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U.S. DEPARTMENT OF COMMERCE / National Bureau of Standards

Retrofitting a Residence for Solar Heating and Cooling: The Design and Construction of the System

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[2] Located at Boulder, Colorado 80302.

Retrofitting a Residence for Solar Heating and Cooling: The Design and Construction of the System

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TABLE OF CONTENTS

Retrofitting a Residence for Solar Heating and Cooling-
The Design and Construction of the System

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ABSTRACT

During 1972 and 1973, the National Bureau of Standards conducted controlled laboratory tests on a factory-built four-bedroom house having a floor area of 110 m^2 (1200 ft^2) equipped with a conventional gas furnace and central electric air conditioner incorporated into a forced air distribution system. During 1974, the house was moved onto the NBS grounds and a solar heating and cooling system was designed to be added to the house. Calculations have been made to show that more than 75% of the yearly energy needs for heating, cooling, and supplying domestic hot water could be obtained from the sun.

This report deals with the design and construction of the retrofitted system. It consists of 45 m^2 (485 ft^2) of double-glazed, flat-plate solar collector, 5.7 m^3 (1500 gallons) of water storage, and a 10,000 W (3 ton) lithium bromide absorption air cooling unit.

Key Words: Retrofitted solar residence; solar collector; solar heating and cooling system; solar-powered absorption refrigeration.

1. Introduction

In order to study energy usage in residential buildings and to experimentally verify computer programs that have been constructed for calculating heating and cooling loads and energy requirements in buildings, the National Bureau of Standards purchased a factory-produced four-bedroom house. During 1972, it was installed in a high-bay-environmental laboratory of approximately 2000 m^3 (70,000 ft^3) in volume and tested under simulated summer and winter conditions. Later it was moved to a site on the NBS grounds in Gaithersburg, Maryland and tested under actual weather conditions. References [1] and [2] give the details of the testing that was done prior to the beginning of the calendar year 1974. The purpose of this report is to give the details of the design of a solar heating and cooling system that was added to the house during the latter part of 1974.

During the thirty years prior to 1970, there were twenty to thirty buildings built around the world designed to utilize solar energy for partially or totally heating the building space. Some of the buildings that were parts of well-documented experiments are described in references [3-10]. During the 1970's there has been an increased emphasis in exploring the utilization of solar energy in buildings. Reference [11] is one of the most up to date surveys of current activity and in it are described 135 buildings past and present that are now using or will shortly use solar energy for heating and/or cooling.

Almost all of these 135 buildings have been designed and constructed to be solar equipped. The present research project was conceived to determine the feasibility of adding solar heating and cooling components to a house that had originally been designed to operate with a conventional system. In addition, this is one of the first studies in which the same building will have been tested with both a completely conventional system as well as an integrated solar system.

The specific objectives of the present study are as follows:

1. To design a fully automated and instrumented "state-of-the-art" solar heating and cooling system that can effectively be integrated with the existing heating and cooling system of the NBS four-bedroom test house.

2. To construct, test, and document the system performance under typical winter and summer weather conditions for Washington, D.C.

3. To determine the fraction of the energy supplied by the auxiliary and solar components respectively and project the savings in fossil fuels on a yearly basis.

4. To fully document the economic implications of utilizing solar energy in this manner.

2. Description of the Test House

The test house has approximately 110 m^2 (1200 ft^2) of floor area and is of modular design and lightweight (wood) construction. The house would typically be the end dwelling unit of a row of townhouses at a field site. The house is shown in Figure 1 at its present location on the NBS campus. A series of wooden racks are shown added to the roof of the house which now hold the solar collector modules (not shown).

Two modules compose the first floor and contain the kitchen, dining area, utility room, living area and two bedrooms separated by a full bath. A floor plan of the first floor is shown in Figure 2. The second floor module contains two bedrooms and a second full bath with a stairway from the kitchen to the hallway connecting the bedrooms. A floor plan of the second floor is given in Figure 3. The floors of the living area, dining area, and the four bedrooms are carpeted. All other floor areas are finished with asphalt tile. Construction details of the test house are given in Table 1. As received from the factory, the house was equipped with a refrigerator, an electric stove, an 0.3 m^3 (80 gallon) electric hot water heater, a gas-fired forced air furnace system with a central electric air conditioner.

The windows consist of brown anodized aluminum frames and sash, with window panes, storm windows, and screens. The thickness of the glass panes and air space are 0.32 cm (1/8 in.) and 0.48 cm (3/16 in.), respectively. The total window area is 12.7 m^2 (137 ft^2) or approximately 11.8 percent of the floor area. The double-wide front door contains two insulating glass sheets. The rear door is solid wood.

The conventional equipment supplied for heating, cooling, and air distribution is located in the left side of the living area closet on the first floor and consists of a gas-fired furnace, evaporator coil, and forced air blower. The furnace is rated at input and output capacities of 22,000 W (75,000 Btu/h) and 17,600 W (60,000 Btu/h), respectively. The vapor compression air conditioning unit has a listed capacity of 7000 W (2 tons). The condensing unit is located in an interior cabinet under the kitchen window with the outdoor coil projecting through the wall.

The air distribution system consists of a common return located in the hallway between the living room and the utility closet. A circulating blower forces air through the gas furnace into the distribution ducts.

Since interior furnishings have an effect on the thermal behavior of a structure, the test house if fully furnished with 1500 kg (3300 lbs.) of furniture, draperies, and other household accessories and appliances.

3. Design of the Solar Heating and Cooling System

In designing the solar energy system for the NBS test house to accomplish the objectives of the study, specific design criteria for the system and components were established:

1. The system must
   a. utilize an existing forced air distribution system,
   b. utilize solar components that are commercially available,
   c. provide a comfort level fully equal to that obtainable with the conventional system, and
   d. supply greater than 75% of the energy needs for the house for heating, cooling, and the heating of domestic water.

2. The solar components must
   a. have a predictable performance,
   b. be reliable, durable, and safe,
   c. have a minimum cost without jeopardizing performance, and
   d. be easily replaced for repair or testing with other components.

Based on these design criteria, the system as depicted in Figure 4 was designed. The primary components are 45 m^2 (485 ft^2) of PPG Industries'* prototype flat-plate solar collector, a water to air heat exchanger mounted in the furnace plenum, 1.9 m^3 (500 gallon) and 3.8 m^3 (1000 gallon) water storage tanks, and a 10,000 W (3 ton) lithium-bromide absorption air cooling unit. An ethylene glycol-water solution will be used as the heat transfer fluid throughout the system. A small cooling tower is required in conjunction with the absorption

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* Identification of commercial products does not imply recommendation or endorsement by the National Bureau of Standards.

refrigeration machine. In addition, an electric water boiler is to be used as the auxiliary energy source and a small preheater (heat exchanger and 0.3 m^3 (80 gallon) tank) will be used to preheat city water prior to putting it into the conventional electric water heater installed in the house.

The system has been designed to be as flexible as possible allowing operation in 20 to 30 different modes. Figure 5 shows the detailed piping diagram for the system including all valves and pumps. Figure 6 through 16 have been included to show the operation of the system in several of the modes.

Figures 6, 7, and 8 show the system operating in the space heating mode where the source of the energy is the solar collector (Figure 6), the small storage tank (Figure 7), and the large storage tank (Figure 8), respectively. In each case, the fluid is shown passing through the auxiliary boiler. The boiler could be on or off. Therefore, the flow diagram would be identical for the three additional operational modes where the electric boiler was being used to supplement the three primary energy sources.

Figures 9 and 10 show the system again in the space heating mode where the two storage tanks are operated in series (Figure 9) or parallel (Figure 10). The series operation could prove beneficial in creating an artificial condition of "thermal stratification" whereby the hottest fluid is in the small storage tank and used for space heating.

Figure 11 shows the system in the space heating mode where the auxiliary energy source is the only source in the system. Isolating the storage tanks from the "loop" in this mode eliminates the use of auxiliary energy for "charging" the storage tanks, a wasteful and inefficient use of such energy.

Figures 12 and 13 show the system in the space heating mode where one or the other of the storage tanks are used in series with the solar collector array. The fluid is drawn from the tanks, heated by the solar collector and then passed through the water-to-air heat exchanger.

Figure 14 shows the system operating in the space cooling mode where the energy source for the absorption air cooler is the solar collector array. Diagrams similar to Figures 7 through 13 could also be shown for space cooling where the various combinations of solar collector, auxiliary boiler, and two storage tanks are used.

Figure 15 shows the system operating in a mode where the solar collector is being used to preheat the domestic hot water. In Figure 16, the solar collector is being used to "charge" the small storage tank.

From the above description, it is obvious that the solar heating and cooling system has been designed for operational flexibility. One of the primary objectives will be to experimentally examine the feasibility and relative efficiency of these various modes.

Solar Collectors

Based on the projected needs for a heated fluid to heat the supply air and also to "drive" an absorption refrigeration unit, a purchase specification was written for modular solar collectors and was distributed by the Department of Commerce on a request for proposal basis. The specification is given in Appendix A. Five proposals were received and the quoted prices ranged from \$69 per m^2 (\$6.40 per ft^2) to \$1500 per m^2 (\$140 per ft^2).

The collector that was selected is manufactured by PPG Industries* and its price was \$69 per m^2 (\$6.40 per ft^2). It is a flat-plate collector with two cover glasses and 0.076 m (3 in.)

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of fiberglass insulation attached to the back. The experimental and theoretical thermal efficiencies of the collector are compared in Figure 17. More detailed technical specifications are given in reference [12].

This collector is normally available with a metal pan enclosing the back insulation. NBS purchased the collectors without the pan; however, prior to placing the collectors on the roof of the house, pans were added by NBS personnel.

The absorber of the collector is an aluminum ROLL BOND* panel that is painted with a high quality black paint and consequently the absorbing surface is nonselective (properties are given in reference [12]). Part of the contract with PPG Industries calls for them to supply NBS in the summer of 1975 with another set of collector modules of identical construction except for the addition of a selective surface which minimizes the emission of long wavelength radiation from the absorbing surface. As part of the research program, operational data will be obtained during two cooling seasons with both types of collectors.

Air Cooling Unit

There are several ways in which solar energy can be used for providing space cooling. Attention is being given to the study of rock bed regenerative cooling at CSIRO in Australia [13], the use of desiccants in general [14, 15], and the use of an expansion engine with compression cooling [16-22]. However, the most intensive work in the solar energy field has been done with absorption refrigeration machines at the University of Wisconsin [23, 24], the University of Florida [25, 26], and in Australia [27-29]. Based on these studies and the potential availability of absorption cooling machines, a 10,000 W (3 ton) lithium bromide absorption unit manufactured by Arkla Industries** was selected. The machine was modified at the factory to utilize hot water (instead of natural gas) as the source of energy. It should also be noted that this machine is currently being used in residential solar cooling experiments at Colorado State University [30], at NASA Marshall Space Flight Center [31], by the Honeywell Corporation in Minneapolis, Minnesota [32], at Ohio State University [33], and in the "Decade 80" house built in Tucson, Arizona by the Copper Development Association [34].

In a typical absorption refrigeration machine, a solution of refrigerant and absorbent, which have a strong chemical affinity for one another, are heated in a device called the generator. This drives the refrigerant out of the solution. The refrigerant vapor is then cooled until it condenses and can be passed through an expansion valve into the "low pressure" side of the system. At this low pressure, the refrigerant vaporizes (in the evaporator) and absorbs energy from the environment (the cooling effect). The vaporized refrigerant is then recombined with the abosrbent mixture from which it was initially obtained. The mixture then moves back to the generator on the "high pressure" side of the system and the cycle continues.

Figure 18 is a schematic diagram of the absorption unit being used in this experiment. The system is charged with lithium bromide and water, the water being the refrigerant and the lithium bromide solution being the absorbent. The entire unit operates under a vacuum at all times. The absolute pressure within the generator and condenser is of the order of 6700 to 8000 N/m^2 (50 to 60 mm of Hg) absolute.

With reference to Figure 18, the generator contains a solution of lithium bromide in water. As heat is applied in the heat exchanger of the generator, it causes the refrigerant (water) to be boiled off. As this water vapor is driven off, the absorbent solution is raised by vapor lift action through tube (2) into the separating chamber (3). Here the refrigerant vapor rises through tube (4) to the condenser, and the absorbent solution flows be gravity through tube (6), through the heat exchanger, and then to the absorber. This circuit will be described in more detail; the refrigerant circuit will be described first.

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* ROLL BOND process patented by Olin Brass, East Alton, Illinois.

** Identification of commercial products does not imply recommendation or endorsement by the National Bureau of Standards.

After the refrigerant (water vapor) passes from the separating chamber to the condenser through tube (4), it is condensed to a liquid by the action of cooling water flowing through the condenser tubes. The cooling water is brought from an external source (a cooling tower in this case).

The refrigerant vapor thus condensed to water within the condenser then flows through tube (5) into the cooling coil. Tube (5) contains a restriction which offers a resistance and therefore a pressure barrier to separate the slightly higher absolute pressure in the condenser from the lower pressure within the cooling coil. The high vacuum within the evaporator (cooling coil) lowers the boiling temperature of water sufficiently to allow evaporation to occur within the coil. The cooling coil is constructed with finned horizontal tubes over which the air to be cooled is blown. The heat of evaporation for the refrigerant is extracted from the air stream, and the cooling and dehumidifying are accomplished.

In the absorber, the solution absorbs the refrigerant vapors which are formed in the evaporator directly adjacent. To explain the presence of the absorbent, it is necessary to divert attention back to the generator. The absorbent was separated from the refrigerant by boiling action. The absorbent then drains from the separator (3), down to the liquid heat exchanger, and thence to the absorber through tube (8). The flow of solution in this circuit can actually exist by gravity action alone, because the absorber is slightly below the level of the separating chamber. It is also aided by the pressure difference existing between the separator and the absorber.

The absorber is a cylindrical shell which contains a coil through which cooling water is circulated. The solution flowing into the top of the absorber is distributed over the entire outside surfaces of the coil so that a maximum area of absorbent solution is exposed to the refrigerant vapor which is flowing into this chamber from the evaporator.

It must be understood at this point that cool lithium bromide in either dry or solution form has a very strong affinity for water vapor. It is because of this principle that the refrigerant vapor is absorbed back into solution again. The rate of absorption is increased at lower temperatures; therefore, a cooling water coil has been provided within the absorber shell. The resultant mixture of refrigerant and absorbent drains back through the heat exchanger through tube (9), to the refrigeration generator where it is again separated into its two component parts by boiling action, to repeat the cycle.

The air conditioning unit is rated at 10,000 W (36,000 Btu/h) of cooling when the fluid enters the generator at 99 °C (210 °F) and 6.9×10^{-4} m^3/s (11 gal/min) and the cooling tower water enters the condenser at 29 °C (85 °F) and 6.3×10^{-4} m^3/s (10 gal/min). Figure 19 shows how the performance is expected to vary as a function of outdoor air wet-bulb temperature and temperature of fluid entering the generator. Due to the absence of a mechanical pump from the generator by vapor lift action, the unit cannot be operated at less than 60% capacity. Below this condition, vapor formation occurs at a rate too low for effective lifting of the solution. The concentration would then increase to the crystallization point.

Water Cooling Tower

In order to match the capacity of the air conditioning unit, the cooling tower must be able to reject 27,000 W (91,000 Btu/h) with water entering the tower at 6.3×10^{-4} m^3/s (10 gal/min). A 28,000 W (8 ton) cooling tower was selected. It weighs approximately 186 kg (410 pounds) and measures 0.79 m (31 in.) wide, 1.55 m (61 in.) long and 1.4 m (55 in.) high. The tower is designed for water flow rates of 1×10^{-3} to 1.7×10^{-3} m^3/s (16 to 27 gal/min).

Thermal Storage

Conventional steel pressure-tested tanks were selected as the means for storing the solar heated fluid in the system. The tanks have a design pressure of 6.9×10^5 N/m^2 (100 psi) and were pressure tested to 10.3 x 10^5 N/m^2 (150 psi). They have no interior baffling installed and are unlined. The 1.9 m^3 (500 gallon) tank weighs approximately 485 kg (1070 pounds), has an outside diameter of 0.9 m (3 ft), and is 3.1 m (10 ft) in length. The 3.8 m^3 (1000 gallon) tank weighs approximately 4853 kg (2400 pounds), has an outside diameter of 1.1 m (3.5 ft), and is 4.3 m (14 ft) in length. After the tanks were installed, they were insulated with approximately 0.1 m (4 in.) of fiberglass insulation.

Water-to-Air Heat Exchanger

The finned-tube heat exchanger incorporated into the duct-work of the distribution system has a face area of 0.31 m (12 in.) by 0.56 m (22 in.) and consists of six rows of 0.016 m (5/8 in.) outside diameter finned copper tubes. The fins are 0.0002 m (0.008 in.) aluminum and spaced at 354 fins/m (9 fins/in.). The heat exchanger is housed in a galvanized steel casing and insulated on the inside with 0.025 m (1 in.) fiberglass insulation. The exchanger is rated to heat 0.38 m^3/s (800 cfm) of air from 18 °C (65 °F) to 34 °C (94 °F) with 6.3 x 10^{-4} m^3/s (10 gal/min) of water entering the coil at 57 °C (135 °F) (7300 W (25,000 Btu/h) capacity).

Auxiliary Boiler

Even though the gas furnace installed in the house is still operable and could be used as the auxiliary energy source for space heating, an electric water boiler was installed for supplying auxiliary energy for the cooling and domestic water preheating processes. Since electrical use is generally determined more accurately than natural gas use*, the water boiler will probably be used for the space heating process as well.

The boiler has a heating capacity of 17,600 W (60,000 Btu/h). It consists of electrical resistance heating elements which are modulated in five steps of 3500 W each. The modulating steps were chosen so that the boiler outlet temperature could be easily thermostated.

Domestic Water Preheater

In order to preheat the domestic hot water before passing it into the existing electric hot water tank in the house, a shell and tube heat exchanger and additional 0.3 m^3 (80 gallon) water tank were obtained. The heat exchanger is rated to heat 6.3 x 10^{-5} m^3/s (1 gal/min) of domestic water from 18 °C (65 °F) to 49 °C (120 °F) in the tubes when supplied with 6.3 x 10^{-4} m^3/s (10 gal/min) of a 40% ethylene glycol solution entering the shell at 54 °C (130 °F). The heat exchanger is cylindrical in shape with an approximate diameter of 0.13 m (5 in.) and an approximate length of 1.8 m (6 ft). The 0.3 m^3 (80 gallon) water tank is a conventional glass lined electric water heater having a diameter of 0.58 m (23 in.).

Transfer Fluid

In designing the system to minimize the possibilities of corrosion, it was decided to construct a closed, pressurized system in which the fluid is in the solar collector panels at all times. Therefore, to prevent freezing, expansion, and cracking of the solar collector panels, a 1:1 water - antifreeze solution is to be used. Industrial grade ethylene glycol was purchased. The chemical had no additives as purchased and therefore additional corrosion inhibitors were added (see next section). Thermal properties of ethylene glycol water solutions are given in references [35, 36].

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* The energy use in an electric furnace can be determined to an accuracy of less than 1 per cent. The corresponding accuracy with a gas furnace is usually on the order of several per cent.

