-10.6	-8.3	-11.7	-5.0	-5.6
16	13	0.89	-23.9	-1.1	5.0	13.3	12.8	14.4	20.6	25.0	26.1	43.9	39.4	40.0	54.4	20.6	10.6	1.7	4.4	-2.8	3.3	2.8
16	14	0.82	-23.9	1.1	7.8	12.2	16.1	15.6	22.8	22.8	28.3	36.7	47.8	40.0	55.6	23.9	20.0	12.2	15.6	6.7	11.1	8.9
16	15	0.66	-23.9	-0.6	7.8	10.0	14.4	12.8	19.4	18.3	22.8	29.4	37.2	33.3	43.3	23.7	25.6	20.6	23.3	13.9	17.2	13.3
16	16	0.44	-23.9	-3.9	3.9	4.4	8.9	5.6	11.7	2.2	18.3	15.0	28.3	8.3	25.6	17.8	25.0	25.0	27.2	18.9	20.0	15.6
16	17	0.19	-26.1	-6.9	-1.7	-2.8	1.1	-3.9	0.6	-12.8	-5.3	-10.6	-1.7	-9.4	-2.2	4.4	20.0	24.4	27.2	20.6	15.0	13.9
16	18	0.02	-27.8	-16.1	-10.6	-12.8	-11.1	-15.6	-13.3	-17.8	-15.0	-17.2	-13.9	-17.2	-16.7	-9.4	10.0	20.0	22.2	18.9	10.6	9.4
16	19		-27.8									-20.0	-17.8	-20.6	-20.0	-17.2	-0.6	12.8	15.6	16.1	8.3	6.7
16	20		-28.3									-22.2	-20.6	-22.8	-22.8	-21.1	-8.9	5.0	7.8	12.2	5.0	3.3
16	21		-30.0									-24.4	-23.9	-25.6	-25.6	-23.9	-16.1	-3.9	0.0	7.2	1.7	-0.6
16	22		-30.0									-26.7	-26.7	-27.2	-27.8	-26.1	-20.6	-10.6	-7.2	1.1	-2.5	-4.7
16	23		-29.4									-28.3	-28.3	-29.4	-29.4	-27.8	-23.9	-16.1	-13.9	-4.7	-7.2	-9.2
16	24		-28.9									-28.9	-28.9	-29.4	-29.4	-28.9	-26.7	-21.1	-18.9	-10.3	-11.4	-13.3

TABLE F. CONTINUED

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
		PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER																				
17	1		-28.3									-28.9	-28.9	-28.9	-28.9	-28.9	-27.8	-24.4	-22.8	-15.0	-15.0	-16.7
17	2		-27.8									-28.9	-28.9	-28.9	-28.9	-28.9	-28.3	-26.1	-25.0			
17	3		-27.2									-28.9	-28.9	-28.9	-28.9	-28.3	-28.3	-27.2	-26.7			
17	4		-26.7									-27.2	-27.2	-27.2	-27.2	-27.8	-28.3	-27.8	-27.2			
17	5		-24.4									-26.1	-26.1	-26.1	-26.1	-26.7	-27.8	-27.8	-27.8			
17	6		-23.3									-25.0	-25.0	-25.0	-25.0	-25.6	-26.7	-27.2	-27.8			
17	7	0.02	-22.2									-24.4	-24.4	-24.4	-24.4	-25.0	-26.1	-26.7	-26.7			
17	8	0.07	-21.7									-22.2	-22.2	-22.2	-22.2	-23.3	-24.4	-25.6	-26.1			
17	9	0.24	-20.0									-19.4	-18.9	-18.3	-17.8	-20.0	-22.2	-23.9	-24.4			
17	10	0.44	-18.3									-16.1	-16.1	-14.4	-14.4	-16.7	-19.4	-21.7	-22.2			
17	11	0.52	-17.2	-13.1	-12.2	-11.7	-10.8	-8.9	-8.9	-13.9	-13.9	-13.9	-13.9	-12.2	-12.2	-13.9	-16.1	-16.7	-16.1	-17.8	-17.8	-17.2
17	12	0.62	-16.1	-11.1	-9.4	-9.4	-8.3	-6.7	-6.7	-12.2	-12.2	-11.7	-11.1	-10.0	-10.0	-11.1	-13.3	-17.6	1649.1	-16.4	-16.1	-14.4
17	13	0.62	-15.0	-8.3	-6.1	-5.6	-4.4	-2.8	-2.2	-9.4	-9.4	-7.2	-7.2	-5.0	-4.4	-8.3	-10.6	-13.3	-13.3	-13.9	-12.2	-11.7
17	14	0.54	-15.6	-10.6	-9.4	-8.9	-7.8	-6.7	-6.7	-11.7	-11.1	-11.1	-10.0	-9.4	-9.4	-7.2	-7.8	-11.1	-11.1	-11.1	-10.6	-10.0
17	15	0.36	-15.6	-10.6	-8.9	-8.9	-7.8	-7.2	-7.2	-11.7	-11.1	-11.1	-10.6	-10.0	-10.0	-9.4	-7.2	-8.9	-9.4	-10.0	-10.0	-9.4
17	16	0.26	-15.6	-12.2	-10.8	-10.6	-10.3	-10.0	-10.0	-13.1	-12.8	-12.8	-12.2	-12.2	-12.2	-10.6	-7.2	-8.3	-8.3	-9.4	-10.0	-9.4
17	17	0.08	-16.7	-13.6	-12.8	-12.8	-12.8	-12.8	-12.8	-14.4	-14.4	-14.4	-14.4	-14.7	-14.7	-13.3	-9.4	-8.9	-8.9	-9.2	-10.0	-10.0
17	18	0.02	-16.7	-14.4	-13.9	-13.9	-14.2	-14.4	-14.4	-15.0	-14.4	-15.6	-15.6	-15.6	-15.6	-14.4	-11.7	-10.0	-9.4	-9.4	-10.6	-10.3
17	19		-16.1	-14.4	-14.4	-14.4	-14.7	-14.7	-14.7	-15.0	-15.0	-16.1	-16.1	-16.1	-16.1	-15.0	-13.3	-11.1	-11.1	-10.0	-10.8	-10.8
17	20		-16.7	-15.0	-15.0	-15.0	-15.0	-15.3	-15.3	-15.3	-15.3	-16.7	-16.7	-16.7	-16.7	-16.1	-14.4	-12.8	-12.8	-10.8	-11.4	-14.2
17	21		-16.7	-15.6	-15.6	-15.0	-15.6	-15.6	-15.6	-15.6	-15.6	-16.7	-16.7	-16.7	-16.7	-16.1	-15.0	-13.9	-13.3	-11.7	-12.2	-12.2
17	22		-16.1	-15.6	-15.6	-15.6	-16.1	-16.1	-16.1	-16.1	-15.6	-16.7	-16.7	-16.7	-16.7	-16.7	-16.1	-15.0	-14.4	-12.8	-12.8	-12.8
17	23		-16.7	-15.6	-15.6	-15.6	-16.1	-16.1	-16.1	-16.1	-15.6	-17.2	-17.2	-17.2	-17.2	-16.7	-16.1	-15.6	-15.6	-12.8	-12.8	-12.9
17	24		-16.7	-16.1	-15.6	-15.8	-16.1	-16.1	-16.1	-15.6	-16.1	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.1	-16.1	-14.4	-14.4	-14.2
18	1		-16.7	-16.1	-15.8	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.1	-15.0	-15.6	-14.4
18	2		-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-15.3	-15.6	-15.0
18	3		-16.1	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-15.6	-15.6	-15.0