Corrosion Considerations

The transfer fluid in this system is pumped through a variety of equipment including the aluminum absorber of the collector, copper pipe, bronze or brass valves, and steel tanks. This mixture of metals with an aqueous mixture could result in significant chemical attack on the aluminum by galvanic, concentrated cell (crevice), pitting, erosion, or stress corrosion. Of the metals listed, aluminum is the most anodic in the electro-chemical series. Thus any foreign metal deposit or concentration of other metal ions could result in "sacrificing" the aluminum and in pitting.

Unfortunately the collector plate is usually the most expensive and the most difficult component to replace. Therefore, it is incumbent on the design and operation of the system that provision be made for corrosion protection of the panel. Of particular concern are the fluid passages formed by diffusion bonding and expansion which result in crevices on each side of the passage. Even though chemically inert titanium oxide ($Ti\ 0_2$) is used as the stop-weld material, the $Ti\ 0_2$ particles can still provide a site for the initiation of corrosion by foreign particles or even in an uninhibited aqueous solution by interfering with the normal formation of aluminum oxide on the surface.

A review of the literature regarding liquid cooling system antifreeze solutions used in automotive and other commercial applications [37] uncovered the existence of both federal [38] and military [39] specifications for inhibited mixtures. While the temperature levels during standby and operation of the solar heating and cooling system are similar to the internal combustion engine, the combination of metals in an engine system does not usually contain a large amount of aluminum.

In addition to the referenced specifications cited above, several other sources were consulted prior to making a decision on the addition of inhibitors. Contact with experts from the automotive industry led to the conclusion that the high borate concentrations recommended in the federal and military specifications [38, 39] are not desirable with aluminum. Another formula using nearly a 1:1 ratio of borate to other chemicals was mentioned as having performed well in automotive tests over a two-year period [40]. An additional source [41] recommended using a mixture with a high phosphate concentration in a predominately aluminum system. A third source described tests using a proprietary inhibitor with aluminum solar collectors in which the results have been very encouraging [42].

A series of tests have been conducted on aluminum solar collector panels by the Reynolds Metals Company [43]. Successful corrosion mitigation has been achieved in a 1:1 mixture of tap water and ethylene glycol using an amine neutralized acid phosphate [44]. Based on the test results in reference [44], a decision was made to use this inhibitor in the system. Twenty three kilograms (50 pounds) were required for a system having a capacity of 5.7 m^3 (1500 gallons).

Besides the addition of the inhibitor, other steps have been and will be taken to minimize the possibility of corrosion. Prior to charging the system, the cloride concentration of the local water will be checked and if found to be higher than 50 ppm, deionized water will be used. Steps have been taken to galvanically isolate the dissimilar metals. Rubber hoses (see below) connect the copper header pipes to the aluminum collectors. Copper-silicon fittings are used to connect the copper pipes to the steel tanks.

Representatives of Olin Brass suggests [45] that a "getter" column be installed, through which the transfer fluid passes before entry into the aluminum collectors. Such a "getter" column would consist of a plastic cylinder containing a series of aluminum sheets. The fluid would circulate over this surface and the function of the surface would be to pick up "heavy metal" ions which may have gotten into the system as the result of corrosion of other metal components or as the result of "tramp" material within the system. Because of other precautions taken, it was decided not to use the "getter".

"Buffers" in the inhibitor function to control the pH* of the solution to a desirably high value between 6.0 and 8.0. As the "buffers" in the solution become exhausted, the pH will drop significantly indicating a formation of organic acids which serve to make the mixture more corrosive. Reference [44] describes a method of monitoring the inhibitor concentration which will be used periodically during the experiment. If the pH is found to be below the level of 6.0, it will be increased by the addition of sodium carbonate; if it is found to be higher than 8.0, it will be lowered by the addition of concentrated sulfuric acid to the solution.

Pumps

Six centrifugal pumps are used in the system. All are rated to pump a 40% solution of ethylene glycol and water at a temperature 121 °C (250 °F) at a flow rate of 7.6 x 10^{-4} m^3/s (12 gal/min). All pumps have an iron body, bronze impeller and have a rotation speed of 59 revolutions/s (3500 rpm). The pump circulating the fluid through the collector is driven by a 746 W motor (1 horsepower) and the other five are driven by 250 W motors (1/3 horsepower).

Valves

In order to control the flow through the system and to divert it through the various loops, nine proportional valves and thirty-one automatic open-close type valves are used. The proportional valve assembly consists of a single-seat globe valve mechanically linked to a reversible actuator with a driving motor and gear train. The valve assembly is connected to two relays and the flow is adjusted by activating one of the two relays for a certain length of time. The power input to the valve motors is 24 volts a.c. The automatic valves are all two position, two way valves. Depending upon the location in the system, the automatic valves are either straight way or 90° angle and are either normally open or normally closed. All of the valve actuators are connected to a 24 volt a.c. source through a relay contact.

Piping

The plumbing that comprises the solar heating and cooling system includes approximately 035 m (1000 ft) of nominal 0.32 m (1 1/4 in.) copper pipe. The pipe is insulated with urethane pipe insulation having a thickness of 0.051 m (2 in.). For a pipe temperature of 93 °C (200 °F), the heat loss is expected to be less than 9.6 W per lineal m (10 Btu/h per lineal ft).

Hoses

As mentioned previously, connections from copper headers to the solar collector modules are made with high quality "heater" hose. The material used was 0.13 m (1/2 in.) inside diameter tubing which will withstand 1.7 N/m^2 (250 psi) working pressures and temperatures in excess of 149 °C (300 °F).

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* A scale based on the hydroxide-ion concentration of a solution. All neutral solutions have pH of 7. Acid solutions have a pH less than 7; basic aolutions have pH greater than 7.

Simulation Study for the Sizing of Components

In order to properly size the critical components of the system, namely, the collector and storage tanks, a detailed mathematical simulation of the system and house should be used that accounts for the dynamic way in which the collector and the house respond to changing environmental conditions. The building simulation model NBSLD [46] is currently available at NBS for just such studies but as of yet, a simulation model of a solar heating and cooling system has not been written and combined with the program. The University of Wisconsin computer program TRNSYS [47] which contains solar component simulation routines has recently been purchased but was not available to NBS at the time the present solar heating and cooling system was being designed. In addition, arrangements have been made to obtain a similar program being developed by the Lockheed Corporation [48] as aoon as it is available. It is the intent of the authors to critically examine the extent to which the University of Wisconsin and Lockheed computer programs can accurately predict the performance of the heating and cooling system in this house.

The technique used to size the solar components was to develop a simplified computer program utilizing the knowledge obtained in previous research on the thermal characteristics of the house [1, 2], and an empirical routine for solar collector performance developed by Kusuda [49] and based on experimental data reported by the University of Pennsylvania [50, 51].

The empirical routine used for predicting solar collector performance is explained in Appendix B. Sample output data for a south-facing flat-plate collector tilted at angles of 12° and 50° from the horizon is given in Appendix C. These were the two angles finally selected for arrays of modular collectors. The 12° angle corresponds to the slope of the flat roofs of the test house. It was felt that part of the collector could be placed flat on the roof for ease of installation and operate with a relatively high thermal output during the summer months when the air cooling unit is used. The 50° angle was selected as being one which would allow a row of normal-sized modular collectors to be installed between the lower and upper roofs of the house and operate with a high thermal output during the winter months. The collector calculations proved that these angles were acceptable.

In constructing the simplified computer program for matching the solar collector output with the building heating and cooling load, the following assumptions were made:

1. Daily house heating and cooling loads (Q_L) could be computed by using the average temperature difference for that day and an overall loss coefficient U_L (determined from the test results in [1] and [2]), such that $Q_L = U_L \cdot \Delta t$.

2. Internal heat generation due to appliances and occupants would be 1.1 x 10^8 J/day (105,000 Btu/day) (summer) and 1.05 x 10^9 J/day (100,000 Btu/day) (winter).

3. When the collectors supply more energy than is required to meet the load, the excess would be stored as hot water. Of that energy added to storage, 90% could be retrieved when the water temperature is below 60 °C (140 °F) and 80% could be retrieved when it is between 60 °C (140 °F) and 104 °C (220 °F). Above 104 °C (220 °F), further storage would no longer be possible and excess energy would be "thrown away".

4. Useful energy could be extracted from the heat transfer fluid when it is above 27 °C (80 °F) for winter heating and above 88 °C (190 °F) for summer cooling.

5. Winter and summer thermostat settings would be 21 °C (70 °F) and 24 °C (75 °F), respectively.

On a day to day basis, the thermal requirements of the house were matched against the output of the collector and the difference was either stored in or retrieved from storage. The calculation was done for an entire year of 1957 weather*. The storage and collector sizes were varied and the simulation repeated until a final decision was made on the size of the system components. Sample output is given in Appendix D for the case of a south-facing collector having an area of 43 m^2 (460 ft^2) and a tilt angle of 12° with a storage tank capacity of 194 m^3 (1200 gallons). Figure 20 shows the predicted monthly energy demand and the part that will be supplied by the collector and the auxiliary energy source, respectively. These results are based on the final design of 26.7 m^2 (288 ft^2) of collector at the 12° slope and 18.3 m^3 (197 ft^2) of collector at the 50° slope.

4. Addition of the Solar Heating and Cooling System to the Test House

The major tasks required during installation were a) mounting the collectors on the house, b) constructing an additional room on the back of the house to contain the storage tanks and other components of the solar system (the house had no basement), c) making modifications to the existing space heating and cooling system, and d) installation and connection of all components.

The collector rack consists of wooden boxes that were fabricated in the NBS carpenter shop and then moved to the site of the house (Figure 21). They were mounted on the house (Figure 22) and the sides and edges were trimmed with simulated redwood and then finished off so that they blend with the exterior of the house. The collectors were then moved to the site, lifted to the roof of the house (Figure 23), put in place, and then sealed with a neoprene gasket (Figure 24) to prevent any large amount of moisture from getting behind the panels. The collectors themselves have a metal pan enclosing the insulation and in addition, "weep holes" are present in the lower edges of both the metal pans and wooden boxes.

During 1973 and after the test house was moved onto the NBS grounds, a special two-story instrument room was built on the north side of the house to hold the computerized data acquisition system. The room is located midway between the west and east ends of the house and measures approximately 3.7 m (12 ft) by 3.7 m (12 ft). During 1974, a second two-story room was built on the northwest corner of the house, again measuring approximately 3.7 m (12 ft) by 3.7 m (12 ft) and finished off in artificial redwood to match the rest of the house. The room is shown being constructed in Figure 25. Prior to putting up the walls of this second room, the storage tanks were moved into place (Figure 26 shows one of the tanks being moved). The tanks are mounted vertically in the equipment room. No consideration was given to burying them since it was felt necessary to have access to them during the experimental program. All pumps are located on the floor of the room, the major part of the piping hung on the four walls, the electric water boiler on the floor, and the cooling tower installed on a special platform at a location corresponding to the second floor of the room. Ducting runs to and from the cooling tower through the walls of the room.

The absorption air cooler was installed in the utility or storage room on the first floor of the house (see Figure 2). The duct work was then modified and connections made between the outlet of air cooler and the horizontal run above the outlet from the existing gas furnace. The water to air heat exchanger was installed in a horizontal run between these two locations.

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* The year 1957 was selected by using the proposed procedure of the ASHRAE Task Group on Energy Requirements [52]. Even though this year may be typical from the standpoint of energy demand, a quick comparison of average monthly radiation values with those predicted using the procedures of Liu and Jordan [53] would indicate that for several months, the predicted incident solar radiation was rather low.

5. Economic Considerations

During the testing program, an economic analysis will be made of retrofitting an existing residence with a solar heating and cooling system. The analysis will take into account the energy saved based on test results as well as the cost of components, material, and labor to install the system. An attempt will be made to separate those costs that have occurred as a result of the engineering experiment being conducted from those that would normally be incurred by the homeowner. The economic analysis will be done using techniques outlined in references [54-56].

The approximate cost of the major components purchased for the system (excluding instrumentation) are as follows:

1.	solar collectors (31 panels)	$3,575
2.	Lithium bromide absorption air cooling unit	$2,000
3.	3.8 m^3 (1000 gallon) storage tank	$ 990
4.	1.9 m^3 (500 gallon) storage tank	$ 700
5.	cooling tower for the absorption air cooling unit	$ 410
6.	heat exchanger and tank for domestic hot water preheating	$ 510
7.	furnace plenum heat exchanger for space heating and cooling	$ 200
8.	auxiliary 17,600 W (60,000 Btu/h) electric water boiler	$1,065
9.	automatic two-way valves (31 total)	$2,470
10.	proportional valves (9 total)	$1,490
11.	centrifugal pumps (6 total)	$1,400
12.	2.9 m^3 (770 gallons) of industrial grade ethylene glycol	$1,890
13.	22.7 kg (50 pounds) of corrosion inhibitor	$ 150
14.	305 m (1000 ft) of high temperature pipe insulation	$2,470
15.	130 m (425 ft) of high temperature hose	$ 245
16.	Storage tank insulation	$ 300
	Subtotal	$19,865

Other major cost items not listed include approximately 305 m (1000 ft) of copper pipe, material and labor for the construction of a solar collector rack and an additional room on the back of the house (see below) to hold the storage tanks, pumps, cooling tower, and other associated components, and the labor cost for the plumbing.

6. Instrumentation

One of the primary advantages in conducting the solar heating and cooling experiment on this particular house is that a significant amount of instrumentation already exists and is installed in the house. A brief description of the instrumentation follows.

Ambient air and surface temperatures are measured with 24 gauge type T thermocouples. Thermocouple strings, suspended by 0.0048 m (3/16 in.) diameter polycarbonate rods, are placed at the geometric center of each room and 0.61 m (2 ft) horizontally centered in front of each of the windows. The locations of the thermocouple strings, numbered 1 through 19, are depicted with solid circles on the floor plans of Figures 2 and 3. Six thermocouples are attached to a rod and located at 0.076 m (3), 0.76 (30), 1.83 (72), and 2.13 (84) m (in.) above the floor, and 0.076 m (3 in.) below the ceiling. Four thermocouples are placed in the crawl space 0.15 m (6 in.) below the floor joists. The location of the crawl space thermocouples is depicted with the symbol C on the floor plan of Figure 2. All thermocouples are referenced to the ice point (0 °C, 32 °F) by connecting them to a thermoelectric ice-point reference system.

During the previous test program, globe thermometers were used to determine the mean radiant temperature (MRT) at the geometric center of the living room, den, kitchen, and four bedroom areas at the 0.76 (30 in.) level above the floor. The locations of the globe thermometers are shown with the symbol G on the floor plans of Figures 2 and 3. A globe thermometer consists of a 0.15 m (6 in.) diameter hollow copper sphere with a thermocouple supported in the center. The outside surface of the sphere is painted with matt-black paint, so as to absorb most of the long wave thermal radiation emitted from the inside surfaces of a room. Recently NBS has developed a "scanning radiometer" [57] that will also be used to determine the mean radiant temperature in the house.

Relative humidity transducers (H) are placed in the geometric center of the living room, kitchen, bathrooms, and bedrooms at the 1.5 m (60 in.) level above the floor. The humidity transducers produce a millivolt output signal proportional to the relative humidity.

The temperature of the return air to the heating and cooling plant will be measured with a network of four thermocouples connected in parallel. The temperature of the supply air will be measured with a network of eight thermocouples connected in parallel placed in the air outlet past the water to air heat exchanger. The air delivery rate of the blower will be determined with a calibrated vane anemometer and a calibrated hot wire anemometer.

The volume of natural gas consumed by the furnace in the test house during the previous test program was measured with a calibrated domestic gas consumption meter that was specially modified so that the passage of a cubic foot of gas produced an electrical pulse. This was accomplished by placing an excitation voltage across a microswitch that rode on a cam shaft of the metering circuit. The temperature and pressure of the gas at the inlet to the gas meter were monitored, so that the volumetric consumption of gas could be corrected for changes in density. For those tests where the gas furnace will be used for the auxiliary energy source, this technique will continue to be used.

The gross electrical energy supplied to the house will be measured using a calibrated watthour meter equipped with a photo-electric device that generates a pulse for each revolution of a disk inside the meter. The individual electric energy consumption of such items as the blower fan, pumps, and electric water boiler will also be monitored using individual watthour meters.

An energy analysis of the system will also require the determination of fluid flow rates and temperature differences across individual pieces of equipment in the fluid transport loops. Five oscillating piston, positive displacement, flow meters were recently purchased along with a series of ceramic-insulated sheathed thermocouples. The flow meters are equipped with pulse generators which provide a resolution of 2.6×10^5 pulses/m^3 (1000 pulses/gallon) with an accuracy of $\pm$ 0.25%. The thermocouples are 0.0032 m (1/8 in.) in diameter and 0.31 m (12 in.) long and will be inserted directly into the pipe at specified locations.

During the past year, a new and versatile data acquisition system was purchased for the test house. The system consists of:

1. a six digit integrating digital voltmeter,
2. a scanner permitting the voltmeter to read any of 400 channels of data,
3. a magnetic tape system to record measured values,
4. four data source input channels (DSI) that allow the input of binary coded decimal (BCD) information,
5. a relay register with 48 separate contacts that will enable the system to control not only external measuring devices but also the pumps, motors, valves, etc. that comprise the solar heating and cooling system, and
6. a mini-computer which serves as the central control for the total system.

In order to automatically record the output of the watthour meters and gas meter (if used) and in order to eliminate the need for digital to analog conversion on the flow meters, totalizers have been purchased that have a BCD output which in turn will be fed through one of the DSI channels in the data acquisition system.

In previous years, the analysis of the test results for the house and conventional heating and cooling system was not as dependent on accurate measurements of the weather conditions as will be the case for the coming year. As a result, a compact weather station was purchased that contains instrumentation for the accurate measurement of:

1. Wind speed
2. wind direction,
3. dry-bulb temperature,
4. relative humidity,
5. rain fall,
6. barometric pressure,
7. direct component of incident solar radiation, and
8. total incident solar radiation.

The system has been designed and built so that the output from each sensor is a voltage that ranges from 0 to 5 volts DC and varies linearly with temperature, relative humidity, etc. These voltages will be input through the digital voltmeter and scanner of the data acquisition system.

7. Plans for Test Program

In planning the tests to be conducted on the house, emphasis has been place on continuing the philosophy used in previous years when the house was tested with its conventional equipment [1, 2]. The house was installed in a high-bay environmental laboratory and a series of ten tests were conducted in which the house was subjected to 24-hour outdoor temperature and relative humidity patterns taken from records of actual weather data for the summer, fall, and winter in Kalamazoo, Michigan and Macon, Georgia. For each test, the weather variation was maintained for a period of two to three days before a final set of 24-hour energy consumption data was taken.

The test series to be conducted on the house as it is now equipped with a solar heating and cooling system must obviously be done in a different way since the house is now located outside and will be tested under actual weather conditions. However, the philosophy of testing for short periods of time and obtaining detailed data will be maintained for several reasons:

1. It is impossible to test continuously for extended periods of time (months) taking even hourly data where two to three hundred channels of information are obtained and still be able to reduce and synthesize the data properly.

2. It would be impossible to examine alternate modes of operation or configurations of equipment for seasons at a time and still produce meaningful data in a reasonable period of time.

3. Heating and cooling equipment and/or instrumentation inevitably require some downtime during an experimental program such as this.

The general procedure followed in the previous years was to take the detailed test data for the 24-hour periods and then compare the energy consumption data with the predicted data using the actual test weather data as input to the calculations, the computer program NBSLD [46] in which the building was precisely modeled, and additional routines added to NBSLD that modeled the gas furnace, electric heater (used in some tests), and electric air conditioner. In this way, an accurate semi-empirical model of the building and equipment were established and the model could be used with the actual weather data for an entire year to determine yearly performance.