18	4		-16.7	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-17.2	-17.2	-17.2	-17.2	-16.9	-16.9	-16.9	-16.9	-15.6	-15.6	-15.0
18	5		-16.7	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-17.2	-17.2	-17.2	-17.2	-16.9	-16.9	-16.9	-16.9	-15.6	-15.6	-15.0
18	6		-16.7	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-15.6	-15.6	-15.0
18	7	0.02	-16.7	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-17.2	-15.6	-15.6	-15.0
18	8	0.04	-16.7	-16.4	-16.4	-16.1	-16.4	-16.4	-16.4	-16.4	-16.4	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-16.7	-17.2	-15.6	-15.6	-15.0
18	9	0.28	-15.6	-11.1	-8.9	-8.3	-7.2	-5.6	-5.6	-9.4	2.2	-5.6	-0.6	-5.0	7.8	-12.2	-15.6	-16.1	-16.1	-15.0	-13.9	-13.3
18	10	0.55	-14.4	-6.1	-2.2	-0.6	0.6	4.4	5.0	4.4	8.3	14.4	11.7	11.1	23.3	0.0	-7.8	-11.7	-10.6	-10.6	-6.1	-6.7
18	11	0.68	-13.9	-3.3	1.1	2.8	4.4	7.2	6.1	0.0	0.0	9.4	8.9	10.0	14.4	6.1	0.0	-5.6	-3.9	-6.1	-2.2	-2.8
18	12	0.75	-12.8	0.6	6.1	7.2	9.4	11.7	13.9	13.9	7.2	15.6	11.7	18.9	20.6	11.1	6.7	1.1	2.2	-0.6	3.3	2.2
18	13	0.88	-11.7	1.7	7.2	7.8	11.7	12.2	15.0	8.9	5.6	12.8	12.8	16.7	18.9	15.6	12.8	7.8	8.9	5.0	8.3	6.7
18	14	0.66	-11.7	2.2	6.7	7.8	10.0	10.6	12.8	6.1	4.4	5.0	7.8	8.3	10.6	11.7	15.0	11.7	12.8	8.9	8.9	8.3
18	15	0.62	-11.7	4.4	11.1	11.7	15.0	14.4	17.8	18.9	13.9	25.0	25.0	25.0	27.8	16.1	16.7	16.1	17.2	13.9	15.6	13.3
18	16	0.38	-11.7	2.2	7.8	7.8	9.4	8.9	11.1	6.7	14.7	13.3	20.6	10.0	18.9	13.3	17.2	18.3	20.0	16.7	17.2	15.0
18	17	0.16	-12.2	-3.1	1.7	0.6	1.7	0.6	1.7	-4.4	-2.2	-3.9	0.6	-2.8	-0.6	4.4	20.0	18.3	20.0	17.2	13.3	12.8
18	18	0.02	-13.9	-7.2	-4.4	-5.6	-5.0	-6.7	-6.1	-7.8	-7.2	-8.3	-6.7	-8.3	-8.3	-3.9	8.3	14.4	16.1	16.1	10.6	9.4
18	19		-14.4	-8.3	-6.1	-7.8	-7.2	-9.4	-8.9	-9.4	-8.9	-10.6	-9.4	-11.1	-11.1	-8.9	1.7	10.0	11.1	13.3	8.3	7.2
18	20		-15.6	-9.4	-7.8	-9.4	-9.4	-11.1	-11.1	-11.1	-10.6	-11.7	-11.7	-12.8	-12.8	-11.1	-3.9	4.4	6.1	10.6	6.1	5.0
18	21		-15.6	-11.1	-9.4	-11.1	-11.1	-12.2	-12.2	-12.2	-11.7	-13.3	-12.8	-13.9	-13.9	-13.3	-8.3	-0.6	1.1	6.7	3.3	2.2
18	22		-15.6	-12.2	-11.1	-12.5	-12.8	-13.9	-13.9	-13.3	-12.8	-14.4	-14.4	-15.0	-15.0	-13.9	-10.6	-4.4	-2.8	3.3	0.8	-0.6
18	23		-16.1	-13.3	-12.8	-13.3	-13.9	-14.4	-14.4	-14.2	-14.2	-15.0	-15.0	-15.6	-15.6	-15.0	-12.8	-8.3	-6.7	-0.6	-1.7	-3.3
18	24		-16.7	-13.9	-13.9	-14.4	-15.0	-15.6	-15.6	-15.0	-14.4	-16.1	-16.1	-16.1	-16.1	-15.6	-13.9	-10.6	-9.4	-3.9	-4.7	-5.6

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
19	1		-16.7	-15.3	-15.0	-15.6	-16.1	-16.1	-16.1	-15.6	-15.6	-16.7	-16.7	-16.7	-16.7	-16.7	-15.0	-12.8	-11.7	-7.2	-7.2	-7.8
19	2		-15.6	-15.0	-15.0	-15.3	-15.6	-16.1	-16.1	-15.6	-15.6	-16.7	-16.7	-16.7	-16.7	-16.7	-16.1	-14.4	-13.9	-9.4	-9.4	-10.0
19	3		-15.6	-15.0	-15.0	-15.3	-15.6	-15.6	-15.6	-15.0	-15.0	-16.1	-16.1	-16.1	-16.1	-16.7	-16.1	-15.0	-14.4	-11.1	-11.1	-11.4
19	4		-15.0	-15.0	-15.0	-15.3	-15.6	-15.6	-15.6	-15.0	-15.0	-15.6	-15.6	-16.1	-15.6	-16.7	-16.1	-15.6	-15.6	-12.2	-12.2	-12.5
19	5		-15.0	-15.0	-15.0	-15.3	-15.6	-15.6	-15.6	-15.0	-15.0	-16.1	-16.1	-16.1	-16.1	-16.7	-16.7	-16.1	-16.1	-13.3	-13.3	-13.3
19	6		-14.4	-15.0	-15.0	-15.3	-15.6	-15.6	-15.6	-15.0	-15.0	-15.6	-15.6	-15.6	-15.6	-16.1	-16.1	-16.1	-16.1	-14.2	-14.2	-13.9
19	7	0.02	-14.4	-15.0	-15.0	-15.3	-15.6	-15.6	-15.6	-15.0	-15.0	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-16.1	-14.4	-14.4	-14.2
19	8	0.13	-13.9	-12.2	-12.2	-11.9	-11.7	-11.1	-11.1	-13.3	-13.3	-13.9	-13.3	-13.3	-11.7	-14.4	-15.6	-16.1	-16.1	-14.4	-13.9	-13.3
19	9	0.32	-11.7	-7.2	-6.7	-6.7	-5.6	-3.9	-3.9	-8.9	-6.1	-6.1	-3.9	-3.3	3.3	-8.3	-12.8	-14.4	-14.4	-13.3	-12.2	-11.1
19	10	0.45	-9.4	-4.4	-3.3	-2.2	-1.7	0.6	1.1	-4.4	-3.3	-1.7	-1.1	0.6	2.2	-4.4	-8.3	-11.1	-11.1	-11.1	-8.9	-8.3
19	11	0.76	-8.3	2.2	5.6	5.6	7.2	10.0	11.1	4.4	4.4	6.7	7.2	9.4	12.2	6.1	-1.1	-6.1	-5.6	-6.1	-2.2	-2.2
19	12	0.76	-5.0	7.2	10.6	12.2	13.9	17.2	18.3	18.3	12.8	18.9	15.0	21.7	21.7	11.7	5.0	-1.1	0.0	-1.7	3.9	3.3
19	13	0.70	-3.9	6.1	10.6	11.1	12.8	15.0	17.8	10.6	10.0	10.7	16.1	20.0	20.0	16.7	11.7	5.6	6.7	3.3	7.2	6.7
19	14	0.77	-1.7	13.9	18.9	20.6	23.9	25.6	27.8	34.4	25.6	32.2	30.6	35.0	37.2	18.9	15.6	11.1	11.7	8.3	13.3	12.2
19	15	0.63	-1.7	13.3	17.8	19.4	21.7	23.9	25.6	31.7	25.6	38.3	36.1	37.8	40.6	25.0	21.7	17.8	18.9	15.0	18.9	16.7
19	16	0.40	-2.2	10.0	13.9	14.4	16.7	17.2	18.3	15.6	22.2	20.6	26.1	18.3	24.4	22.2	24.4	22.2	23.3	18.9	20.6	17.8
19	17	0.15	-2.2	4.4	7.2	7.2	7.8	6.7	7.8	3.9	5.6	5.0	7.8	5.6	6.1	11.7	21.7	22.8	23.9	19.4	16.7	15.6
19	18	0.02	-3.3	1.7	4.4	3.3	3.9	1.7	2.2	1.1	2.2	1.1	2.8	1.1	1.1	5.0	16.1	20.6	21.1	18.9	14.4	13.9
19	19		-4.4	-1.1	1.1	0.0	0.6	-1.1	-0.6	-2.2	-0.6	-1.7	-0.6	-1.7	-1.7	0.6	10.6	17.8	18.3	17.8	13.3	12.2
19	20		-5.0	-3.3	-1.1	-2.2	-1.7	-3.3	-2.8	-3.9	-2.8	-3.3	-2.2	-3.9	-3.9	-2.2	5.6	13.3	13.9	15.6	11.7	10.6
19	21		-5.0	-3.9	-2.2	-3.9	-3.9	-5.3	-5.3	-5.0	-4.4	-5.6	-5.0	-6.1	-6.1	-4.4	1.7	8.9	10.0	12.8	9.4	8.6
19	22		-6.7	-7.2	-5.6	-6.7	-6.7	-7.8	-7.8	-7.8	-7.2	-8.9	-8.3	-8.9	-8.9	-6.7	-2.2	5.0	6.1	10.0	7.2	6.1
19	23		-6.7	-6.7	-5.6	-6.7	-7.2	-7.8	-7.8	-7.8	-7.2	-8.3	-8.9	-8.9	-8.9	-8.3	-5.0	1.1	1.7	6.7	5.0	3.9
19	24		-7.8	-7.2	-7.2	-7.2	-7.8	-8.1	-8.1	-8.3	-7.8	-8.9	-8.9	-8.9	-8.9	-8.3	-6.7	-2.2	-1.1	3.9	2.8	1.7
20	1		-8.9	-7.8	-7.8	-7.8	-8.3	-8.3	-8.3	-8.6	-8.3	-9.4	-9.4	-9.4	-9.4	-8.9	-7.8	-4.4	-3.9	1.1	0.6	-0.6
20	2		-8.9	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-8.9	-8.9	-9.4	-9.4	-9.4	-9.4	-8.9	-8.3	-6.1	-5.6	-1.7	-1.7	-2.2
20	3		-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-10.0	-10.0	-10.0	-10.0	-9.4	-8.9	-7.8	-7.2	-3.9	-3.9	-3.9
20	4		-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-8.9	-9.7	-9.7	-9.7	-9.7	-9.4	-8.9	-8.3	-7.8	-5.3	-5.3	-5.6
20	5		-8.9	-9.4	-9.4	-8.9	-9.4	-9.4	-9.4	-9.4	-9.4	-10.0	-10.0	-10.0	-10.0	-9.4	-9.4	-8.9	-8.9	-6.7	-6.7	-6.7
20	6		-8.9	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-9.4	-10.0	-10.0	-10.0	-10.0	-10.0	-9.4	-8.9	-8.9	-7.8	-7.8	-7.2
20	7	0.02	-8.9	-9.7	-9.7	-9.4	-9.7	-9.7	-9.7	-9.7	-9.7	-10.6	-10.6	-10.6	-10.6	-10.0	-10.0	-9.4	-9.4	-8.3	-8.3	-7.8
20	8	0.06	-7.8	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-9.4	-9.4	-9.4	-9.4	-10.0	-10.0	-10.0	-10.0	-8.3	-8.3	-7.8
20	9	0.14	-8.9	-6.1	-6.1	-6.1	-5.6	-5.0	-5.0	-6.7	-6.7	-6.7	-6.7	-6.1	-6.1	-7.8	-8.9	-9.4	-9.4	-8.1	-7.8	-7.2
20	10	0.26	-6.7	-3.9	-3.9	-3.3	-2.8	-1.7	-1.7	-5.6	-5.0	-5.0	-4.4	-3.3	-2.8	-5.0	-6.7	-8.3	-8.3	-7.2	-6.7	-6.1
20	11	0.37	-6.1	-1.1	-0.6	0.0	1.1	2.8	2.8	-2.2	-2.2	-1.7	-1.1	0.6	0.6	-1.7	-3.9	-6.1	-6.1	-5.6	-5.0	-3.9
20	12	0.36	-5.6	0.0	1.1	0.6	2.2	2.8	3.3	-2.2	-1.7	-1.7	-1.1	0.0	0.6	0.0	-1.7	-3.9	-4.4	-3.9	-3.3	-2.8
20	13	0.39	-5.0	-0.6	1.7	1.7	1.7	3.9	4.4	0.0	-1.1	-0.6	0.0	1.1	1.7	1.1	0.6	-2.8	-2.8	-2.2	-1.7	-1.1
20	14	0.60	-3.9	0.8	2.2	2.8	3.6	5.0	5.0	-0.6	0.3	0.6	1.1	2.2	2.8	2.2	1.7	-1.1	-1.7	-1.7	-1.1	0.0
20	15	0.30	-3.9	0.0	1.1	1.7	2.2	3.3	3.6	-1.1	-0.8	-0.6	0.0	1.1	1.1	2.2	2.8	0.0	0.0	-0.3	0.0	0.6
20	16	0.14	-6.1	-2.8	-1.7	-1.1	-0.6	-0.3	0.0	-3.9	-3.9	-3.3	-2.8	-2.8	-2.8	0.0	2.2	1.1	1.1	0.0	-0.3	0.0
20	17	0.08	-8.3	-5.0	-3.9	-3.6	-3.6	-3.6	-3.3	-6.1	-5.6	-6.1	-5.6	-5.8	-5.8	-3.3	1.1	1.1	0.8	0.3	-0.8	-0.6
20	18	0.02	-8.9	-5.8	-5.3	-5.0	-5.3	-5.6	-5.6	-6.7	-6.1	-6.7	-6.7	-6.9	-6.9	-5.6	-3.9	0.0	0.0	0.0	-1.1	-1.1
20	19		-9.4	-5.8	-5.8	-5.8	-6.1	-6.4	-6.4	-6.1	-5.8	-6.7	-6.7	-6.7	-6.7	-6.7	-3.3	-1.1	-1.1	-0.6	-1.7	-1.7
20	20		-10.0	-6.7	-6.7	-6.7	-6.9	-6.9	-6.9	-6.9	-6.7	-7.2	-7.2	-7.2	-7.2	-7.2	-5.0	-2.8	-2.8	-1.1	-2.2	-2.2
20	21		-10.0	-7.2	-7.2	-7.2	-7.8	-7.8	-7.8	-6.7	-6.9	-7.8	-7.8	-7.8	-7.8	-7.8	-6.1	-4.4	-3.9	-2.2	-2.8	-3.1
20	22		-10.0	-7.8	-7.8	-7.8	-8.3	-8.3	-8.3	-7.5	-7.2	-8.3	-7.8	-8.3	-8.3	-7.8	-7.2	-5.6	-5.0	-3.3	-3.6	-3.9
20	23		-10.0	-8.3	-8.3	-8.1	-8.3	-8.3	-8.3	-7.8	-7.8	-8.3	-8.3	-8.3	-8.3	-8.3	-7.8	-6.7	-6.1	-4.2	-4.4	-4.4
20	24		-10.0	-8.9	-8.9	-8.6	-8.9	-8.9	-8.9	-8.3	-8.3	-8.9	-8.9	-8.9	-8.9	-8.9	-8.3	-7.2	-7.2	-5.0	-5.3	-5.3

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
21	1		-11.1	-9.2	-9.2	-8.9	-9.2	-9.2	-9.2	-8.6	-8.6	-8.9	-8.9	-9.4	-9.4	-8.9	-8.3	-7.8	-7.8	-6.1	-6.1	-6.1
21	2		-11.7	-10.0	-10.0	-10.3	-10.6	-10.6	-10.6	-9.4	-9.4	-10.6	-10.6	-11.1	-10.6	-10.0	-9.4	-8.3	-8.3	-6.9	-6.9	-6.9
21	3		-11.7	-11.1	-11.1	-10.8	-11.1	-11.1	-11.1	-10.6	-10.6	-10.0	-10.0	-10.6	-10.0	-11.1	-10.0	-8.9	-8.9	-7.5	-7.5	-7.5