To achieve realistic test conditions, the occupancy and activities of a family living in the house were simulated. A complete description of what was done is given in reference [1]. In each of the tests described below, it is planned to use the same or a similar simulation and activity schedule.

Since the weather parameters influence the performance of the house and its solar system to a much greater extent than in the previous tests, it is envisioned (will be verified once the experimental program begins) that each of the tests described below will be conducted for at least two week periods in which all the detailed data is taken and analyzed. The house and system will be kept operational as much as is feasible during the next two years and gross energy measurements (electrical and gas consumption) as well as hourly recordings of weather data will be taken during periods when the detailed tests are not being conducted.

Test results from the detailed tests are expected to be similar to those displayed in Figure 27 (taken from reference [2]) except they will cover longer periods of time. The predicted performance of the house and system will again be determined using NBSLD with the solar system and its components simulated using the appropriate parts of the TRNSYS computer program [48] now in use at NBS. The results will then be used to generate seasonal performance data similar to that shown in Figure 28 for the MIT house IV [4]. This seasonal performance data will be generated for each of the testing configurations chosen.

The scope of the detailed testing configurations include space heating tests, space cooling tests, and a series of special tests.

Space Heating Tests

For each of two basic operational modes (single-loop and two-loop configurations*), a series of tests will be run in which both the amount of thermal storage and size of collector will be varied independently. The system is valved so that the storage size can be adjusted to 1.9 m^3 (500 gallons), 3.8 m^3 (1000 gallons), or 5.7 m^3 (1500 gallons) and any combination or all three of the collector arrays can be used. In addition, when using 5.7 m^3 (1500 gallons), the storage tanks can be connected in parallel or in series (simulating extreme stratification in a single 5.7 m^3 (1500 gallon) tank).

Space Cooling Tests

The major area to be investigated for cooling operation is the extent to which auxiliary energy must be used to supplement the collector output to properly operate the absorption cooler and what sort of control could be used that would optimize the performance of the unit. One possible mode of operation is to run the collector array and auxiliary boiler in parallel with the flow rate to the collector adjusted to always obtain the desired temperature level and the remaining energy obtained from the auxiliary boiler. A second possibility would be to operate the collector array and boiler in series maintaining the required (for the absorption unit) flow rate through the collector and then boosting the temperature level with the boiler. Intuitively, the second mode would result in higher system efficiency due to a lower operating temperature for the collector array. In addition, plans are being made to replace the present collector panels during the second cooling season (1976) with ones identical in design except for the addition of a selective coating on the absorber plate.

Special Tests

Additional tests are being planned as follows:

1. The collector array will be run in series with the cooling tower and an efficiency curve in accordance with references [58] will be determined for this installed array.

2. NBS has published a recommended test procedure for determining the "effective storage capacity" of thermal storage devices [59]. To the extent possible, this test procedure will be carried out for the two installed tanks.

3. Much concern has been expressed recently over the cost of ethylene glycol which must be used in water systems to prevent freezing, expansion, and cracking in the collectors. Two possibilities for eliminating its use are a two loop configuration in which only a small amount of ethylene glycol is required and a heat exchanger is inserted in or near the storage tank to transfer the energy from one loop to another or simply draining the collectors. Another possibility for a mild climate such as Washington, D. C., when a closed system must be used for anti-corrosion purposes and draining is not possible, is to have the control system circulate warm water through the collectors on those few occasions when freezing might occur. This will be investigated experimentally.

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* In the two loop configuration, two pumps are used independently, one to circulate fluid between the storage tank and the collector array when energy can be collected and the second one to circulate fluid between the storage tank and space heat exchanger when there is a heating demand from the house. In the single loop configuration, only one pump is used and the fluid is circulated through the collector, the storage tank and space heat exchanger all in series.

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Figure 1. Four-bedroom test house on the NBS grounds.

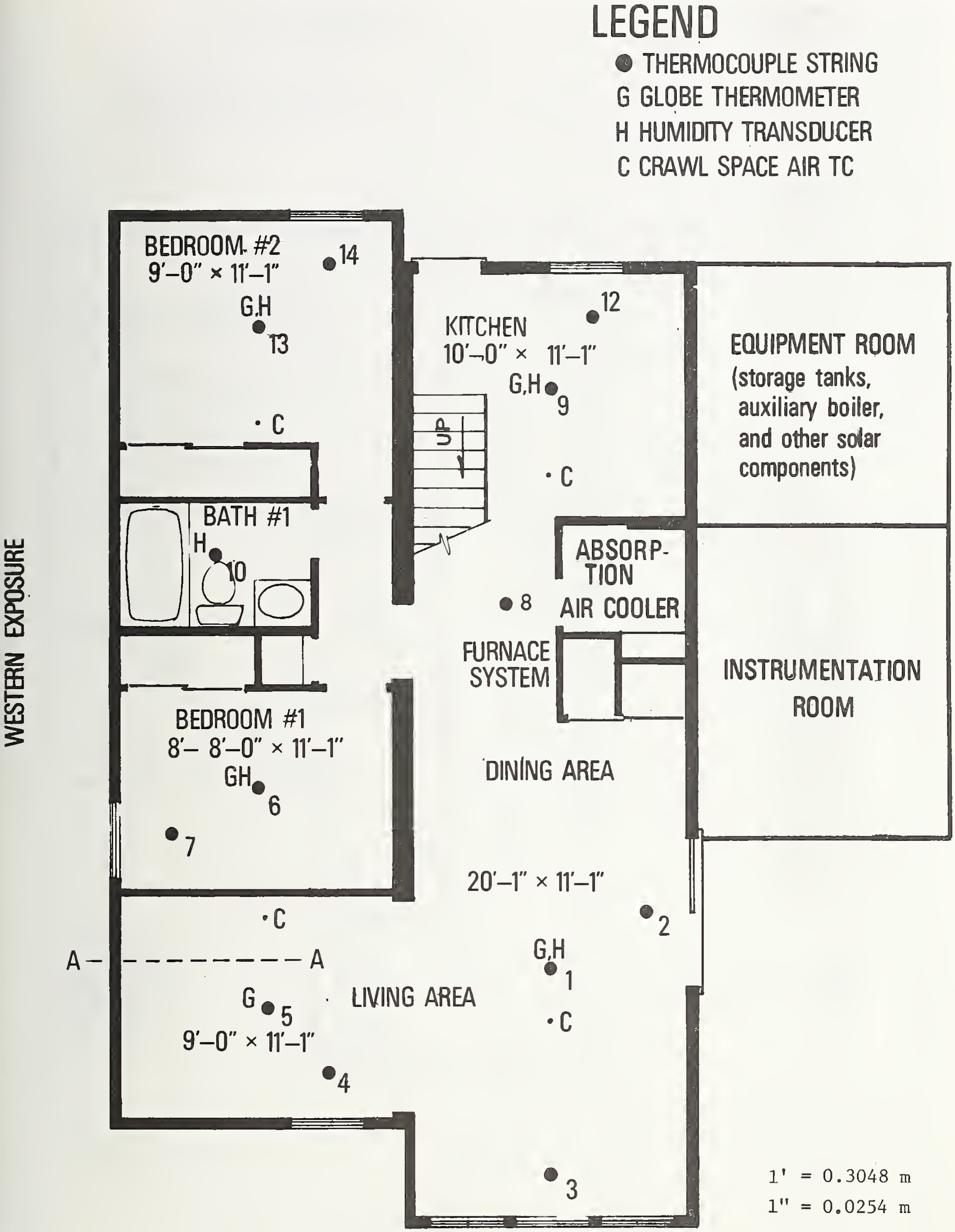


Figure 2. First floor plan of test house.

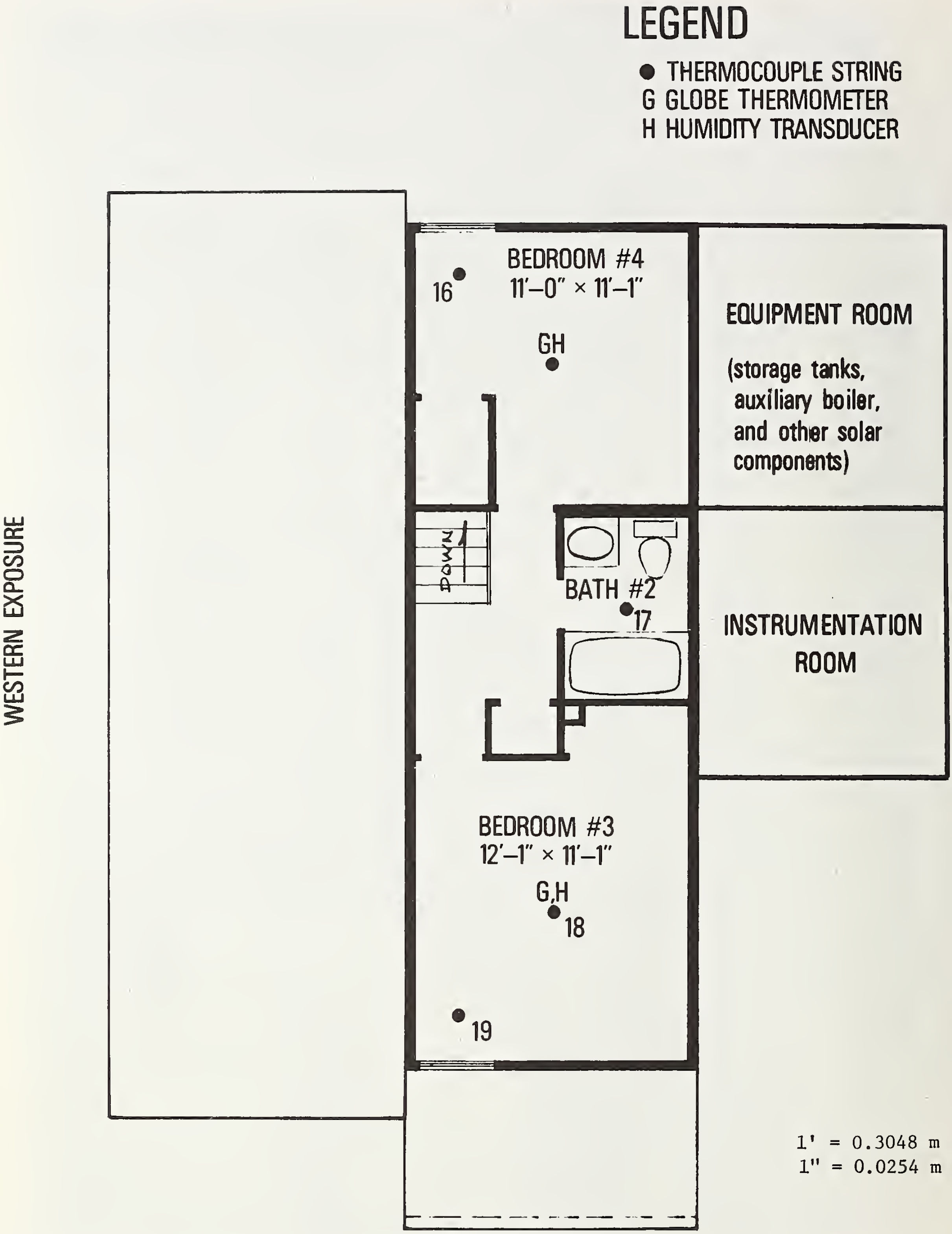


Figure 3. Second floor plan of test house.

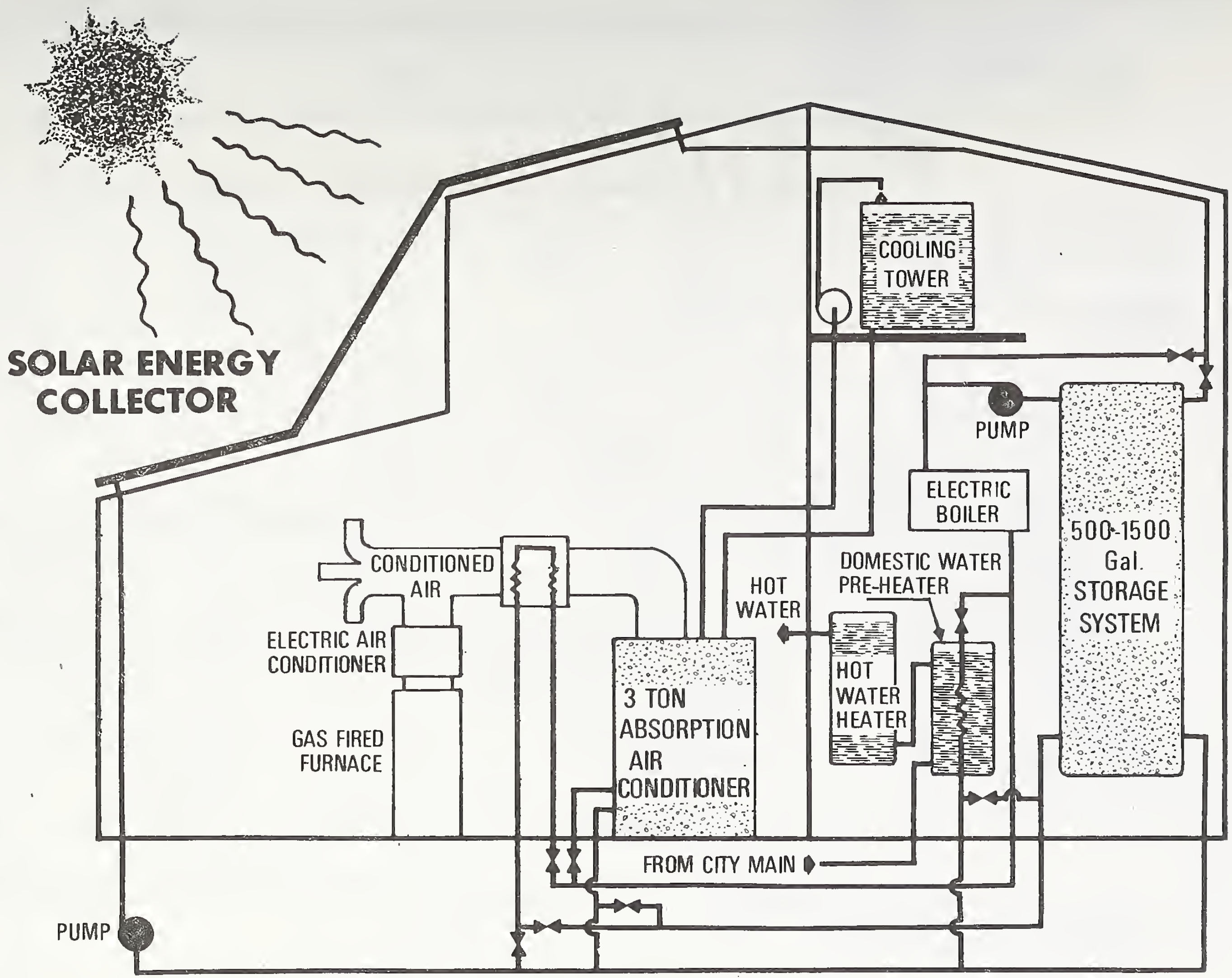


Figure 4. Schematic of the solar heating and cooling system in the NBS test house.

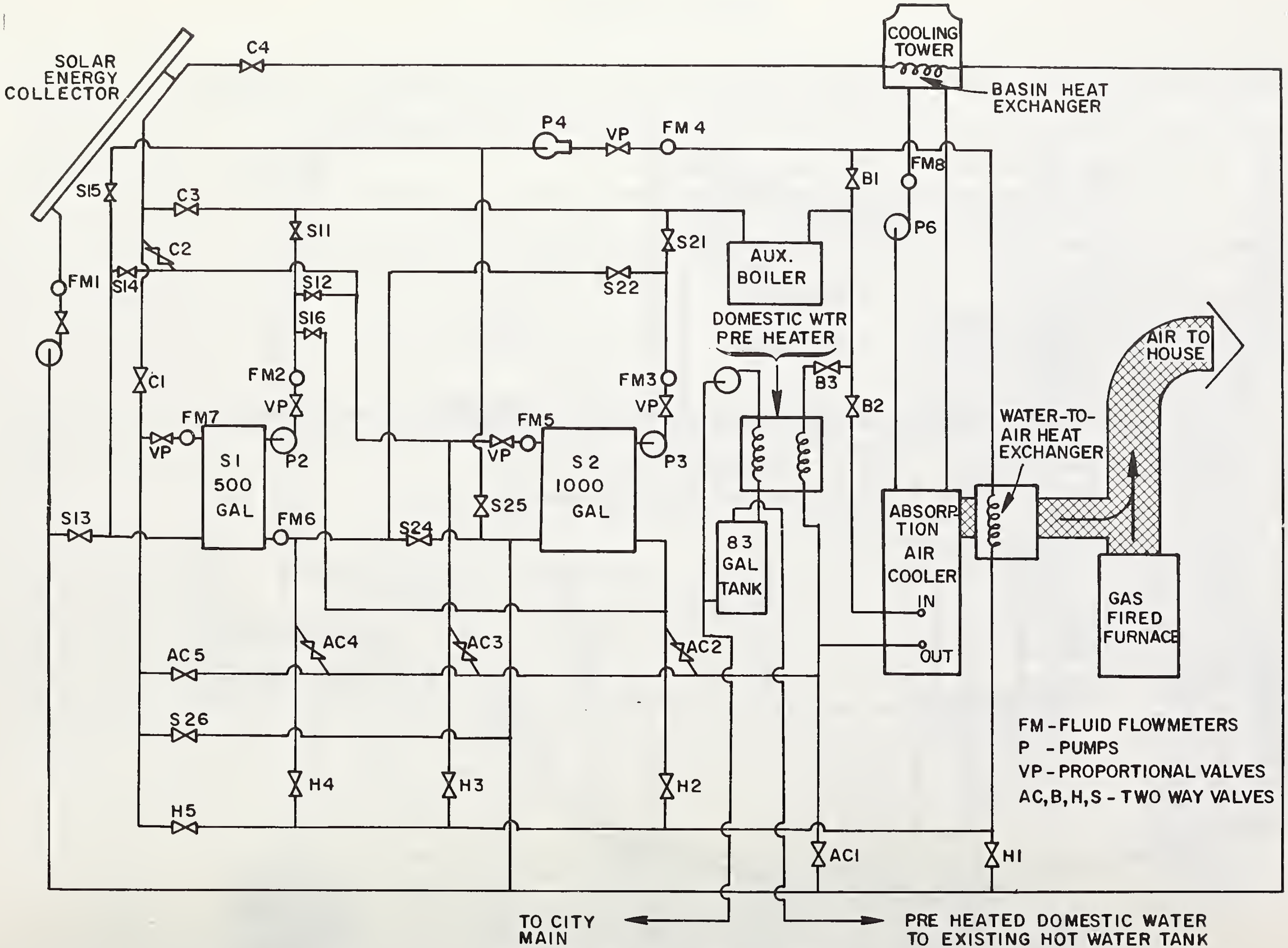


Figure 5. Piping diagram of the solar heating and cooling system in the NBS test house.