21	4		-12.2	-10.8	-10.8	-10.6	-10.8	-10.8	-10.8	-10.0	-10.3	-10.6	-11.1	-10.6	-10.8	-11.1	-11.1	-10.6	-9.4	-8.1	-9.1	-7.8
21	5		-12.2	-11.4	-11.4	-11.1	-11.4	-11.4	-11.4	-9.7	-9.7	-11.1	-11.1	-11.1	-11.1	-11.4	-10.8	-10.0	-10.0	-8.6	-8.6	-8.3
21	6		-12.2	-13.1	-13.1	-12.8	-13.3	-13.3	-13.3	-11.1	-11.7	-12.2	-12.2	-12.2	-12.2	-11.9	-11.1	-10.6	-10.6	-9.2	-9.2	-8.9
21	7	0.02	-12.8	-14.2	-14.2	-14.2	-14.2	-14.4	-14.4	-13.6	-13.9	-13.9	-13.9	-14.2	-14.2	-13.6	-12.2	-11.1	-11.1	-10.0	-10.0	-10.0
21	8	0.16	-13.9	-11.9	-11.9	-11.4	-11.7	-11.7	-11.7	-12.5	-12.2	-12.5	-12.2	-11.9	-11.1	-13.1	-12.5	-11.7	-11.7	-10.3	-10.3	-10.0
21	9	0.27	-13.3	-10.6	-10.6	-10.0	-10.0	-9.7	-9.7	-10.8	-10.8	-11.1	-11.1	-10.6	-10.6	-11.1	-12.2	-11.7	-11.7	-10.0	-10.0	-10.0
21	10	0.47	-11.1	-6.4	-6.4	-5.6	-5.0	-4.2	-4.2	-7.8	-7.8	-6.7	-7.2	-5.0	-5.0	-7.8	-10.6	-10.6	-10.6	-9.4	-9.4	-8.6
21	11	0.77	-10.6	2.8	6.1	8.9	10.3	13.9	15.6	25.0	20.0	38.1	21.1	37.8	34.4	8.9	-2.8	-6.1	-5.0	-5.3	0.0	-0.6
21	12	0.86	-9.4	7.8	12.5	15.0	17.2	20.3	23.3	39.4	21.1	51.7	27.8	51.1	39.4	21.1	8.6	2.8	4.4	1.7	8.3	6.9
21	13	0.88	-8.3	11.7	16.7	20.6	23.3	25.6	30.0	46.1	23.6	52.2	35.0	57.8	49.4	29.4	18.9	12.2	14.4	8.6	15.0	13.3
21	14	0.82	-7.8	13.3	18.9	21.9	25.6	26.1	31.1	42.2	27.8	54.4	42.2	55.0	52.8	32.8	27.2	20.8	23.9	16.1	21.1	18.9
21	15	0.66	-7.8	12.8	18.9	21.1	25.0	24.4	30.0	32.2	23.3	34.4	35.0	28.3	35.0	27.8	32.2	32.2	34.4	20.3	24.4	21.1
21	16	0.48	-7.8	10.6	16.1	17.8	21.1	19.7	24.4	24.4	27.2	6.1	12.8	7.8	11.7	17.2	28.9	32.8	35.0	26.7	28.3	24.4
21	17	0.17	-7.2	3.9	8.9	7.8	11.1	8.9	11.9	4.4	9.4	-2.2	0.6	-1.7	-1.7	5.6	21.7	29.4	31.1	28.1	25.0	22.8
21	18	0.02	-10.0	-2.2	1.7	1.7	2.2	-0.8	0.8	-3.3	-1.4	-4.7	-2.8	-5.0	-5.0	-1.1	13.3	23.9	25.6	27.5	20.6	19.9
21	19		-10.0	-3.3	0.6	-0.8	0.0	-2.8	-1.9	-5.0	-3.3	-6.1	-5.0	-6.7	-6.7	-3.9	6.7	17.8	19.4	25.3	18.1	16.7
21	20		-10.6	-3.6	-0.6	-2.5	-1.9	-4.4	-3.9	-5.6	-4.2	-7.2	-6.1	-7.5	-7.5	-6.1	1.1	11.7	13.9	22.5	16.1	14.4
21	21		-11.1	-3.9	-1.9	-3.3	-3.3	-5.0	-5.0	-6.1	-5.0	-7.8	-7.2	-7.8	-7.8	-7.2	-3.1	5.6	7.2	18.6	13.9	12.2
21	22		-10.0	-4.4	-3.1	-4.4	-4.4	-5.6	-5.6	-6.7	-5.6	-7.5	-7.5	-8.1	-8.1	-7.2	-5.0	1.7	3.3	15.0	11.1	9.4
21	23		-10.0	-5.0	-4.2	-5.3	-5.6	-6.4	-6.4	-6.7	-6.1	-8.3	-8.3	-8.3	-8.3	-7.8	-3.3	-2.2	-0.6	10.6	8.1	6.7
21	24		-8.9	-5.6	-5.3	-6.1	-6.7	-6.7	-6.7	-6.9	-6.7	-8.6	-8.6	-8.6	-8.6	-7.8	-7.2	-4.2	-3.3	6.4	5.3	3.9
22	1		-8.9	-6.1	-5.8	-6.7	-7.2	-7.2	-7.2	-7.2	-7.2	-8.9	-8.9	-8.9	-8.9	-8.3	-7.8	-5.8	-5.0	2.8	2.2	1.1
22	2		-8.9	-6.7	-6.7	-7.2	-7.5	-7.5	-7.5	-7.5	-7.5	-8.6	-8.6	-8.6	-8.6	-8.3	-7.8	-6.7	-6.4	0.0	0.0	-1.1
22	3		-7.8	-7.2	-6.9	-7.2	-7.8	-7.8	-7.8	-7.8	-7.5	-8.9	-8.9	-8.9	-8.9	-11.1	-11.1	-7.8	-7.2	-2.2	-2.2	-2.8
22	4		-8.3	-7.5	-7.5	-7.5	-7.5	-7.5	-7.5	-7.8	-7.8	-8.3	-8.3	-8.3	-8.3	-8.3	-8.3	-7.8	-8.1	-3.9	-3.9	-4.2
22	5		-7.8	-7.2	-6.9	-7.2	-7.5	-7.5	-7.5	-7.8	-7.8	-7.8	-7.8	-7.8	-7.8	-8.1	-8.1	-8.1	-8.1	-5.0	-5.0	-5.0
22	6		-6.7	-6.9	-6.9	-6.7	-6.9	-6.9	-6.9	-6.9	-6.9	-7.2	-7.2	-7.2	-7.2	-7.5	-7.8	-7.8	-8.1	-6.1	-6.1	-5.8
22	7	0.02	-6.7	-6.7	-6.7	-6.7	-6.9	-6.9	-6.9	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-7.2	-7.5	-7.5	-7.8	-6.4	-6.4	-6.1
22	8	0.03	-5.6	-6.7	-6.7	-6.4	-6.4	-6.4	-6.4	-6.4	-6.4	-6.9	-6.9	-6.9	-6.9	-6.9	-7.2	-7.2	-7.5	-6.7	-6.4	-6.4
22	9	0.10	-6.1	-6.1	-6.1	-6.1	-5.8	-5.8	-5.8	-6.7	-6.7	-6.1	-6.1	-6.1	-6.1	-6.1	-6.7	-6.7	-7.2	-6.7	-6.1	-6.1
22	10	0.15	-6.7	-5.0	-4.4	-5.3	-4.4	-4.4	-4.4	-6.1	-6.1	-4.4	-4.4	-3.9	-3.9	-5.0	-5.6	-6.1	-6.7	-6.1	-6.1	-6.1
22	11	0.20	-5.0	-3.9	-2.8	-3.3	-2.5	-2.2	-2.2	-4.7	-4.7	-3.3	-3.3	-2.8	-2.8	-2.8	-4.4	-5.0	-5.6	-5.6	-5.6	-5.0
22	12	0.26	-3.3	-1.9	-1.9	-1.4	-0.6	-0.3	-0.3	-3.3	-3.3	-2.2	-2.2	-1.7	-1.7	-2.2	-3.1	-3.9	-4.4	-4.7	-4.4	-3.9
22	13	0.23	-2.8	-1.1	-0.6	-0.8	0.0	0.3	0.3	-2.2	-2.2	-0.6	-0.6	0.0	0.0	-0.6	-1.7	-2.8	-3.3	-3.9	-3.6	-2.8
22	14	0.18	-1.7	0.6	0.8	0.6	1.1	1.7	1.7	-0.6	-0.3	0.6	0.6	1.7	1.7	0.6	-0.6	-1.4	-1.7	-2.8	-2.5	-1.9
22	15	0.18	0.0	1.1	1.7	1.7	1.7	2.2	2.2	0.6	0.6	0.6	0.6	1.1	1.1	1.1	0.3	-0.6	-1.1	-1.7	-1.7	-3.6