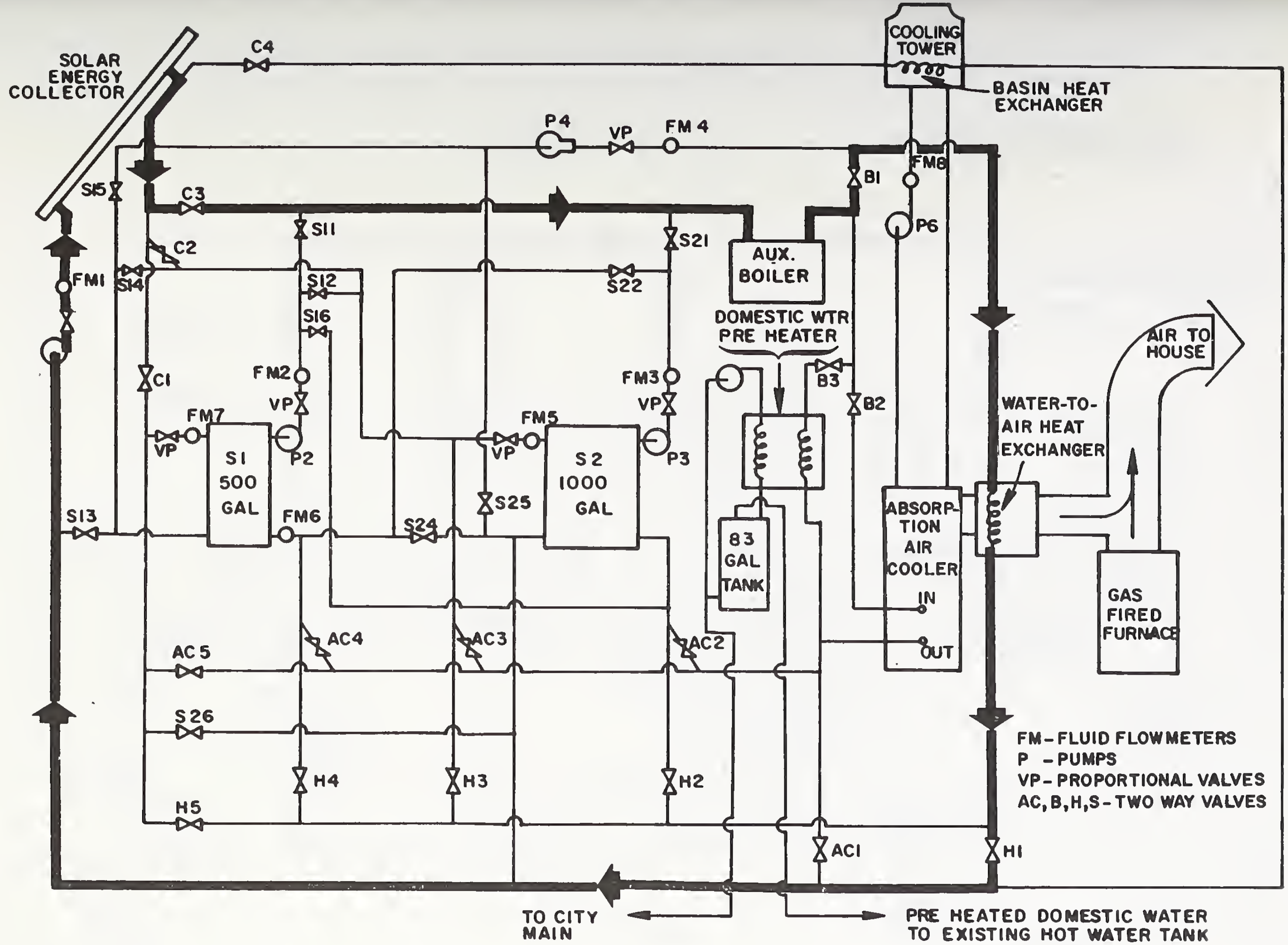


Figure 6. NBS solar heating and cooling system in the space heating mode with the solar collector as the energy source.

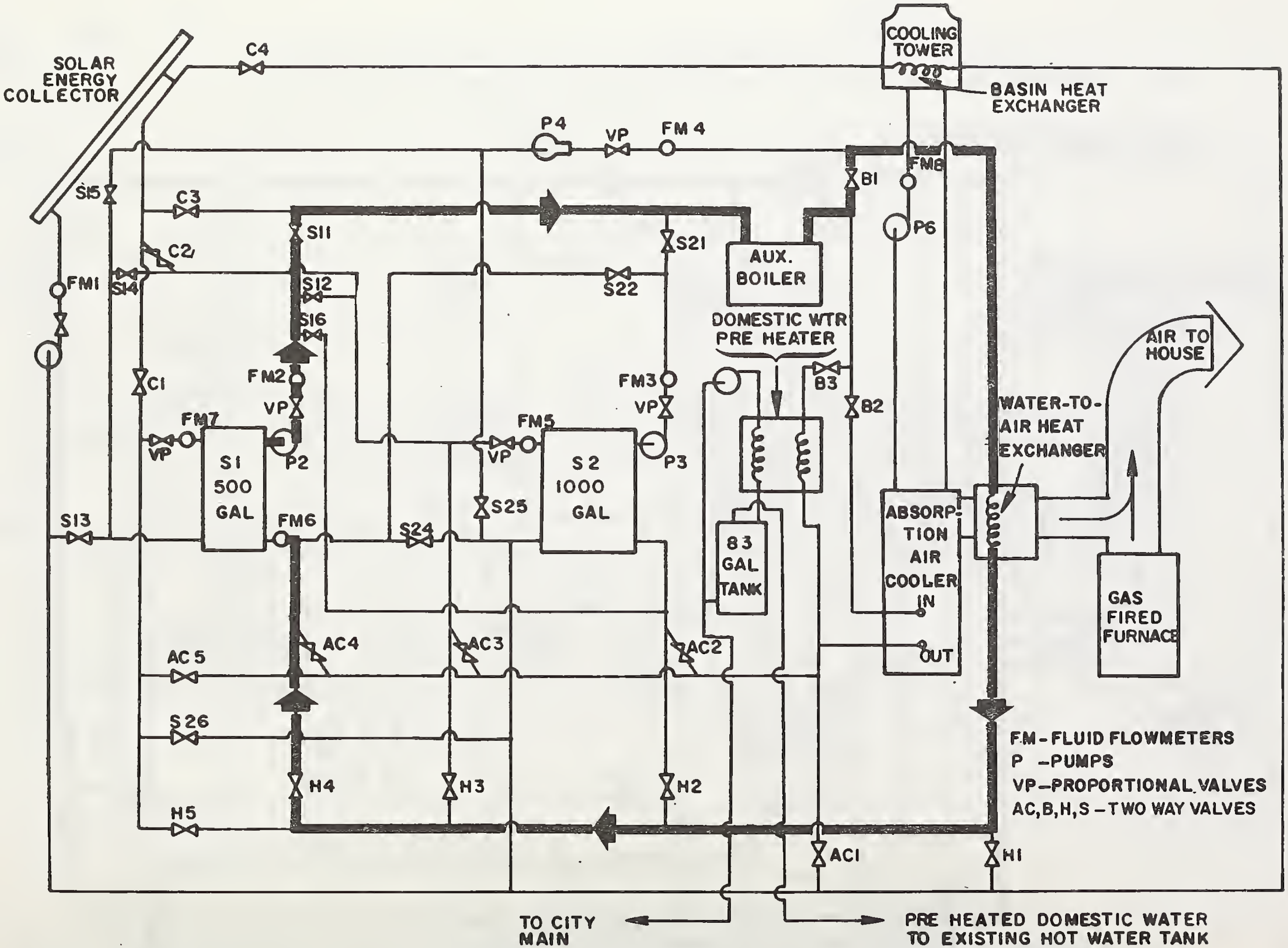


Figure 7. NBS solar heating and cooling system in the space heating mode with the small storage tank as the energy source.

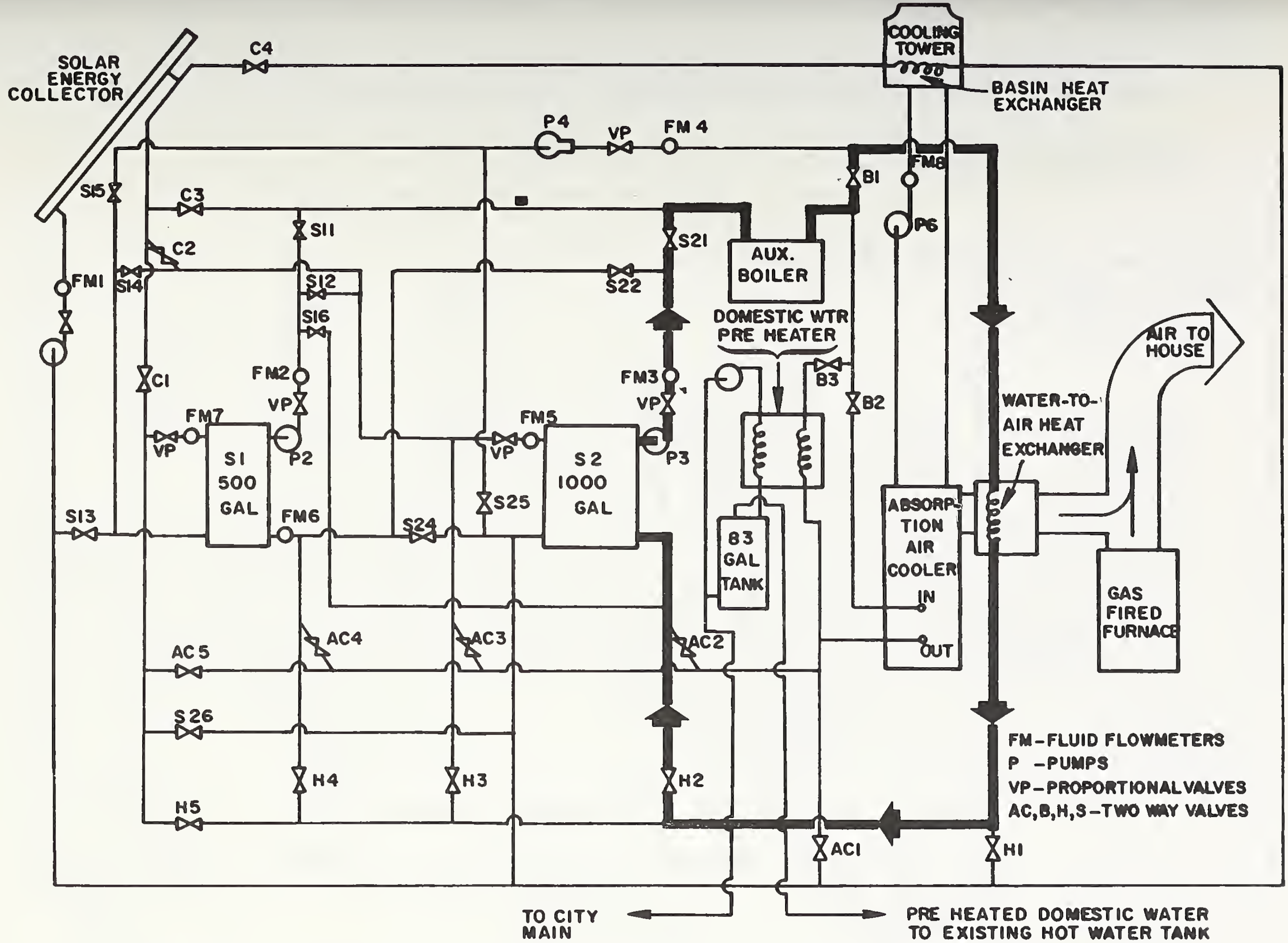


Figure 8. NBS solar heating and cooling system in the space heating mode with the large storage tank as the energy source.

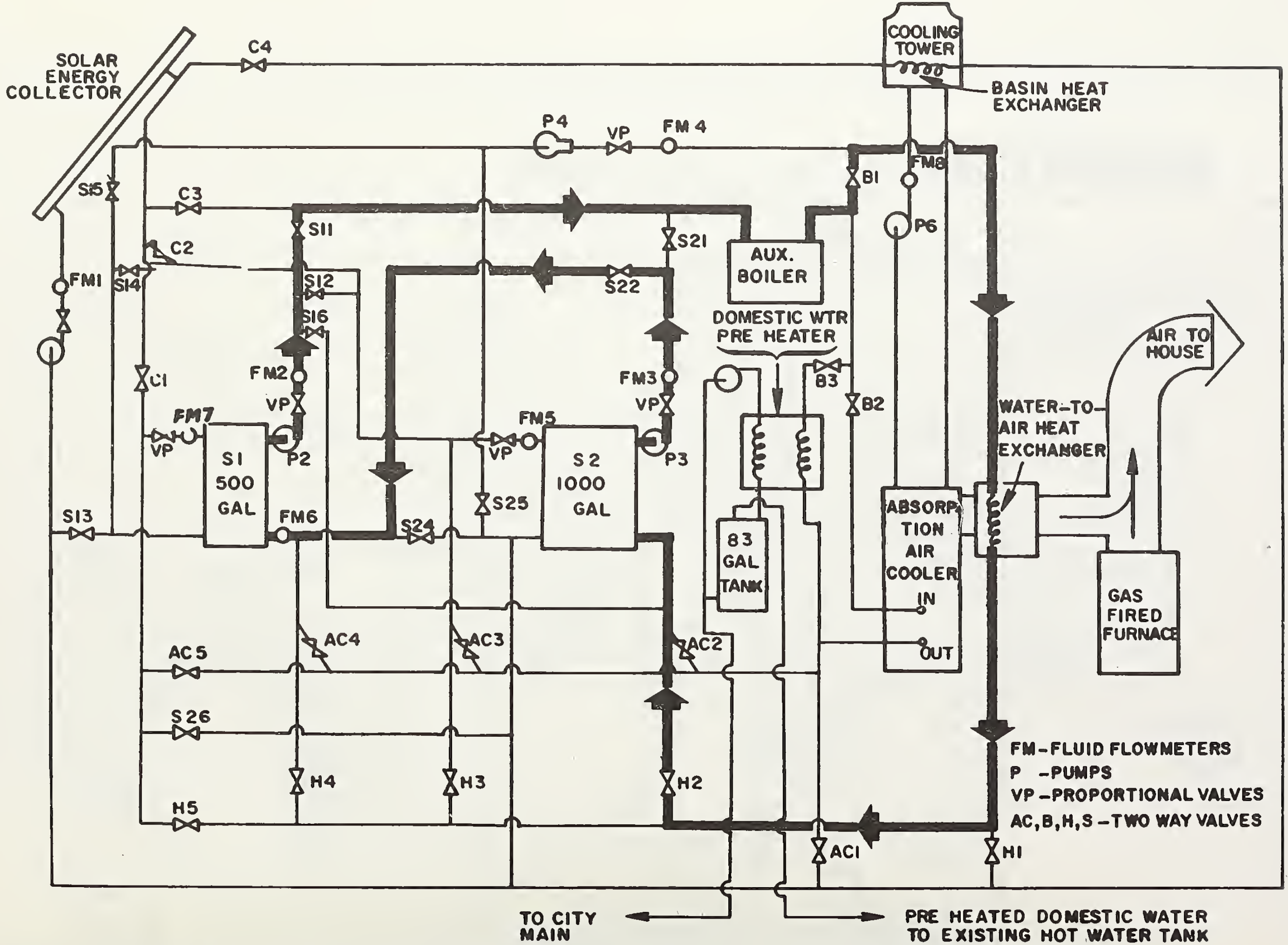


Figure 9. NBS solar heating and cooling system in the space heating mode with the storage tanks in series.

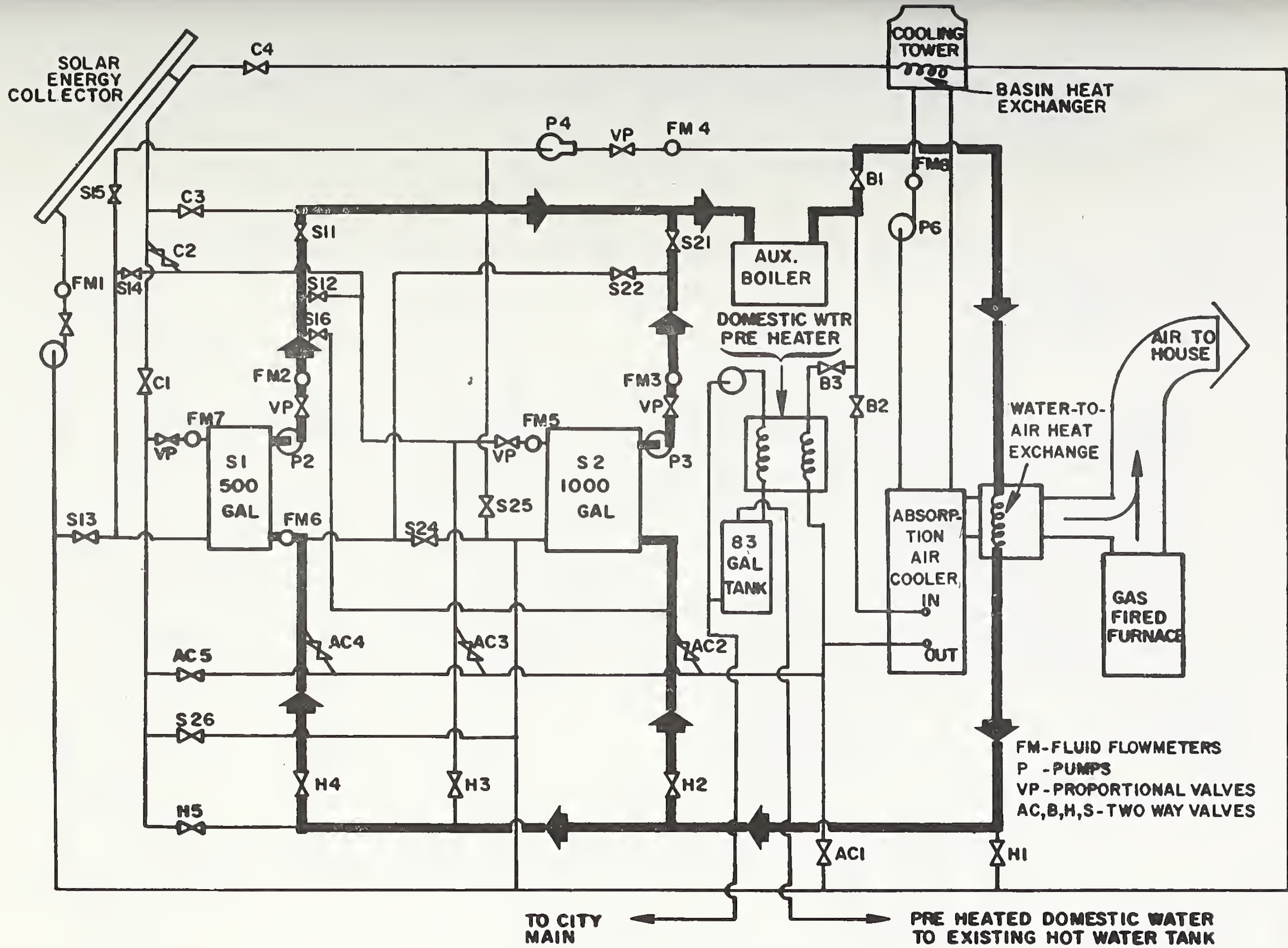


Figure 10. NBS solar heating and cooling system in the space heating mode with the storage tanks in parallel.