22	16	0.16	1.1	1.1	1.1	1.4	1.7	1.9	1.9	0.6	0.8	0.3	0.3	0.6	0.6	0.6	0.6	0.0	0.0	-0.6	-0.6	0.0
22	17	0.06	0.6	0.8	0.8	0.6	1.1	1.1	1.1	0.6	0.6	0.0	0.0	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0
22	18	0.04	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.8	0.8	0.6	0.6	0.0	0.0	0.6
22	19		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
22	20		0.6	0.3	0.3	0.6	0.6	0.6	0.6	0.8	0.8	-0.6	-0.6	-0.6	-0.6	0.0	0.6	0.0	0.0	0.6	0.6	0.6
22	21		-0.6	-0.3	0.0	0.0	-0.3	-0.6	-0.6	0.3	0.0	-1.7	-1.7	-1.7	-1.7	-1.1	0.0	0.0	0.0	0.0	0.0	0.6
22	22		-2.2	-1.7	-1.4	-1.4	-1.7	-1.7	-1.7	-1.1	-0.8	-3.3	-3.9	-3.3	-3.3	-2.8	-1.1	-0.6	-0.6	0.0	-0.3	0.0
22	23		-4.4	-3.9	-3.6	-2.8	-3.3	-3.3	-3.3	-3.9	-3.6	-4.4	-4.4	-5.0	-5.0	-3.9	-2.2	-1.1	-1.1	-0.6	-1.1	-0.8
22	24		-5.6	-4.4	-4.2	-4.2	-4.4	-4.7	-4.7	-4.2	-3.9	-6.1	-6.1	-6.4	-6.4	-5.6	-3.3	-2.2	-2.2	-1.1	-1.7	-1.4

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
23	1		-7.2	-5.8	-5.8	-5.6	-5.8	-5.8	-5.8	-5.6	-5.6	-7.2	-7.2	-7.5	-7.5	-6.9	-5.0	-3.3	-2.8	-1.7	-2.2	-2.2
23	2		-8.9	-7.2	-7.2	-6.9	-7.5	-7.5	-7.5	-7.2	-7.2	-8.3	-8.3	-8.9	-8.9	-8.3	-6.1	-4.4	-3.9	-2.2	-2.8	-2.8
23	3		-10.0	-7.8	-7.8	-7.8	-8.3	-8.3	-8.3	-7.8	-7.8	-8.3	-8.3	-8.9	-8.9	-8.9	-7.2	-5.8	-5.6	-3.1	-3.9	-3.9
23	4		-10.0	-7.8	-7.5	-7.8	-8.3	-8.3	-8.3	-7.8	-7.8	-8.9	-8.9	-8.9	-8.9	-9.2	-8.3	-6.7	-6.4	-3.9	-4.4	-4.4
23	5		-8.9	-8.3	-8.1	-8.3	-8.9	-8.9	-8.9	-7.8	-7.8	-8.9	-8.9	-8.9	-8.9	-9.2	-8.9	-7.8	-7.2	-5.0	-4.7	-5.3
23	6		-8.9	-8.3	-8.3	-8.3	-8.6	-8.6	-8.6	-8.3	-8.3	-11.1	-11.1	-11.1	-11.1	-10.6	-9.4	-8.9	-8.3	-5.6	-5.6	-5.6
23	7	0.02	-11.1	-10.6	-10.6	-10.3	-10.8	-10.8	-10.8	-10.6	-10.6	-10.0	-10.0	-10.0	-10.0	-11.1	-10.0	-9.4	-8.9	-6.4	-6.7	-6.7
23	8	0.07	-11.7	-10.0	-10.0	-9.4	-9.7	-9.7	-9.7	-9.4	-9.4	-3.3	-3.9	-0.6	0.0	-8.3	-10.6	-8.9	-8.9	-7.2	-7.2	-7.2
23	9	0.24	-11.7	-6.9	-6.1	-6.7	-5.8	-5.0	-5.3	-6.1	-2.8	21.1	5.6	21.1	16.1	0.0	-6.1	-7.2	-6.7	-7.2	-6.7	-6.7
23	10	0.44	-11.7	0.0	1.7	3.3	3.3	6.9	6.9	8.3	5.6	30.0	26.7	32.2	31.7	10.0	1.1	-2.2	-0.6	-7.8	-2.5	-1.7
23	11	0.74	-11.1	5.3	7.8	10.6	11.1	14.7	15.6	22.8	19.4	31.1	25.3	37.8	30.0	15.6	8.9	4.4	6.1	-0.8	4.4	4.2
23	12	0.85	-11.1	8.9	11.4	15.0	16.1	19.2	20.6	24.4	18.9	47.8	31.1	47.8	38.3	22.8	16.1	11.1	13.3	4.2	10.0	8.9
23	13	0.87	-10.6	11.7	15.6	21.7	20.3	22.8	25.0	32.2	28.6	45.6	33.9	48.3	42.2	25.6	22.2	18.9	20.6	10.6	16.4	14.7
23	14	0.84	-10.6	11.9	16.1	21.7	20.8	22.5	25.1	32.5	37.2	42.8	32.8	43.9	40.6	24.4	23.9	21.7	23.9	16.7	21.7	18.9
23	15	0.71	-10.6	11.1	15.8	16.3	20.0	20.6	23.1	32.8	23.3	40.0	31.1	38.3	38.3	22.8	26.1	24.4	27.2	22.2	25.6	22.5
23	16	0.47	-10.6	6.1	10.6	13.3	13.3	13.3	15.6	15.6	11.7	27.2	21.7	20.6	22.2	20.0	26.7	27.8	30.0	25.0	25.0	22.8
23	17	0.22	-11.1	-0.3	6.4	6.4	7.2	5.0	6.1	4.7	12.8	5.0	11.7	3.9	6.7	9.4	22.2	26.7	28.9	25.6	22.2	20.6
23	18	0.05	-12.8	-3.1	0.0	-1.1	0.0	-2.8	-2.2	-3.3	-1.7	-3.3	-1.7	-3.9	-3.9	1.1	15.0	23.9	25.0	24.2	18.3	16.9
23	19		-14.4	-5.0	-2.5	-3.9	-3.6	-6.1	-6.1	-5.3	-3.9	-6.1	-5.0	-7.2	-7.2	-5.0	7.8	18.3	19.4	21.7	15.3	13.9
23	20		-15.6	-7.2	-5.0	-6.9	-6.7	-8.9	-8.9	-8.9	-7.8	-9.4	-9.4	-10.6	-10.6	-8.3	1.1	12.2	13.9	18.1	12.8	11.1
23	21		-16.1	-9.4	-7.8	-8.6	-9.4	-11.1	-11.1	-11.1	-10.0	-11.7	-11.7	-12.2	-12.2	-11.1	-3.9	6.1	7.8	14.2	9.4	7.8
23	22		-17.2	-12.2	-11.4	-11.7	-10.0	-11.7	-13.3	-13.1	-13.1	-13.9	-13.9	-14.4	-14.4	-13.3	-7.8	0.6	2.2	9.7	6.1	4.4
23	23		-18.3	-13.6	-12.2	-13.9	-14.4	-15.6	-15.6	-15.0	-14.7	-16.1	-16.1	-16.1	-16.7	-15.6	-11.1	-3.9	-2.2	5.0	2.8	-1.9
23	24		-18.9	-15.6	-15.0	-15.8	-16.1	-17.2	-17.2	-16.7	-15.8	-17.8	-17.8	-18.3	-18.3	-17.2	-13.9	-8.3	-6.7	0.6	-1.1	-2.5
24	1		-20.0	-16.7	-16.1	-16.7	-17.2	-17.8	-18.3	-17.2	-16.9	-18.3	-18.3	-18.9	-18.9	-17.8	-15.6	-11.1	-10.0	-3.3	-4.4	-5.6
24	2		-20.6	-18.3	-17.2	-18.3	-18.3	-18.3	-18.3	-18.3	-18.3	-19.4	-19.4	-19.4	-20.0	-18.9	-18.3	-21.7	-22.2	-6.9	-7.2	-8.3
24	3		-21.1									-21.1	-21.1	-21.1	-21.1	-20.6	-18.9	-16.1	-15.0	-10.0	-10.0	-11.1
24	4		-21.7									-21.7	-22.2	-21.7	-22.2	-21.7	-20.0	-17.2	-17.2	-12.5	-12.5	-13.3
24	5		-22.8									-22.2	-22.8	-22.2	-22.8	-22.2	-21.1	-19.4	-18.9	-14.4	-14.4	-15.3