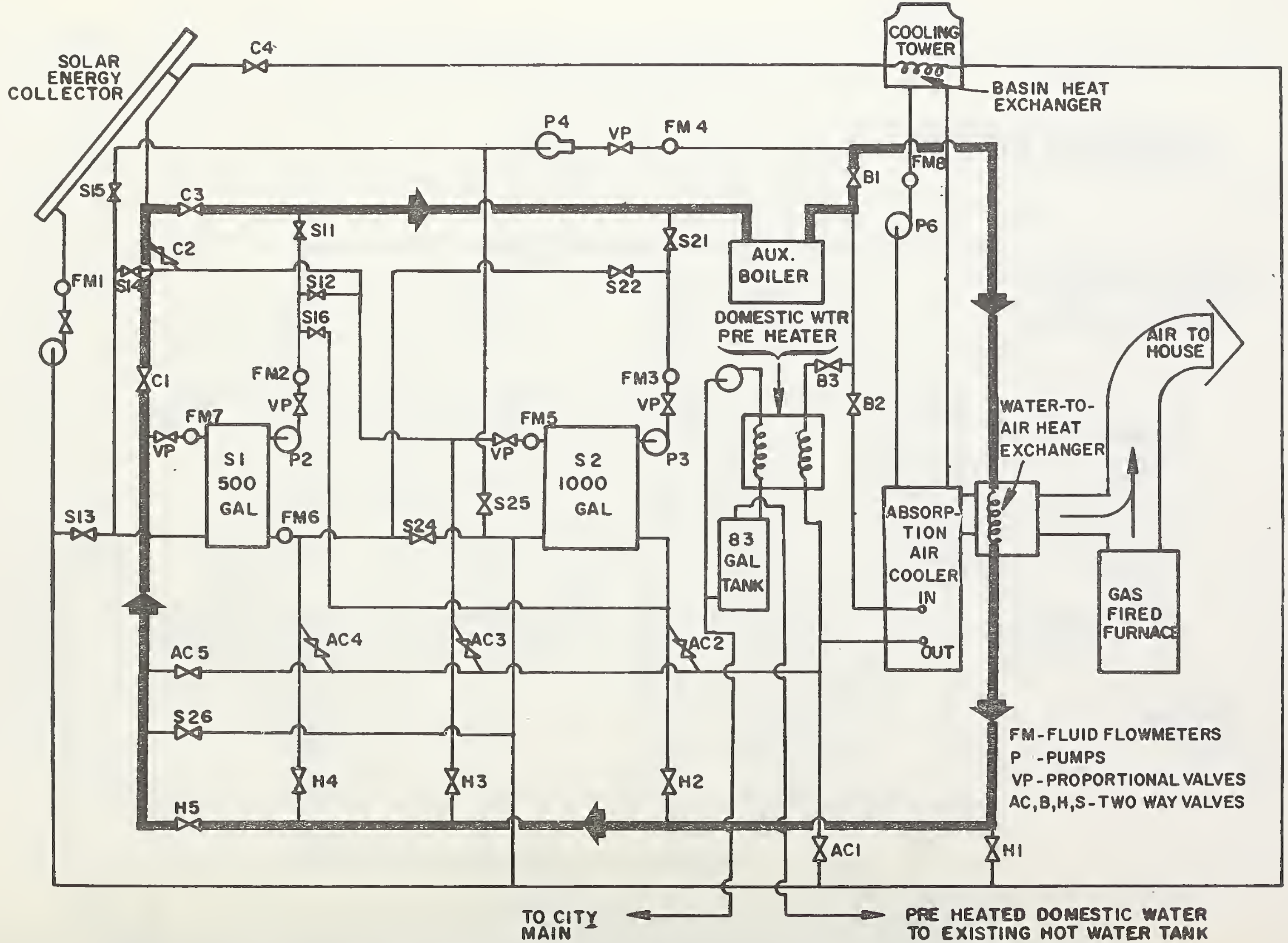


Figure 11. NBS solar heating and cooling system in the space heating mode with the auxiliary boiler as the energy source.

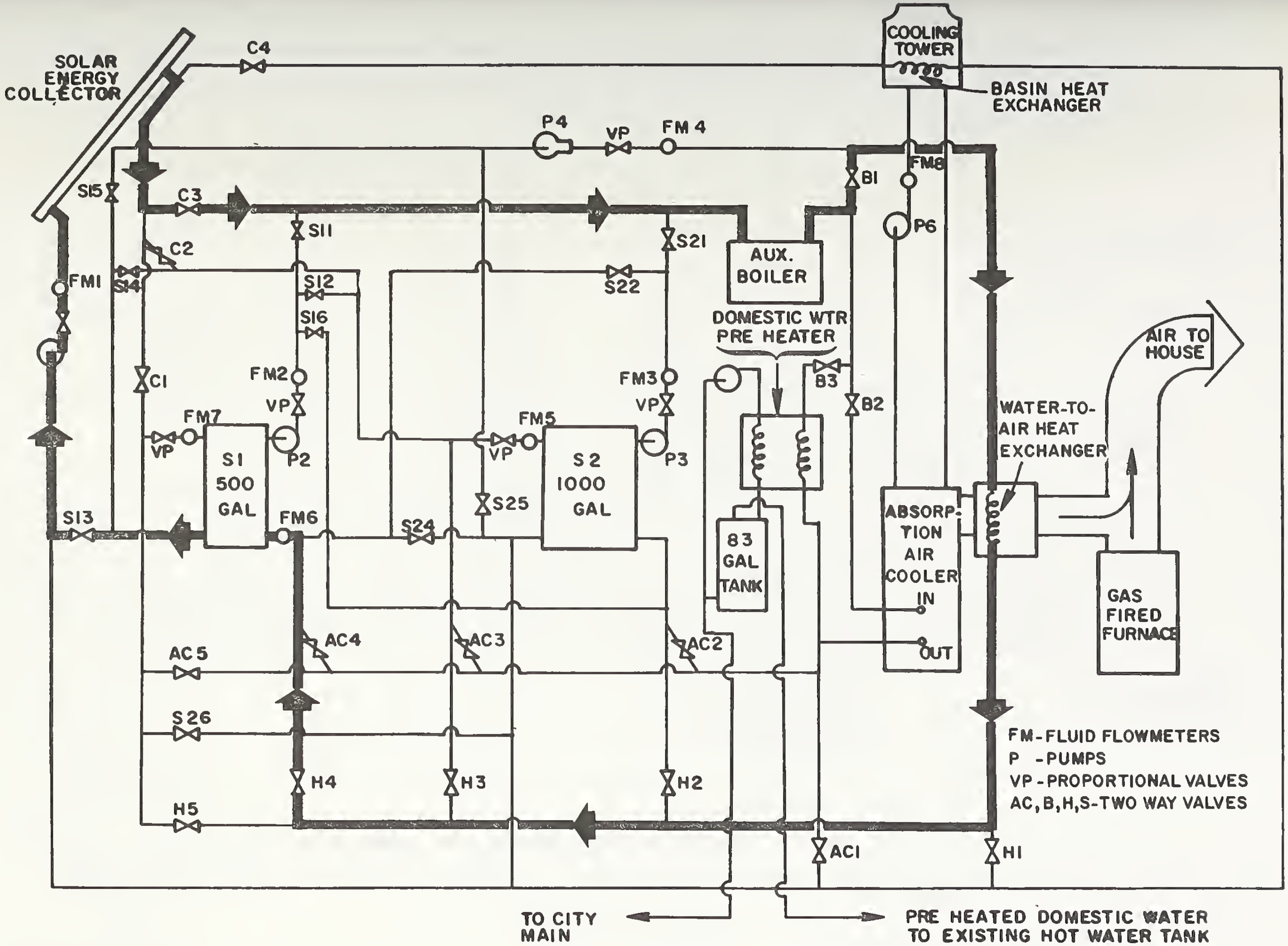


Figure 12. NBS solar heating and cooling system in the space heating mode with the small storage tank and solar collector in series.

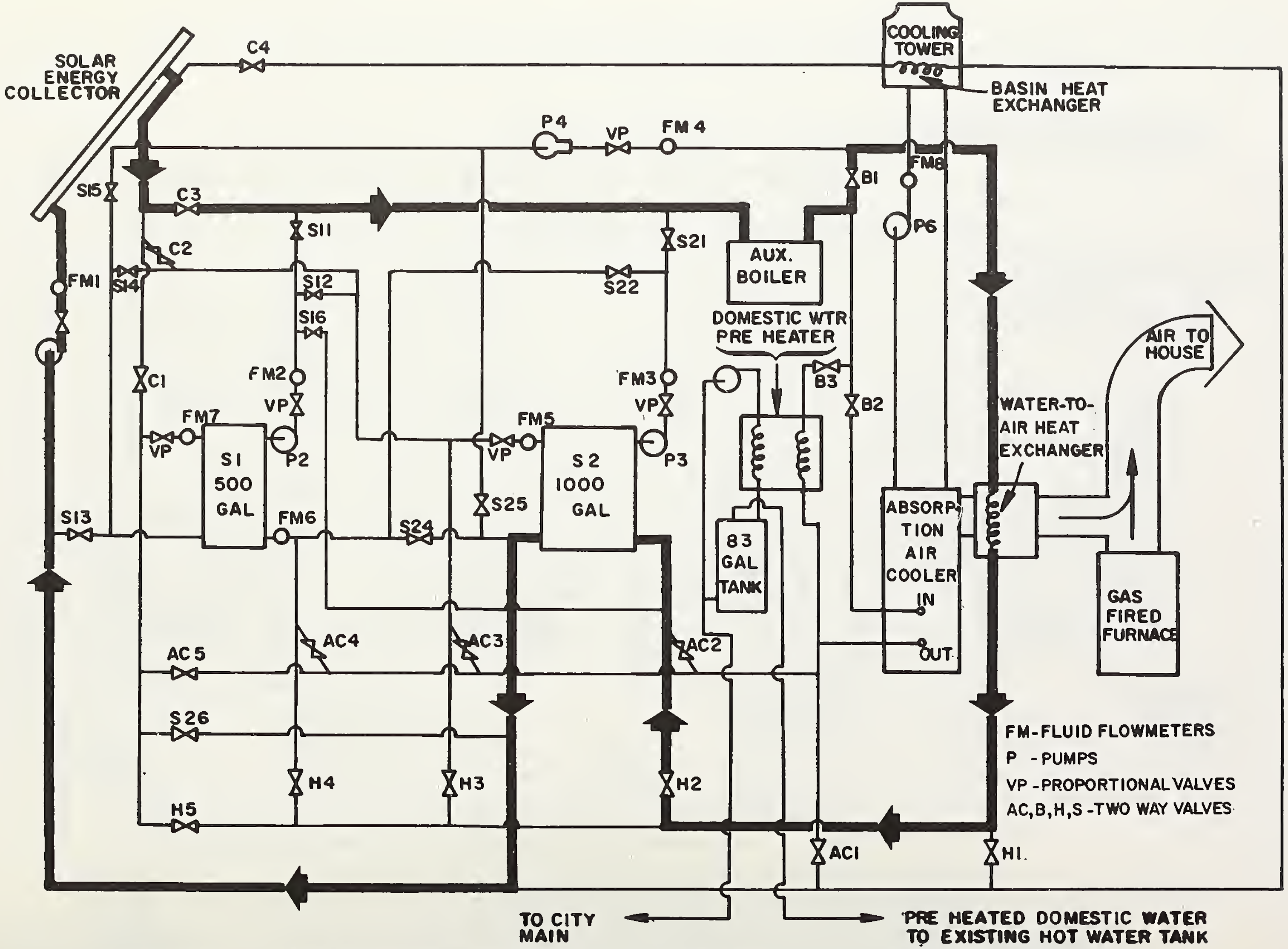


Figure 13. NBS solar heating and cooling system in the space heating mode with the large storage tank and solar collector in series.

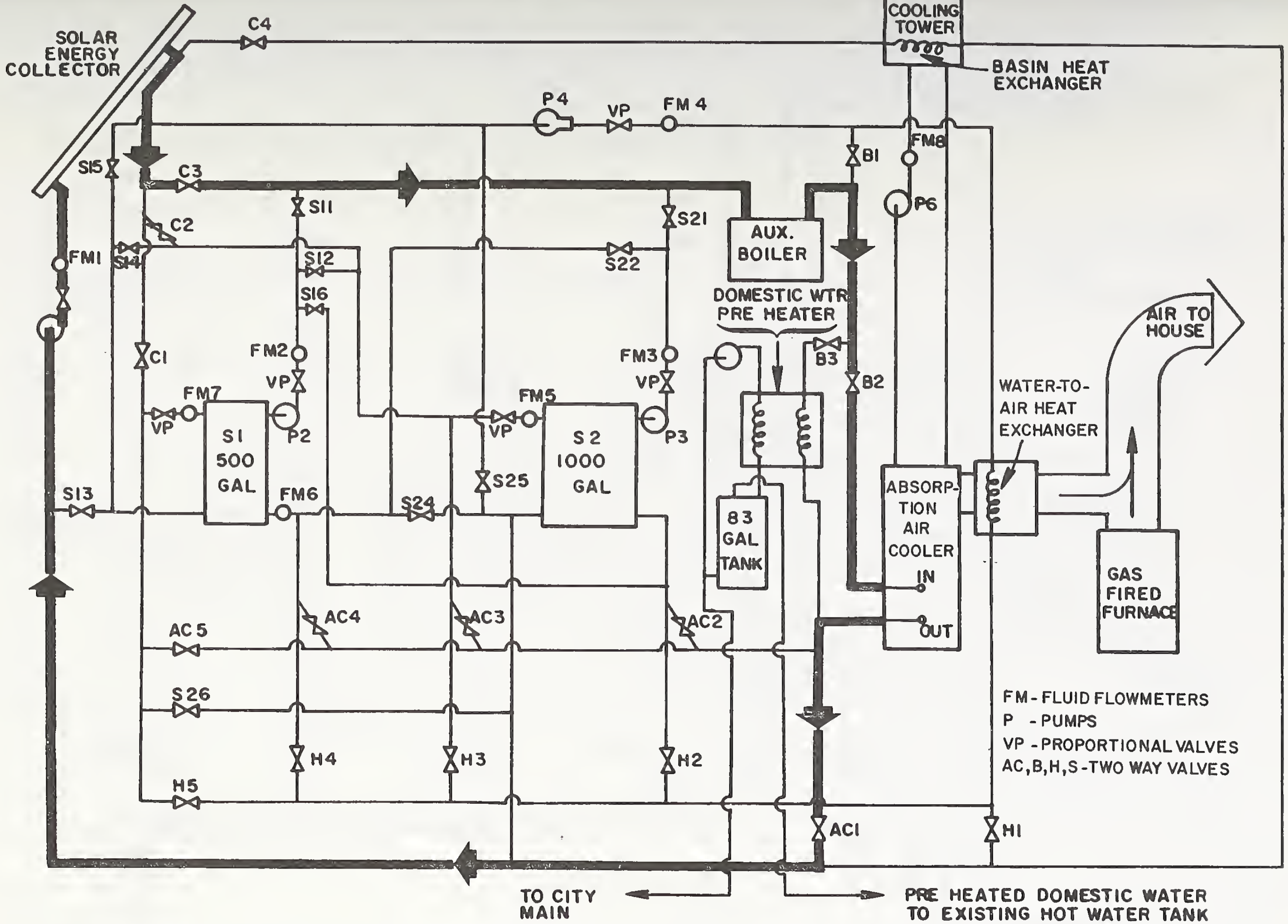


Figure 14. NBS solar heating and cooling system in the space cooling mode with the solar collector as the energy source.

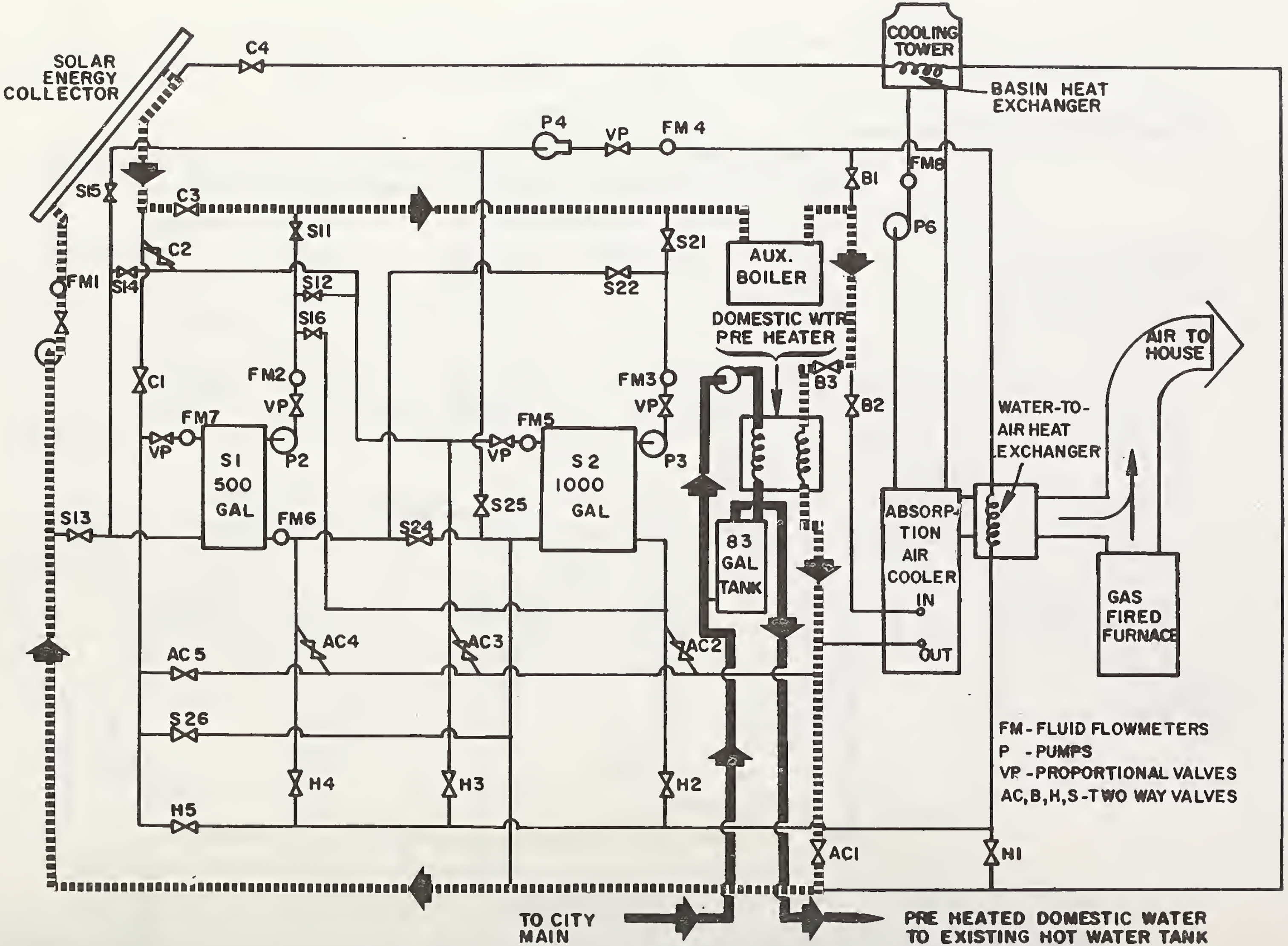


Figure 15. NBS solar heating and cooling system in the domestic hot water preheating mode with the solar collector as the energy source.