24	6		-22.8									-23.3	-23.9	-23.3	-23.9	-23.3	-22.2	-20.6	-20.0	-16.4	-16.4	-16.7
24	7	0.02	-22.2									-23.9	-23.9	-23.9	-23.9	-23.9	-22.8	-21.1	-21.1	-17.8	-17.8	-18.9
24	8	0.25	-21.7	-17.8	-17.8	-17.8	-17.2	-16.7	-16.7	-17.8	-17.8	-20.0	-19.4	-17.8	-11.1	-21.1	-22.8	-21.7	-21.7	-17.8	-17.8	-17.8
24	9	0.52	-20.6	-10.3	-8.3	-7.8	-6.9	-3.9	-3.3	-10.8	-6.7	0.0	-7.2	5.6	5.0	-9.4	-17.8	-19.4	-18.9	-17.2	-15.8	-14.4
24	10	0.64	-18.3	-5.6	-3.1	-0.6	0.3	3.9	5.6	4.4	5.6	16.7	6.7	21.7	17.8	2.2	-8.9	-13.9	-13.3	-13.3	-8.9	-8.9
24	11	0.74	-16.1	1.1	4.4	8.3	10.0	15.0	18.3	20.6	23.3	34.4	35.0	45.6	42.2	14.4	3.3	-3.9	-2.2	-6.1	0.8	0.8
24	12	0.92	-12.8	6.7	11.9	18.3	18.9	21.1	26.4	28.3	30.0	48.9	35.0	57.2	42.2	23.3	13.3	5.6	7.8	2.2	9.7	8.3
24	13	0.90	-12.8	9.4	16.4	21.1	23.9	25.6	31.7	32.2	35.0	56.7	37.2	59.4	46.7	30.6	22.2	15.0	17.8	10.8	17.2	15.6
24	14	0.84	-11.7	11.7	18.9	23.1	26.7	26.7	32.8	26.1	39.4	54.4	37.2	63.3	48.3	34.4	29.4	23.9	26.1	18.3	23.9	20.8
24	15	0.66	-10.6	11.4	19.2	17.5	25.3	23.9	29.4	18.1	36.1	41.7	36.1	45.0	43.9	33.3	33.3	30.0	32.2	24.4	29.4	24.7
24	16	0.38	-10.0	5.6	11.7	12.2	15.6	24.4	17.2	6.7	14.4	15.0	21.1	16.7	22.8	24.4	32.8	33.3	35.0	27.2	26.7	23.6
24	17	0.24	-11.1	3.3	8.3	7.8	10.6	7.8	10.6	1.1	7.2	3.9	10.0	5.6	8.9	13.9	28.3	32.8	33.9	28.3	23.3	22.2
24	18	0.03	-12.2	-2.2	2.2	0.6	1.7	-1.1	0.0	-3.9	-2.2	-2.2	-0.6	-2.2	-2.2	3.9	20.6	28.9	30.0	27.2	19.4	18.9
24	19		-12.2	-3.1	0.3	-1.4	-0.6	-3.3	-2.8	-5.6	-3.9	-5.0	-3.9	-5.0	-5.0	-2.2	11.7	22.8	23.9	24.4	17.8	16.4
24	20		-13.9	-4.4	-1.7	-3.3	-3.3	-5.0	-4.7	-6.7	-5.6	-6.7	-6.1	-6.7	-6.7	-5.0	5.0	16.7	17.8	21.1	15.6	13.9
24	21		-14.4	-6.1	-3.9	-5.6	-5.6	-7.2	-6.9	-8.3	-7.2	-8.3	-8.3	-8.9	-8.9	-7.2	0.0	10.0	11.7	17.2	12.5	10.6
24	22		-13.9	-6.7	-5.3	-6.7	-6.7	-7.8	-7.8	-8.9	-7.8	-8.9	-8.9	-9.4	-9.4	-8.3	-3.9	4.4	6.1	12.8	9.4	7.8
24	23		-13.3	-7.8	-6.7	-7.8	-13.9	-8.9	-8.9	-10.0	-8.9	-10.6	-10.6	-10.6	-10.6	-9.4	-6.7	-0.6	1.1	8.9	6.1	5.0
24	24		-12.8	-8.9	-7.8	-8.9	-9.2	-9.7	-9.7	-10.0	-9.7	-10.6	-10.6	-10.6	-10.6	-10.0	-7.8	-3.3	-2.2	4.4	3.3	1.7

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
25	1		-12.8	-11.1	-10.6	-11.1	-11.9	-12.2	-12.2	-11.7	-11.7	-12.2	-12.2	-12.2	-12.2	-11.1	-8.9	-6.1	-5.0	0.6	-0.3	-1.4
25	2		-13.3	-13.3	-12.5	-13.3	-13.9	-14.4	-14.4	-13.3	-13.3	-13.9	-13.9	-13.9	-13.9	-13.3	-10.6	-7.8	-7.2	-2.5	-3.3	-3.9
25	3		-14.4	-15.6	-15.3	-15.8	-16.7	-16.7	-16.7	-16.7	-16.1	-17.2	-17.2	-16.7	-16.7	-15.6	-12.2	-10.0	-9.4	-5.6	-6.1	-6.7
25	4		-15.6	-17.2	-17.2	-17.2	-17.8	-18.3	-17.8	-17.8	-17.8	-18.3	-18.3	-17.8	-18.3	-17.2	-14.4	-11.7	-11.1	-7.8	-8.3	-8.9
25	5		-15.6									-20.0	-20.0	-19.4	-20.0	-18.9	-16.1	-13.3	-13.3	-10.0	-10.3	-11.1
25	6		-16.7									-20.0	-20.0	-20.0	-20.6	-20.0	-17.8	-15.0	-15.0	-11.9	-12.2	-12.8
25	7	0.02	-20.0									-22.2	-22.8	-21.7	-22.2	-21.7	-19.4	-16.7	-16.7	-13.9	-14.2	-14.7
25	8	0.16	-20.0	-17.2	-16.9	-16.7	-16.7	-15.8	-15.8	-19.4	-18.3	-18.3	-18.3	-17.2	-14.4	-20.0	-20.0	-17.8	-17.2	-15.0	-15.0	-14.7
25	9	0.40	-17.2	-10.8	-9.4	-8.6	-7.8	-5.0	-5.0	-6.1	-10.8	1.7	-7.8	4.4	0.0	-10.0	-16.7	-17.2	-16.1	-14.4	-13.3	-12.5
25	10	0.62	-13.3	-3.3	-1.7	0.6	2.2	6.7	7.2	16.1	0.0	24.4	5.0	28.9	17.8	2.8	-8.9	-12.8	-11.7	-11.1	-7.2	-6.7
25	11	0.82	-10.6	5.0	8.3	11.1	13.3	17.8	21.1	28.3	10.0	42.8	17.8	46.7	32.8	16.1	1.7	-5.0	-3.3	-5.0	2.2	1.7
25	12	0.89	-8.9	10.0	15.6	20.0	21.1	25.6	29.4	41.7	14.7	54.4	26.1	57.2	41.1	27.2	13.3	5.0	6.1	1.7	10.0	9.4
25	13	0.92	-7.2	13.3	18.9	25.6	25.8	29.4	33.3	46.7	18.9	62.8	30.0	61.7	46.7	33.3	22.8	14.4	15.6	9.4	17.2	15.6
25	14	0.85	-5.0	16.1	21.1	26.7	27.8	31.1	34.4	49.4	23.9	61.7	36.1	70.0	51.1	37.2	30.6	23.9	25.0	17.2	23.3	21.7
25	15	0.71	-5.0	15.6	21.1	26.7	27.2	28.9	32.8	43.3	22.8	54.4	35.0	56.7	45.6	36.7	35.6	31.7	33.3	23.9	27.2	25.6
25	16	0.40	-3.3	12.8	18.3	20.0	21.7	21.7	23.9	36.1	19.4	38.9	27.8	32.8	30.6	29.4	36.1	35.6	37.2	28.3	30.0	27.2
25	17	0.25	-5.0	6.1	11.1	11.4	12.2	11.1	12.8	7.8	11.7	11.7	13.9	11.1	12.8	18.9	31.7	36.7	37.2	30.0	27.9	25.6
25	18	0.04	-6.1	2.8	7.2	5.6	6.7	3.9	4.4	2.8	3.9	2.2	3.9	2.2	2.2	9.4	25.0	33.3	34.4	30.6	24.7	23.1
25	19		-7.8	0.0	3.9	1.7	2.8	-0.6	0.0	-1.1	-0.6	-1.7	-0.6	-2.2	-2.2	2.2	16.7	27.8	28.9	28.9	22.2	20.6
25	20		-10.0	-1.7	1.1	-1.1	-0.6	-2.8	-2.8	-6.1	-2.2	-4.4	-3.6	-5.0	-5.0	-2.2	10.0	21.7	22.8	25.6	19.4	17.8
25	21		-10.6	-3.3	-1.1	-3.3	-3.3	-5.0	-5.0	-5.6	-4.4	-6.1	-5.6	-6.9	-6.9	-5.0	3.3	15.0	16.7	21.7	16.7	14.7
25	22		-11.1	-5.0	-2.8	-5.6	-5.6	-7.2	-7.2	-6.9	-6.1	-7.8	-7.8	-8.3	-8.6	-7.2	-1.1	8.9	10.6	17.8	13.3	11.1
25	23		-11.1	-7.2	-6.1	-7.8	-7.8	-8.9	-8.9	-8.9	-8.3	-9.4	-9.4	-10.0	-10.0	-8.9	-4.4	3.9	5.6	12.8	10.0	7.8
25	24		-11.7	-8.3	-7.8	-8.9	-9.4	-10.0	-10.0	-9.4	-8.9	-10.6	-10.6	-11.1	-11.1	-10.0	-6.7	-0.6	1.1	11.1	6.1	4.4
26	1		-12.2	-8.3	-7.8	-8.9	-9.4	-10.0	-10.0	-9.4	-9.2	-10.6	-10.6	-10.6	-10.6	-10.6	-8.9	-3.9	-2.8	4.4	3.3	1.7
26	2		-11.7	-9.4	-9.4	-9.7	-10.6	-10.8	-10.8	-10.0	-9.4	-11.1	-11.1	-11.1	-11.1	-10.6	-9.4	-6.7	-5.6	0.6	0.0	-1.1
26	3		-11.7	-10.6	-10.0	-10.6	-11.1	-11.7	-11.7	-10.6	-10.6	-11.7	-11.7	-11.7	-11.7	-11.1	-10.3	-7.8	-7.2	-2.8	-2.8	-3.9
26	4		-11.7	-10.6	-10.6	-11.1	-11.7	-11.7	-11.7	-10.6	-10.6	-11.9	-11.9	-11.9	-11.9	-11.7	-11.1	-9.4	-8.9	-5.0	-5.0	-5.6
26	5		-11.7	-11.1	-11.1	-11.4	-11.9	-11.9	-11.9	-11.7	-11.7	-11.9	-11.9	-11.9	-11.9	-12.2	-11.7	-10.3	-10.0	-6.7	-6.7	-7.2
26	6		-11.1	-11.1	-11.1	-11.4	-11.9	-11.9	-11.9	-11.1	-11.1	-11.7	-11.7	-11.7	-11.7	-11.7	-11.7	-10.6	-10.6	-8.3	-8.3	-8.3
26	7	0.02	-11.1	-11.1	-11.1	-11.1	-11.7	-11.7	-11.7	-11.1	-11.1	-11.4	-11.4	-11.7	-11.7	-11.7	-11.7	-11.1	-11.1	-9.2	-9.2	-9.2
26	8	0.14	-10.0	-8.3	-7.8	-8.3	-7.8	-7.8	-7.8	-9.4	-7.8	-10.0	-7.2	-8.9	-3.3	-10.3	-11.7	-11.1	-11.1	-9.4	-8.9	-8.9
26	9	0.38	-7.2	-2.8	-1.7	-1.1	-0.6	1.7	1.7	3.9	-2.8	2.8	-0.6	9.4	4.4	-3.3	-8.3	-9.4	-8.9	-8.3	-7.2	-6.1
26	10	0.38	-7.2	-1.1	1.1	1.7	2.8	5.0	5.0	6.7	-1.1	10.0	1.1	15.0	6.1	4.4	-2.8	-5.8	-5.6	-5.6	-3.3	-2.8
26	11	0.12	-7.2	-3.3	-2.2	-2.2	-1.1	-0.6	0.0	1.7	-2.2	3.3	-2.5	5.6	0.0	0.6	-0.6	-2.8	-2.8	-3.9	-2.8	-2.8
26	12	0.86	-6.1	10.6	14.4	15.6	17.8	21.1	23.3	29.4	9.4	38.9	15.6	42.8	27.8	13.9	5.0	1.7	2.2	0.6	6.7	6.7
26	13	0.96	-1.7	13.5	18.9	22.2	22.8	27.2	29.4	35.0	14.4	47.2	22.8	49.4	36.1	22.8	13.9	9.4	10.6	6.7	14.4	12.8
26	14	0.85	-0.6	16.7	21.1	24.4	26.1	29.4	31.1	42.2	19.4	52.8	28.9	58.3	43.9	31.1	22.2	17.2	18.3	13.3	20.6	18.3
26	15	0.70	0.0	16.1	21.1	23.9	25.6	28.3	30.0	40.0	20.0	50.0	30.0	53.3	39.4	32.2	28.3	24.4	22.8	19.4	25.0	22.8
26	16	0.48	0.0	14.4	18.3	20.6	22.2	22.8	24.4	33.9	18.9	37.2	25.0	32.2	28.6	28.3	30.6	28.9	30.0	23.9	27.2	24.4
26	17	0.24	-1.7	10.0	13.9	13.5	15.0	14.4	15.0	13.3	18.9	16.1	18.3	13.9	16.1	20.0	28.9	30.6	12.8	26.7	26.1	23.9
26	18	0.04	-2.2	5.3	8.9	7.8	8.3	6.1	6.7	5.0	5.6	5.3	6.1	5.0	5.3	11.1	23.9	28.9	0.0	26.7	22.8	21.7
26	19		-3.3	3.9	6.7	5.6	6.1	3.3	3.9	3.3	4.4	3.3	3.9	2.5	2.5	11.1	17.2	25.0	-2.8	25.6	20.6	19.4
26	20		-4.4	2.2	5.0	2.8	3.3	1.1	1.1	1.1	1.7	0.6	0.6	0.0	0.0	2.2	11.1	20.6	-4.4	23.3	18.9	17.2
26	21		-4.4	1.7	3.3	1.7	1.7	0.0	0.0	0.0	1.1	-0.6	-0.6	-1.4	-1.1	0.0	6.7	15.0	-4.4	20.6	16.1	15.0
26	22		-4.4	1.1	2.8	0.6	0.6	-0.6	-0.6	-0.6	0.0	-1.1	-1.1	-1.7	-1.7	-1.1	3.3	10.6	12.2	17.2	13.9	12.8
26	23		-4.4	0.0	1.1	-0.3	-0.6	-1.4	-1.4	-1.1	-0.6	-2.2	-2.2	-2.2	-2.2	-1.7	1.1	6.7	8.3	13.9	11.7	10.0
26	24		-4.4	-1.1	-0.6	-1.1	-1.7	-2.2	-2.2	-2.2	-1.7	-2.8	-2.8	-2.8	-2.8	-2.2	-0.6	3.3	5.0	10.6	8.9	7.8

TABLE F. CONTINUED

PYRANOMETER (PYR) READINGS, CAL/SQ-CM-MIN, AND TEMPERATURES, C, AT LOCATION NUMBER

DAY (FEB 79)	HR	PYR	AMB	4	5	6	7	8	9	11	12	13	14	15	16	17	18	19	20	22	23	24
27	1		-4.4	-1.7	-1.7	-2.2	-2.2	-2.8	-2.8	-2.2	-2.2	-3.3	-3.3	-3.3	-3.3	-2.8	-1.7	1.1	2.2	7.2	6.4	5.6
27	2		-2.2	-1.7	-1.7	-1.9	-2.2	-2.5	-2.5	-1.7	-1.7	-2.8	-2.8	-2.8	-2.8	-2.8	-2.2	-0.6	0.6	4.4	4.4	3.9
27	3		-3.3	-2.2	-2.2	-2.2	-2.8	-2.8	-2.8	-2.8	-2.8	-2.5	-2.5	-2.5	-2.5	-2.2	-2.2	-1.1	-0.6	2.8	2.8	2.2
27	4		-4.4	-2.8	-2.8	-2.8	-3.3	-3.3	-3.3	-3.1	-3.1	-3.3	-3.3	-3.3	-3.3	-3.3	-2.8	-2.2	-1.7	1.1	0.6	0.6
27	5		-3.9	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.3	-3.9	-3.9	-3.9	-3.9	-3.3	-2.8	-2.5	-2.2	-0.3	-0.3	-0.6
27	6		-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.3	-2.8	-2.8	-1.4	-1.4	-1.1