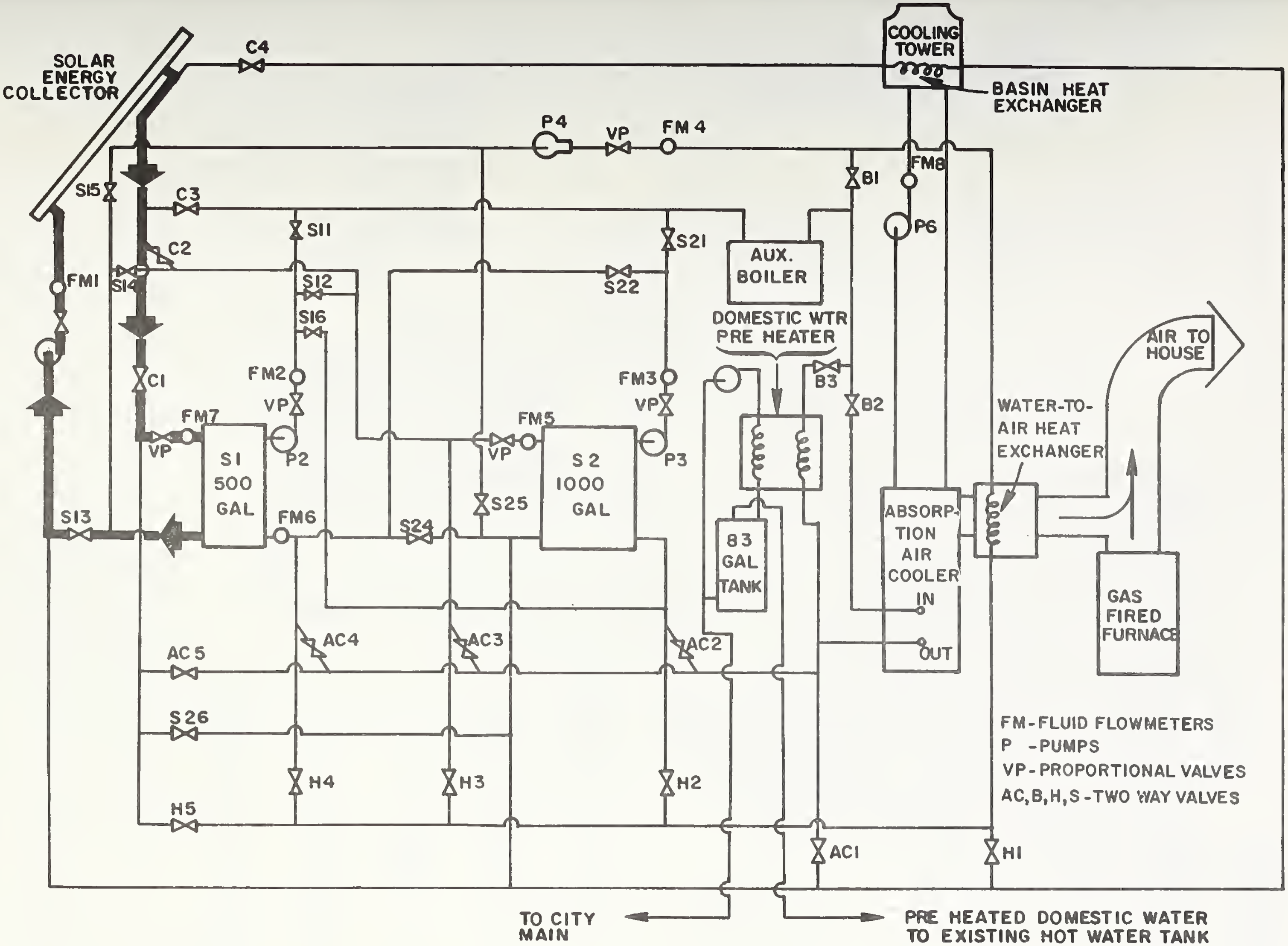
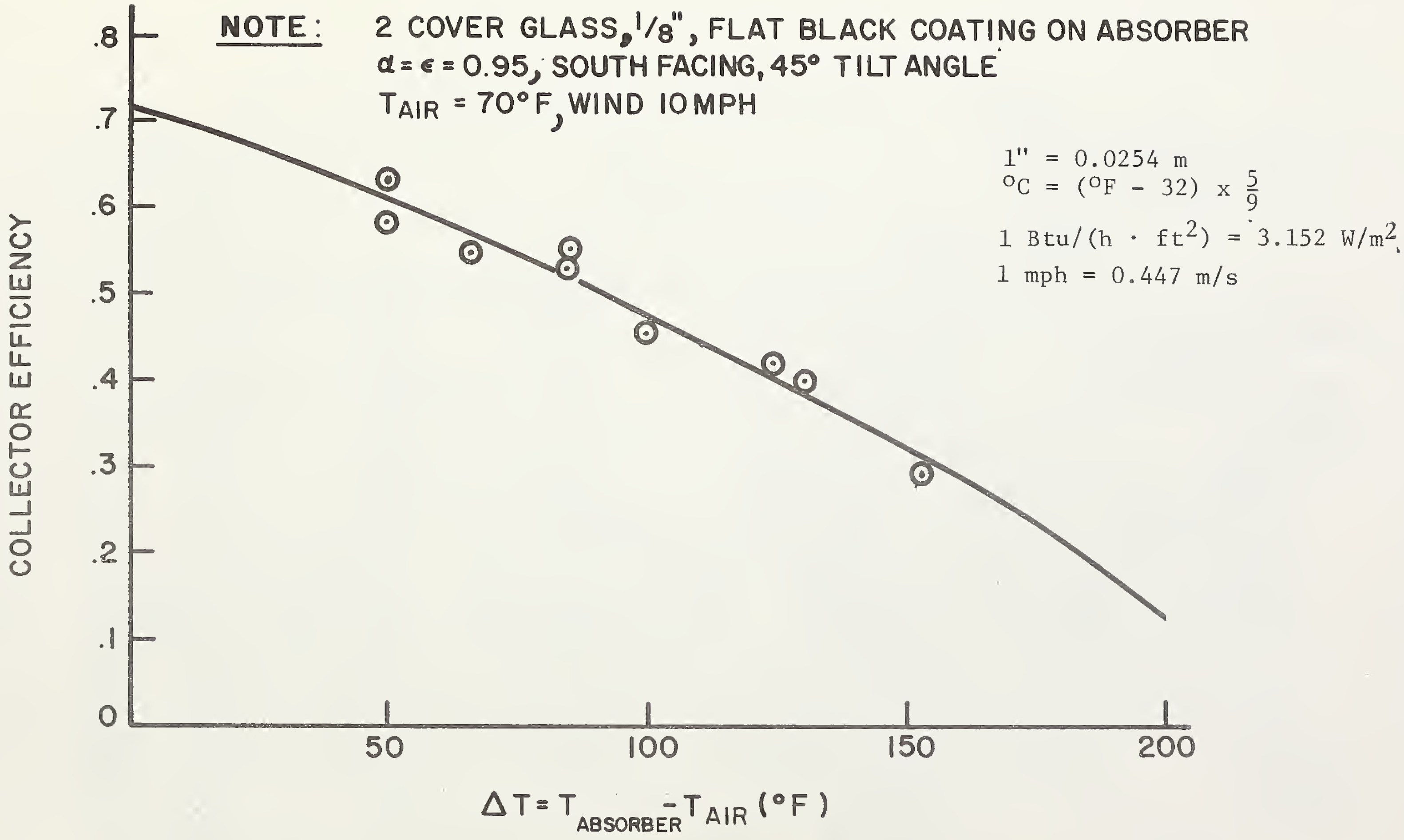


Figure 16. "Charging" the small storage tank with the solar collector in the NBS solar heating and cooling system.



KEY:	SYMBOL	q/A (BTU/HR FT^2)	T_{AIR} (°F)
THEORETICAL	——	300	70
EXPERIMENTAL	⊙	300-325	65-80

Figure 17. Comparison of experimental and theoretical results for the solar collector.

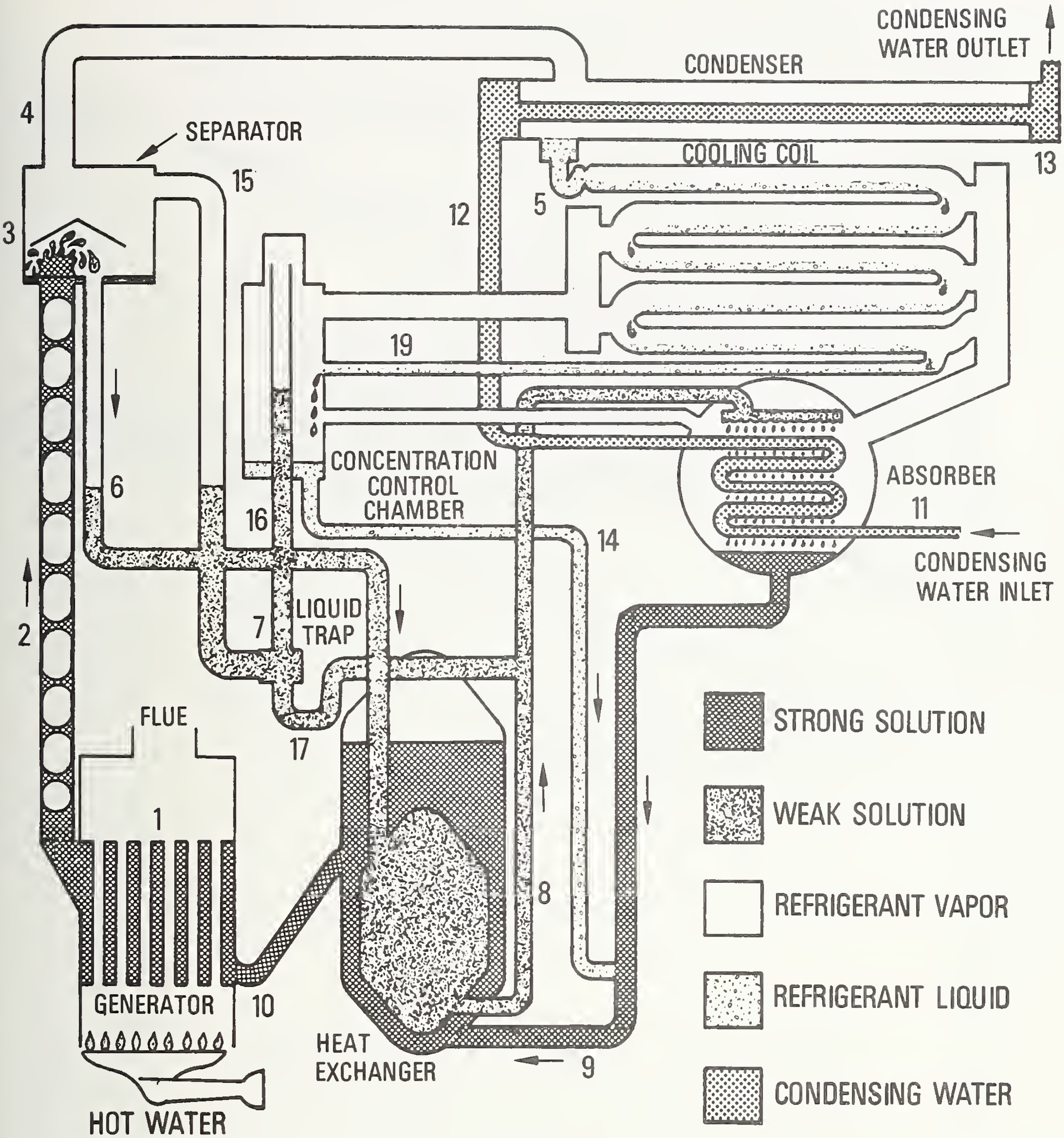


Figure 18. Schematic flow diagram of absorption hot-water-heated air conditioning unit.

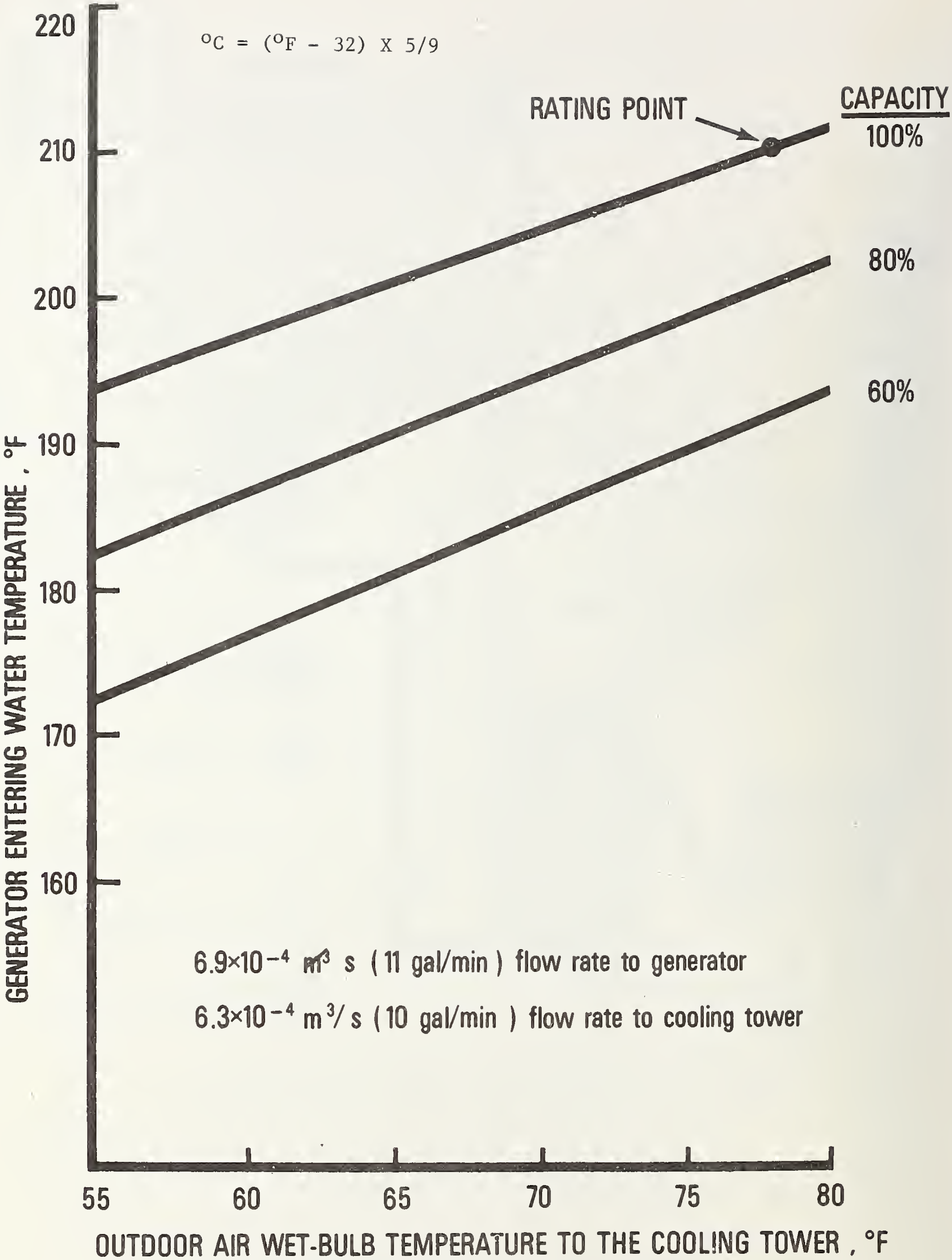


Figure 19. Estimated performance of the absorption hot-water-heated air conditioning unit.

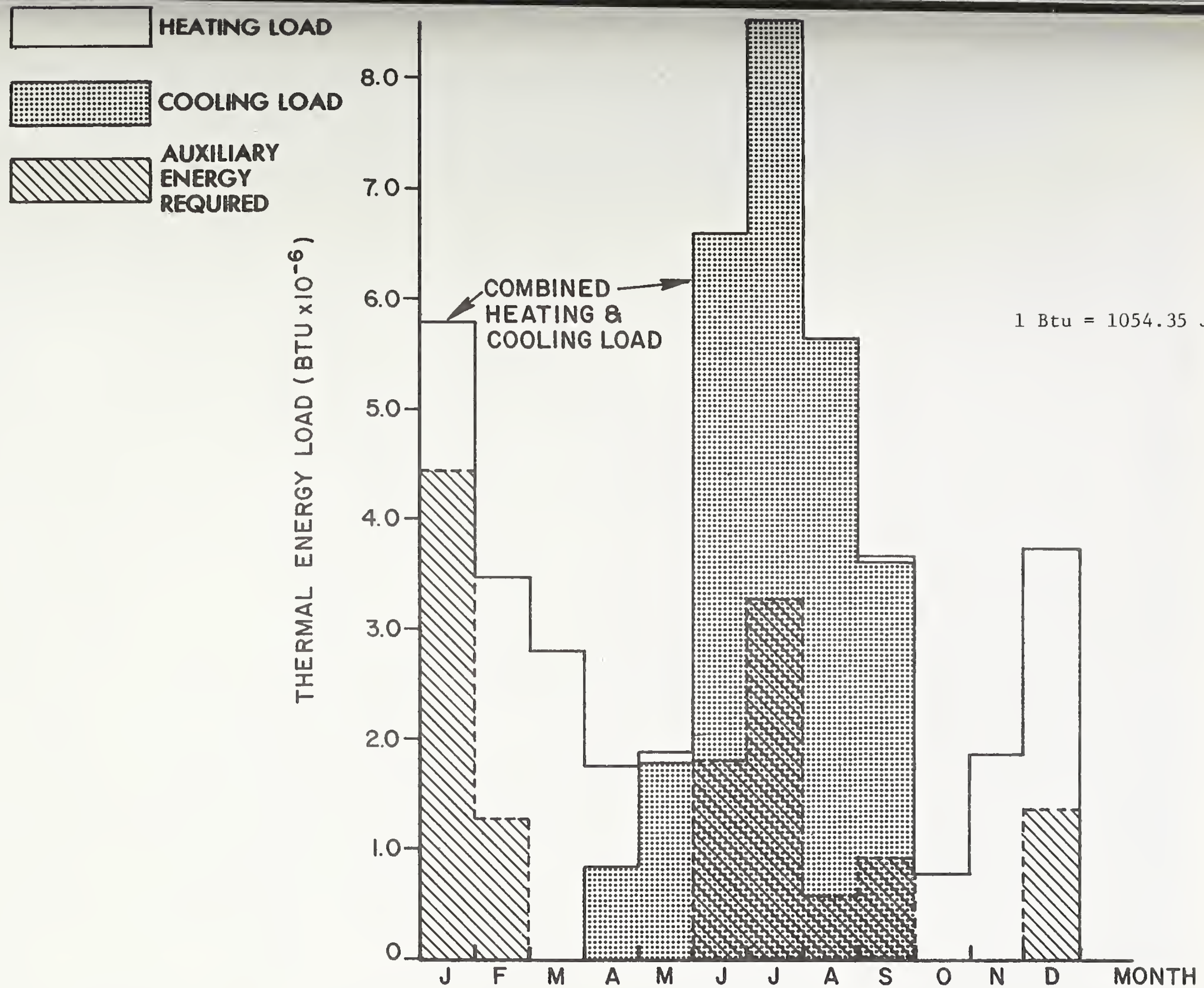


Figure 20. Predicted monthly heating and cooling loads and use of suxiliary energy for the NBS test house.

Figure 21. Solar collector boxes being moved to the site of the NBS test house.

Figure 22. Construction of solar collector rack on the NBS test house.

Figure 23. Solar collectors being lifted to the roof of the NBS test house.

Figure 24. Solar collectors being sealed in the collector rack on the NBS test house.

Figure 25. Mechanical equipment room being constructed on the NBS test house.

Figure 26. Moving 3.8 m^3 (1000 gallon) storage tank into place in the NBS test house.

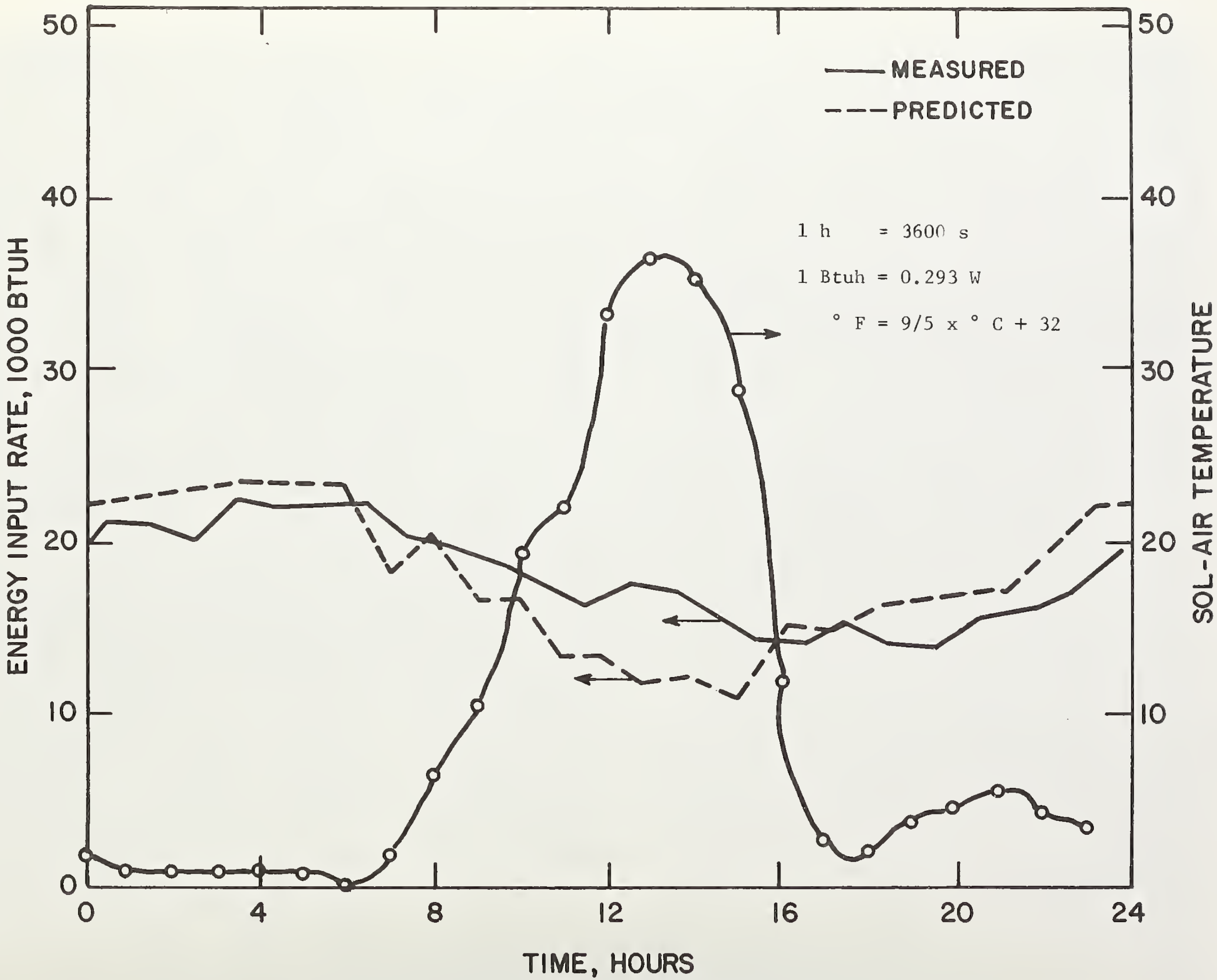


Figure 27. A comparison between measured and predicted rates of energy input for a winter heating test on the NBS test house using its conventional equipment.

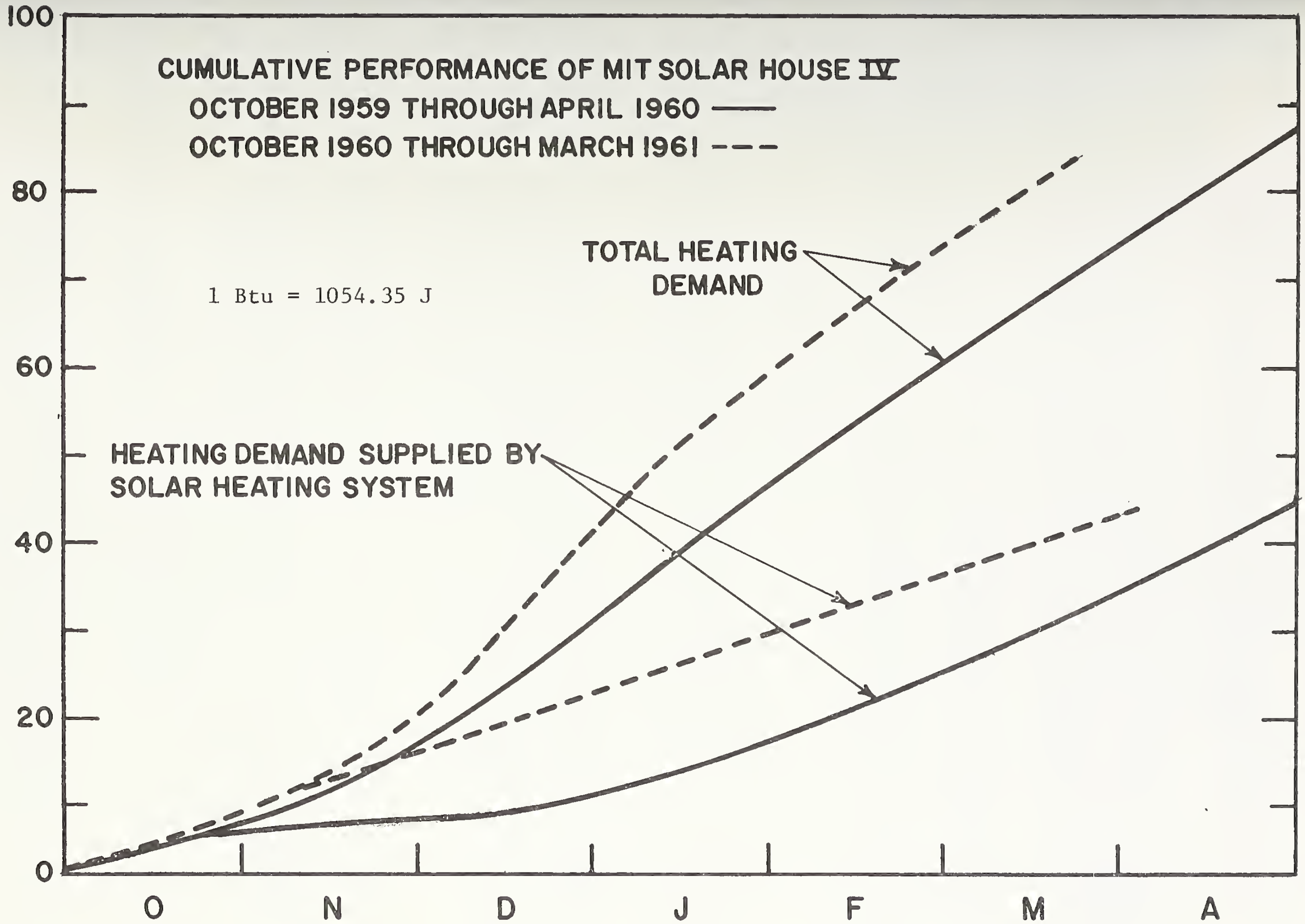


Figure 28. Cumulative energy use for the MIT solar house IV during two winter heating seasons.

Table 1

Construction Details of the Test House
from Inside to Outside

External Walls

1/2 inch (1.27 cm) gypsum board

2 X 4 inch (5.08 X 10.16 cm) wood studs (or 3 1/2 inches (8.89 cm) glass fiber batt insulation)

1/2 inch (1.27 cm) plywood sheathing

5/8 inch (1.59 cm) redwood siding

Roofs

1/2 inch (1.27 cm) gypsum board

2 X 6 inch (5.08 X 15.24 cm) wood joists (or 5 1/2 inch (13.97 cm) glass fiber batt insulation)

1/2 inch (1.27 cm) plywood sheathing

1/16 inch (.159 cm) asphalt roofing felt

1/8 inch (.318 cm) asphalt shingles

Floor

1/4 inch (.635 cm) nylon carpet (or 1/16 inch (.159 cm) asphalt tile)

5/8 inch (.635 cm) plywood sheathing

2 X 8 inch (5.08 x 20.32 cm) wood joists (or 7 1/2 inch (19.05 cm) glass fiber batt insulation)

1/4 inch (.635 cm) wood composition fiber board

Appendix A

Purchase Specification for Solar Collector Modules

1. General Description

A four bedroom townhouse located on the NBS Campus will be retrofitted with a solar energy system. Flat plate collector modules will be attached to the roofs of the test house. Water will be passed through these collector modules where it will be heated by solar energy. This heated water will be subsequently stored in a storage tank for later use for space heating, domestic hot water heating, and air conditioning. The present specification deals with the flat plate collector modules.

2. Technical Requirements

The flat plate collector modules from the top to the bottom in cross-section will consist of the following layers:

1. A tempered glass cover plate, preferably double strength and 0.0048 m (3/16 in.).

2. An air space.

3. An inner cover plate.

4. An inner air space.

5. An absorber plate, coated with a selective surface film, will contain passage ways for circulating water.

6. A backside layer of insulation.

These layers will be supported with a frame and covered with a backside cover plate. The housing for the collector modules must be weatherproof to avoid water condensation when exposed to outdoor weather conditions. The collector modules shall be identical and must be approximately 2.4 m (8 ft) in overall length and 0.9 to 1.2 m (3 to 4 ft) in overall width. The number of modules supplied will be such that the total top cover area is 51 m^2 (550 ft^2). The absorber area shall be greater than 90 percent of the top cover area. The water inlet and outlet piping connections shall not extend more than 0.1 m (4 in.) from the opposite short sides of the collector modules.

It is desirable that the pressure drop at a flow rate of 1.13×10^{-5} $m^3/(s \cdot m^2)$ (1 gal/($h \cdot ft^2$)) of collector as measured between the inlet and outlet piping connections shall be less than 3400 N/m^2 (1/2 psig) when determined with the collector in the horizontal position. The absorber plates must be capable of withstanding a fluid static pressure of 2.07×10^5 N/m^2 (30 psig). The collector modules must weigh less than 2.3 kg/m^2 (5 lb/ft^2) of collector area. Each collector module shall be provided with mounting lugs at its four corners. The design of the modules shall be such as to provide for relative ease of integration of a single collector into a collection system. Allowance must be made for venting of the collector in order to prevent moisture buildup.

The selective surface film on the absorbing surface must have an absorptance to emittance ratio, α/ε, of approximately 4.5 under operating conditions. The thermal conductance of the backside insulation shall be less than 0.57 $W/(m^2 \cdot °C)$ (.10 $Btu/(h \cdot ft^2 \cdot °F)$).

The measured steady-state collector efficiency is defined as the ratio of thermal energy transferred to the heat transfer fluid per square foot of overall collector area to the normal intensity of solar radiation striking the surface area. The steady-state collector efficiency must be at least 50% at the following conditions:

- normal intensity of solar radiation as measured by an Eppley pyranometer or equivalent in a plane parallel to the collector cover plate, $I = 760\ W/m^2$ (240 Btu/(h · ft^2))

- mass flow rate of water, $\dot{m} = 1.13 \times 10^{-5}\ m^3/(s \cdot m^2)$ (1 gal/(h · ft^2))

- surface temperature difference between absorber surface and ambient air, Δt = 61 °C (110 °F)

- water inlet temperature, t_i = 77 °C (170 °F)

- wind velocity: $2.2 < V < 4.5$ m/s ($5 < V < 10$ mph)

This must be a minimum efficiency for all orientations.

3. Exterior Appearance

The exterior housing of the collector modules must be finished, so as to appear like stained redwood. The siding material of the test house is stained redwood, and it is necessary that the collector modules blend in and be compatible with the test house.

4. Other Requirements

A. Packaging

The entire system, when properly packaged, crated, and handled normally, shall be transportable by common carriers without damage. No special carriers or moving techniques shall be required. The vendor will assume responsibility for damages that occur during shipment which are the result of improper packaging.

B. Operating Conditions

The collector modules with water flowing through them must be capable of operating over an ambient temperature range from -18 °C (0 °F) to 43 °C (110 °F) and absorber surface temperatures from -18 °C (0 °F) to 149 °C (300 °F) with a minimum of degradation of the original performance characteristics of the collector modules.

It is desirable that no damage or degradation of thermal performance should occur if the modules are left exposed to normal sunlight conditions without fluid in the collector plates.

C. Service Life

The equipment must have an expected life and service of at least ten years.

D. Documentation

The vendor shall provide in writing a detailed description of the collector modules including information and test data on the collector efficiency and absorptance to to emittance ratio.

E. Warranty

The solar collector modules shall carry a warranty covering repair labor and parts for a period of one year after final acceptance by NBS at no extra cost to the Government. This warranty is intended to cover such failures as leaks, degradation of the selective surface on the absorber plates, and breakage of the cover plates due to faulty design.

F. Delivery

Delivery shall be made to NBS within 30 days after award of contract.

G. Delays - Liquidation Damages

After award is made to a bidder, if he fails to meet the delivery requirements there will be deducted from payment to him, as a liquidated damage, not as a penalty, an amount equal to 100 dollars/day of the undelivered or nonconforming portions of the order for each calendar day of delay.

Appendix B

Empirical Routine for the Prediction of Solar Collector Performance

The energy collected by a flat plate collector depends upon the following parameters:

- Incident solar radiation
- Ambient temperature
- Collector plate (absorber) temperature
- Wind velocity and direction
- Type of glazing
- Emissivity (ε) and absorptivity (α) of the absorber surface
- Thermal properties of the insulation that surrounds the absorber plates
- Air convection patterns in the space between the absorber and cover plate
- Transmittance, reflectance, and absorptance of the cover plate
- Cloud cover
- Moisture and CO_2 content of the atmospheric air

Although it is possible to write a comprehensive analytical simulation model that takes into account most of these parameters, the approach employed in this study was to use an empirical routine developed by Kusuda [49] and based on the performance of double-glazed collectors reported by the University of Pennsylvania [50, 51].

The performance of collectors having a common black absorber and selective black absorber ($\alpha = 0.94$, $\varepsilon = 0.1 \sim 0.15$) were reported in the form of curves showing collector efficiency versus temperature difference between the absorber surface and the cover plate surface such as shown in Figures C1 and C2. Since the cover plate surface temperature is usually unknown, a modification was made to replace the cover plate temperature by the ambient air temperature.

The efficiency curves may be approximated by straight lines in the form of:

$$\eta = \eta_o \left(1 - \frac{\Delta t}{\Delta t_{max}}\right) \tag{1}$$

where

$$\eta = \frac{Q}{I} = \frac{\text{energy collected}}{\text{incident solar radiation}} \tag{2}$$

Δt = temperature difference between the absorber plate and cover plate = $t_p - t_c$

Δt_{max} = intercept of the efficiency curve with the abscissa or the maximum temperature difference between the cover plate and the absorber surface

t_p = absorber surface temperature

t_c = cover plate surface temperature

η_o = intercept of the efficiency curve with the ordinate

The value of Δt_{max} depends upon the incident radiation and the result of the experiments also shows that it is possible to approximate Δt_{max} by a linear function such that

$$\Delta t_{max} = b \times I$$

The data on the double-glazed collector can be reduced to yield

$$b = 1.375$$

for the selective surface absorber plate and

$$b = 0.713$$

for the common black surface absorber. The same data shows that the best numerical value for η_o is 0.78.

There exists the following heat transfer relationship between the cover plate temperature t_c and the ambient temperature t_a if it is assumed that all of the heat loss from the collector takes place through the cover plate.

$$h\ (t_c - t_a) = I - Q = I\ (1 - \eta) \qquad (3)$$

where h = surface heat transfer coefficient at the outer cover plate.

Combining equations (1), (2), and (3), results in the following equation, which is useful for approximating the solar collector efficiency as a function of incident solar radiation I, ambient temperature t_a, and absorber surface temperature t_p:

$$\eta = \eta_o \frac{\{1 - \eta_o - 1 + \frac{h}{I}(t_p - t_a)\}}{\eta_o + hb} \qquad (4)$$

Since the value of h is directly related to the wind speed over the cover plate, equation (4) accounts for the wind as well.

The value of solar collector efficiency was thus evaluated for every hour throughout the day by using the hourly data on h, I, and t_a from the weather tape and for given values of t_s, η_o, and b, which are the basic parameters of the specific collector.

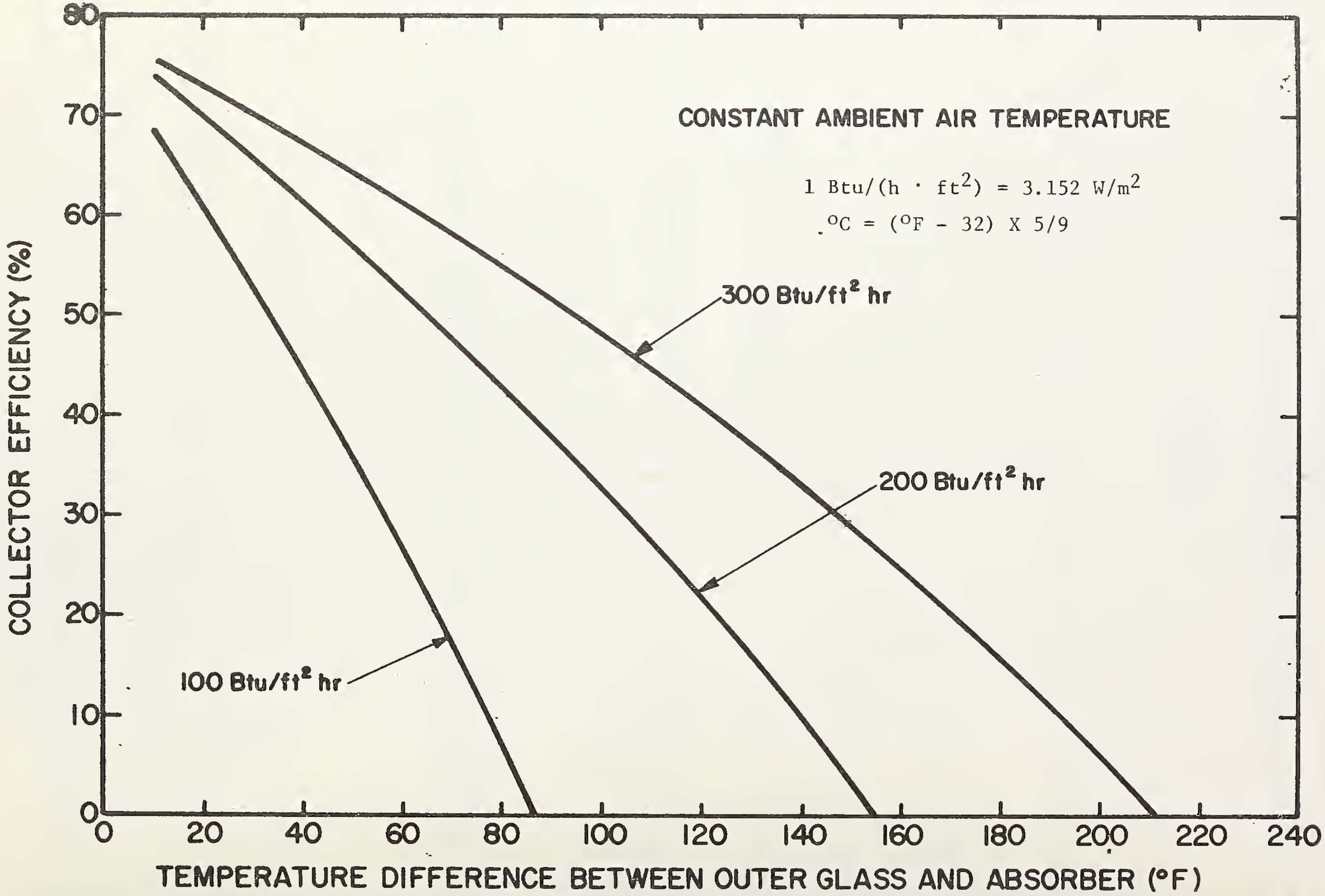


Figure C1. Collector efficiency data as reported by the University of Pennsylvania for a double-glazed flat-plate collector having a flat black absorber surface.