27	7	0.02	-3.3	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-1.7	-1.7	-1.7	-1.7	-4.4	-3.9	-3.3	-3.3	-2.2	-2.2	-1.9
27	8	0.11	-3.3	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	-2.2	0.0	-2.8	-2.2	-1.7	-3.9	-3.9	-3.3	-3.3	-2.2	-2.2	-1.9
27	9	0.24	-2.8	0.0	0.6	0.3	1.1	1.7	1.7	165.6	154.4									-2.2	-1.7	-1.1
27	10	0.44	0.0	3.9	5.0	6.1	6.7	8.3	8.3	6.1	3.3									-1.1	0.6	1.1
27	11	0.60	0.0	8.9	11.1	12.2	12.8	16.1	16.7	13.3	8.9									1.7	4.4	5.6
27	12	0.62	0.6	8.9	11.1	12.8	13.3	16.1	16.7	9.4	8.9									4.4	6.7	7.2
27	13	0.57	1.1	7.8	8.9	10.0	11.1	12.8	12.8	6.1	7.2									6.7	7.8	8.3
27	14	0.57	1.7	8.3	11.1	11.7	12.8	13.9	14.4	6.7	7.2									8.9	8.9	9.7
27	15	0.45	1.1	7.8	10.0	10.6	11.1	12.2	12.2	6.1	7.2									10.0	10.0	10.6
27	16	0.21	1.1	5.6	7.2	7.8	7.8	7.8	8.3	3.9	5.0									10.6	9.4	10.0
27	17	0.16	0.0	4.4	6.1	6.1	6.1	6.1	6.1	3.3	3.9	4.2	4.4	4.7	4.7	6.4	10.6	11.7	7.2	10.8	9.4	9.4
27	18	0.03	0.0	3.3	4.4	4.4	3.9	3.6	3.6	2.2	2.8	2.8	3.3	3.1	3.1	4.4	8.6	10.6	7.8	10.6	8.9	8.9
27	19		0.0	0.0	0.6	2.8	0.6	0.0	0.0	-1.1	-0.6	1.7	1.7	1.7	1.7	3.1	6.1	8.9	2.8	10.0	8.3	5.6
27	20		0.0	2.2	2.6	2.2	2.2	1.7	1.7	1.1	1.7	1.1	1.1	1.1	1.1	2.2	4.4	7.2	4.4	8.9	7.2	7.2
27	21		-0.6	1.7	2.2	1.7	1.7	1.1	1.1	1.1	1.7	1.1	1.1	1.1	1.1	1.7	3.3	5.6	3.3	7.8	6.7	6.1
27	22		-1.1	1.1	1.7	1.1	0.6	0.6	0.6	0.6	0.6	0.3	0.3	0.6	0.3	1.1	2.2	3.9	2.2	6.9	5.6	5.6
27	23		-1.1	0.0	0.6	0.6	0.0	0.0	0.0	0.0	0.0	-0.6	-0.6	-0.6	-0.6	0.6	1.7	3.3	2.2	5.0	4.4	4.4
27	24		-4.4	-1.7	-1.7	-1.7	-1.7	-1.7	-1.7	-2.2	-2.2	-2.8	-2.8	-2.2	-2.8	-1.1	0.6	1.7	-0.6	3.9	3.3	2.8
28	1		-5.6	-3.9	-3.3	-3.3	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-3.9	-2.8	-0.6	0.6	-2.2	2.8	2.2	1.7
28	2		-5.6	-3.9	-3.3	-3.3	-3.9	-3.9	-3.9	-3.9	-3.9	-4.4	-4.4	-3.9	-4.4	-3.3	-1.7	-0.6	-2.8	1.7	1.1	0.6
28	3		-6.1	-4.4	-4.4	-4.2	-4.4	-4.4	-4.4	-5.0	-4.4	-5.0	-5.0	-4.7	-5.0	-4.4	-2.8	-1.7	-3.3	0.6	0.0	-0.6
28	4		-6.7	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-5.0	-2.2	-2.8	-1.9	-2.2	-4.7	-3.9	-2.2	-5.0	-0.6	-1.1	-1.1
28	5		-7.2	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-6.1	-6.1	-6.1	-6.1	-5.8	-6.1	-5.6	-4.4	-0.6	-2.2	-1.7	-1.7	-2.2
28	6		-8.3	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.7	-6.1	-6.7	-6.7	-6.7	-6.7	-5.8	-5.0	-1.1	-6.1	-2.8	-2.8	-2.8
28	7	0.02	-8.9	-6.7	-6.7	-6.7	-6.7	-6.7	-6.7	-7.2	-7.2	-6.7	-7.2	-6.7	-6.7	-6.7	-5.6	-5.0	-6.7	-3.3	-3.9	-3.9
28	8	0.04	-8.9	-7.2	-6.7	-6.9	-6.7	-6.7	-6.7	-7.2	-7.2	-7.2	-7.2	-7.2	-7.2	-6.7	-6.1	-5.6	-6.7	-4.4	-4.4	-4.4
28	9	0.10	-8.9	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.7	-6.7	-6.7	-6.7	-6.1	-6.1	-6.4	-6.1	-5.6	-6.1	-4.4	-4.4	-4.4
28	10	0.20	-8.9	-5.6	-5.0	-4.4	-4.4	-3.9	-3.9	-5.6	-5.6	-4.4	-5.6	-5.0	-4.4	-5.6	-5.6	-6.1	-5.6	-4.4	-4.4	-3.9
28	11	0.25	-8.3	-3.9	-3.3	-3.3	-2.8	-1.7	-1.7	-3.9	-3.3	-2.8	-3.3	-2.2	-2.2	-3.9	-5.0	-5.6	-5.0	-3.9	-3.3	-3.3
28	12	0.26	-8.3	-3.9	-3.3	-2.8	-2.2	-1.7	-1.7	-2.8	-3.3	-3.3	-3.3	-2.2	-2.2	-2.8	-3.9	-4.4	-3.9	-3.9	-3.3	-2.8
28	13	0.40	-7.2	-1.1	-0.6	0.0	1.1	2.8	2.2	-1.7	-1.1	-1.1	-0.6	1.1	1.1	-0.6	-2.2	-3.3	-2.2	-2.8	-2.2	-1.1
28	14	0.43	-7.2	1.1	2.2	2.8	3.9	6.1	6.1	0.0	0.6	1.1	1.7	3.3	3.9	1.1	-0.6	-2.2	-2.2	-1.7	-0.6	0.0
28	15	0.37	-7.2	-0.6	0.6	1.1	1.7	3.3	3.3	-1.1	-1.1	0.0	0.6	1.7	1.7	2.2	1.7	0.0	-0.6	-0.6	0.0	0.6
28	16	0.21	-6.7	-2.2	-1.1	-0.6	-0.6	0.0	0.0	-2.2	-2.2	-1.7	-1.7	-0.6	-0.6	0.6	1.7	0.6	-0.6	0.0	0.0	0.6
28	17	0.14	-7.2	-3.3	-2.2	-1.7	-1.7	-1.1	-1.1	-2.8	-2.8	-2.2	-1.7	-1.7	-1.7	-0.6	1.7	1.1	-3.3	0.0	0.0	0.6
28	18	0.04	-7.8	-4.4	-4.4	-3.9	-3.9	-3.9	-3.9	-5.0	-4.4	-4.7	-4.7	-4.4	-4.7	-2.8	0.3	0.6	-4.4	0.6	-0.6	-0.6
28	19		-7.8	-5.0	-4.4	-4.4	-4.4	-5.0	-5.0	-3.9	-3.9	-4.4	-4.4	-4.4	-4.4	-3.9	-4.4	0.0	-5.0	0.0	-1.1	-1.1
28	20		-7.8	-5.6	-5.6	-5.0	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.6	-5.0	-2.8	-1.1	-5.6	-0.6	-1.7	-1.7
28	21		-7.8	-5.8	-5.8	-5.6	-5.8	-5.8	-5.8	-5.8	-5.8	-5.6	-5.6	-5.6	-5.6	-5.6	-4.4	0.0	-5.6	-1.1	-2.2	-2.2
28	22		-6.7	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.7	-6.7	-6.7	-6.7	-6.1	-5.0	-3.3	-5.6	-2.2	-2.8	-2.8
28	23		-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.1	-6.7	-6.7	-6.7	-6.7	-6.7	-5.6	-4.4	-5.6	-2.8	-3.3	-3.3