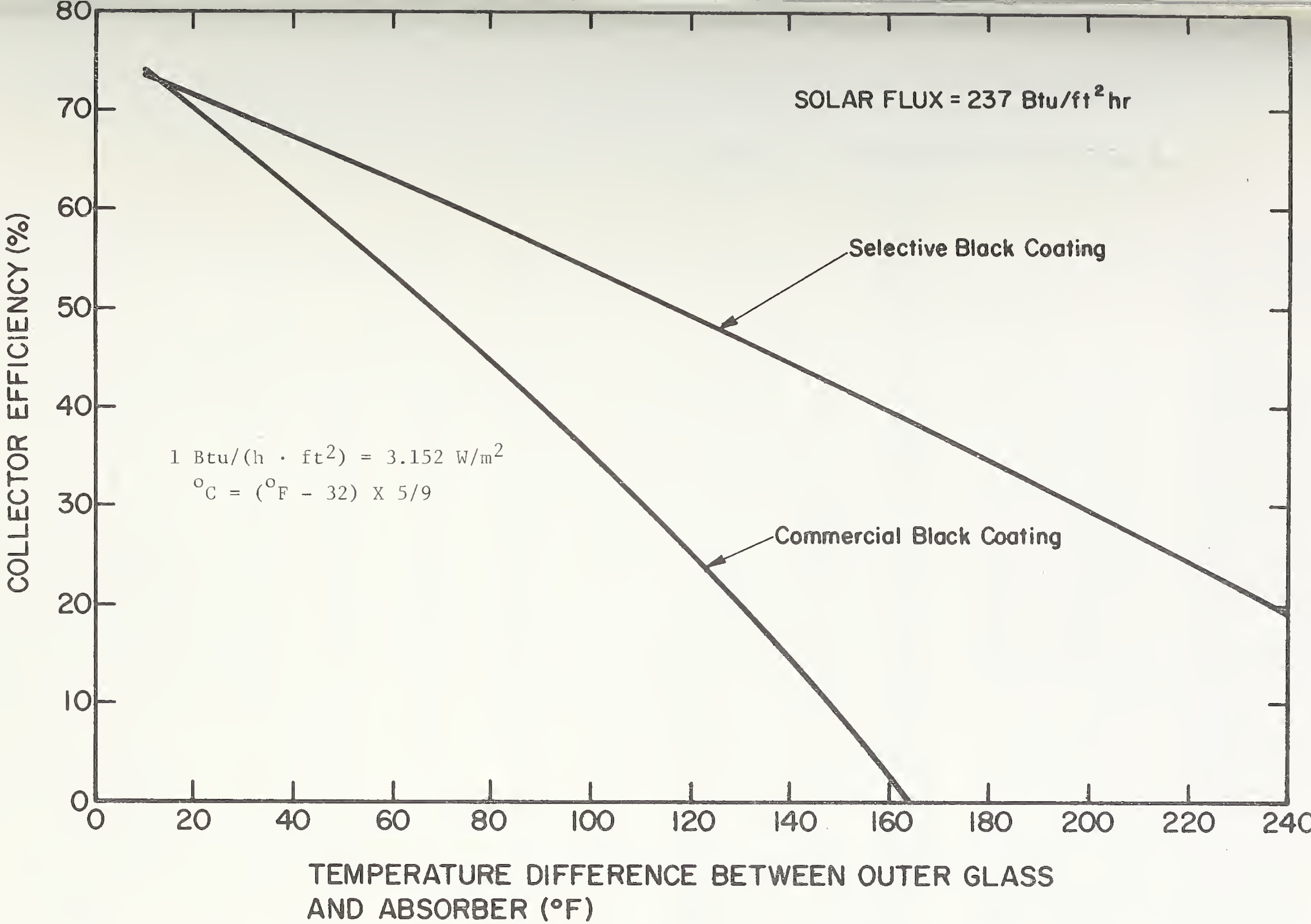


Figure C2. Collector efficiency data as reported by the University of Pennsylvania for a double-glazed flat-plate collector.

Appendix C

Prediction of Solar Collector Performance for a
Typical Weather Year (1957) in Washington, D.C.
for a South-Facing Collector at Various Tilt Angles

Table C1

Thermal Output for the Year 1957 and a 12° Tilt Angle

The following twelve pages show the day by day thermal output in Btu for double-glazed flat-plate solar collectors for the year 1957, Washington, D.C., under all combinations of the following conditions:

absorber surface; flat black and selective black

fluid temperature; 60 °C (140 °F) and 104.4 °C (220 °F)

inclination; normal to the sun, horizontal, and at a tilt angle of 12° from the horizon

1 Btu = 1054.35 J

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
1	1	33.	255.	600.	8.	262.	0.	38.	0.	0.	0.	172.	0.	0.
		1	1		1957	1	1		13743					
1	2	24.	743.	1106.	201.	768.	22.	228.	0.	36.	183.	460.	0.	204.
1	3	29.	348.	659.	2.	345.	0.	101.	0.	0.	57.	233.	0.	57.
1	4	42.	557.	817.	119.	512.	25.	187.	0.	8.	165.	352.	0.	136.
1	5	36.	13.	82.	0.	9.	0.	2.	0.	0.	0.	20.	0.	0.
1	6	31.	0.	45.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	7	36.	88.	214.	19.	81.	3.	38.	0.	0.	34.	69.	0.	29.
1	8	36.	12.	130.	0.	10.	0.	0.	0.	0.	0.	6.	0.	0.
1	9	37.	0.	88.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	10	38.	126.	394.	0.	113.	0.	26.	0.	0.	0.	118.	0.	0.
1	11	28.	81.	238.	0.	75.	0.	19.	0.	0.	3.	61.	0.	4.
1	12	33.	0.	69.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.
1	13	38.	151.	412.	0.	122.	0.	24.	0.	0.	1.	117.	0.	0.
1	14	24.	752.	1093.	248.	762.	55.	248.	0.	67.	221.	465.	0.	231.
1	15	17.	0.	12.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	16	23.	585.	875.	202.	587.	57.	213.	0.	62.	185.	389.	0.	189.
1	17	14.	121.	252.	3.	120.	0.	3.	0.	0.	0.	45.	0.	0.
1	18	18.	386.	715.	110.	397.	18.	117.	0.	19.	87.	256.	0.	90.
1	19	25.	882.	1178.	380.	853.	123.	334.	0.	113.	330.	562.	11.	314.
1	20	33.	10.	143.	0.	10.	0.	0.	0.	0.	0.	16.	0.	0.
1	21	40.	26.	177.	0.	15.	0.	8.	0.	0.	0.	31.	0.	0.
1	22	49.	0.	113.	0.	0.	0.	0.	0.	0.	0.	3.	0.	0.
1	23	49.	119.	368.	0.	102.	0.	42.	0.	0.	1.	123.	0.	0.
1	24	25.	77.	245.	0.	66.	0.	25.	0.	0.	16.	70.	0.	7.
1	25	30.	6.	113.	0.	1.	0.	0.	0.	0.	0.	0.	0.	0.
1	26	38.	60.	231.	0.	47.	0.	13.	0.	0.	0.	49.	0.	0.
1	27	41.	0.	77.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
1	28	37.	0.	69.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
1	29	38.	0.	78.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
1	30	38.	20.	115.	0.	13.	0.	4.	0.	0.	0.	21.	0.	0.
1	31	35.	0.	74.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MONTHLY TOTAL			5418.	10783.	1291.	5268.	302.	1670.	0.	306.	1283.	3645.	11.	1261.
AVERAGE		33.	175.	348.	42.	170.	10.	54.	0.	10.	41.	118.	0.	41.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL				HORIZONTAL				12 DEG TILT			
MONTH	DAY	DB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
2	1	38.	0.	73.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
		32	32		1957	2	1		13743					
2	2	40.	686.	921.	254.	602.	91.	259.	0.	56.	233.	438.	28.	177.
2	3	41.	13.	122.	0.	7.	0.	0.	0.	0.	0.	11.	0.	0.
2	4	51.	86.	282.	0.	49.	0.	34.	0.	0.	9.	85.	0.	0.
2	5	38.	0.	84.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.
2	6	35.	0.	77.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
2	7	40.	0.	102.	0.	0.	0.	0.	0.	0.	0.	7.	0.	0.
2	8	42.	0.	111.	0.	0.	0.	0.	0.	0.	0.	13.	0.	0.
2	9	44.	0.	101.	0.	0.	0.	0.	0.	0.	0.	8.	0.	0.
2	10	51.	459.	778.	0.	396.	30.	212.	0.	10.	130.	365.	0.	94.
2	11	36.	0.	50.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
2	12	31.	600.	919.	165.	562.	84.	246.	0.	63.	181.	417.	13.	153.
2	13	37.	315.	555.	0.	270.	17.	169.	0.	6.	84.	287.	0.	61.
2	14	36.	107.	255.	0.	101.	0.	28.	0.	0.	10.	68.	0.	7.
2	15	34.	0.	107.	0.	0.	0.	1.	0.	0.	0.	16.	0.	0.
2	16	39.	133.	373.	0.	110.	0.	104.	0.	0.	33.	188.	0.	24.
2	17	35.	455.	848.	74.	461.	15.	235.	0.	16.	98.	390.	0.	105.
2	18	41.	931.	1249.	376.	873.	285.	503.	9.	255.	466.	710.	94.	431.
2	19	43.	0.	107.	0.	0.	0.	0.	0.	0.	0.	23.	0.	0.
2	20	32.	1071.	1498.	400.	1073.	296.	587.	0.	301.	502.	830.	88.	509.
2	21	35.	1324.	1636.	710.	1242.	454.	684.	109.	400.	688.	934.	290.	623.
2	22	38.	544.	850.	113.	457.	57.	246.	0.	39.	152.	385.	13.	113.
2	23	45.	154.	364.	0.	100.	6.	68.	0.	0.	36.	144.	0.	12.
2	24	47.	892.	1182.	302.	782.	284.	501.	43.	229.	446.	691.	128.	375.
2	25	49.	8.	163.	0.	0.	0.	11.	0.	0.	0.	54.	0.	0.
2	26	56.	1.	177.	0.	0.	0.	19.	0.	0.	0.	59.	0.	0.
2	27	55.	98.	310.	0.	52.	15.	87.	0.	0.	46.	140.	0.	19.
2	28	34.	0.	55.	0.	0.	0.	0.	0.	0.	0.	4.	0.	0.
MONTHLY														
TOTAL			7877.	13349.	2394.	7137.	1634.	3995.	162.	1375.	3114.	6273.	655.	2703.
AVERAGE		41.	281.	477.	85.	255.	58.	143.	6.	49.	111.	224.	23.	97.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
3	1	35.	14.	143.	0.	9.	0.	0.	0.	0.	0.	21.	0.	0.
		60	60		1957	3	1		13743					
3	2	43.	214.	481.	0.	192.	42.	159.	0.	30.	95.	245.	0.	78.
3	3	36.	1280.	1646.	572.	1236.	446.	747.	56.	424.	678.	981.	206.	649.
3	4	34.	1059.	1379.	434.	1014.	397.	661.	95.	369.	597.	875.	203.	565.
3	5	37.	929.	1243.	366.	869.	378.	611.	39.	338.	553.	798.	156.	510.
3	6	41.	29.	157.	0.	23.	2.	41.	0.	0.	19.	78.	0.	13.
3	7	40.	28.	158.	0.	23.	2.	41.	0.	0.	18.	80.	0.	14.
3	8	42.	53.	195.	0.	44.	2.	77.	0.	0.	33.	120.	0.	25.
3	9	41.	86.	347.	0.	83.	24.	133.	0.	23.	50.	195.	0.	50.
3	10	40.	992.	1402.	384.	973.	416.	707.	51.	404.	594.	901.	179.	580.
3	11	42.	417.	699.	78.	368.	126.	323.	18.	100.	223.	433.	47.	177.
3	12	54.	303.	555.	3.	216.	78.	226.	0.	46.	131.	311.	0.	89.
3	13	53.	977.	1287.	305.	864.	443.	686.	88.	362.	607.	861.	166.	517.
3	14	57.	1247.	1531.	565.	1084.	603.	832.	202.	501.	782.	1023.	324.	671.
3	15	59.	211.	449.	0.	123.	69.	183.	0.	32.	113.	256.	0.	76.
3	16	54.	1350.	1680.	615.	1225.	637.	904.	168.	551.	831.	1108.	308.	741.
3	17	54.	1062.	1370.	327.	921.	463.	707.	73.	378.	614.	877.	161.	524.
3	18	49.	231.	481.	28.	194.	96.	247.	0.	73.	148.	326.	19.	123.
3	19	43.	63.	233.	0.	55.	8.	124.	0.	3.	45.	170.	0.	38.
3	20	43.	64.	257.	0.	56.	7.	128.	0.	1.	48.	178.	0.	40.
3	21	46.	1071.	1423.	443.	1000.	506.	773.	112.	459.	652.	949.	236.	601.
3	22	44.	106.	276.	0.	80.	51.	148.	0.	27.	92.	200.	0.	67.
3	23	49.	1366.	1696.	596.	1245.	689.	963.	210.	605.	868.	1153.	343.	780.
3	24	53.	749.	1005.	224.	627.	377.	599.	65.	296.	503.	722.	133.	407.
3	25	42.	89.	293.	0.	75.	19.	170.	0.	11.	68.	221.	0.	54.
3	26	45.	494.	676.	181.	440.	337.	485.	86.	288.	432.	583.	157.	380.
3	27	47.	294.	572.	60.	255.	177.	352.	18.	151.	244.	434.	41.	216.
3	28	46.	159.	331.	0.	117.	92.	209.	0.	52.	142.	265.	0.	101.
3	29	46.	513.	806.	131.	449.	320.	504.	59.	283.	407.	607.	124.	361.
3	30	45.	697.	1091.	146.	632.	308.	590.	28.	275.	406.	711.	84.	369.
3	31	44.	1433.	1771.	703.	1326.	810.	1088.	330.	729.	988.	1264.	475.	900.
MONTHLY TOTAL			17580.	25631.	6162.	15819.	7925.	13417.	1696.	6813.	10982.	16948.	3361.	9716.
AVERAGE		45.	567.	827.	199.	510.	256.	433.	55.	220.	354.	547.	108.	313.

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SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
4	1	46.	130.	359.	0.	98.	74.	203.	0.	43.	121.	258.	0.	89.
		91	91		1957	4	1		13743					
4	2	61.	694.	1001.	120.	557.	411.	635.	64.	319.	513.	744.	122.	416.
4	3	48.	419.	713.	75.	342.	204.	359.	43.	145.	267.	436.	65.	207.
4	4	44.	101.	318.	0.	84.	36.	224.	0.	25.	84.	277.	0.	67.
4	5	54.	208.	435.	2.	149.	137.	276.	0.	80.	192.	334.	0.	134.
4	6	50.	201.	438.	45.	177.	132.	316.	24.	111.	187.	376.	44.	164.
4	7	57.	1299.	1636.	527.	1157.	746.	1032.	198.	641.	885.	1170.	310.	772.
4	8	49.	133.	361.	0.	101.	72.	250.	0.	42.	123.	305.	0.	92.
4	9	46.	952.	1374.	293.	911.	579.	896.	92.	547.	697.	1022.	185.	663.
4	10	50.	1303.	1690.	504.	1206.	748.	1070.	229.	672.	886.	1207.	344.	808.
4	11	55.	1248.	1574.	549.	1115.	837.	1104.	311.	751.	972.	1241.	426.	883.
4	12	59.	1010.	1262.	413.	889.	689.	887.	236.	582.	794.	994.	314.	686.
4	13	42.	713.	1063.	201.	663.	497.	775.	112.	462.	596.	881.	200.	559.
4	14	43.	817.	1248.	203.	762.	516.	809.	123.	483.	616.	918.	207.	579.
4	15	45.	1513.	1879.	735.	1397.	953.	1253.	397.	865.	1092.	1391.	522.	1002.
4	16	51.	410.	716.	15.	344.	218.	458.	0.	165.	282.	524.	3.	223.
4	17	58.	248.	440.	0.	159.	195.	333.	0.	121.	243.	384.	0.	166.
4	18	63.	414.	655.	48.	274.	297.	462.	43.	196.	352.	523.	58.	249.
4	19	61.	410.	672.	30.	303.	257.	460.	12.	170.	316.	520.	24.	223.
4	20	63.	584.	814.	176.	450.	440.	615.	110.	343.	509.	686.	151.	408.
4	21	75.	1394.	1613.	626.	1153.	972.	1183.	437.	776.	1077.	1284.	530.	879.
4	22	65.	635.	966.	127.	524.	484.	730.	83.	411.	556.	809.	150.	482.
4	23	64.	489.	713.	89.	349.	377.	558.	75.	281.	438.	620.	114.	339.
4	24	76.	1156.	1366.	449.	920.	881.	1064.	387.	692.	975.	1154.	463.	779.
4	25	65.	320.	583.	0.	212.	198.	403.	0.	112.	245.	450.	0.	154.
4	26	67.	801.	1028.	298.	628.	552.	726.	157.	403.	613.	788.	200.	463.
4	27	76.	1636.	1846.	838.	1360.	1197.	1380.	618.	971.	1298.	1478.	714.	1069.
4	28	77.	1279.	1452.	661.	1038.	1054.	1192.	527.	843.	1147.	1282.	616.	931.
4	29	71.	1255.	1513.	572.	1056.	914.	1141.	377.	757.	997.	1224.	459.	835.
4	30	69.	1799.	2076.	934.	1548.	1266.	1510.	594.	1068.	1363.	1604.	693.	1166.
MONTHLY TOTAL			23571.	31804.	8530.	19926.	15934.	22307.	5250.	13078.	18436.	24888.	6913.	15485.
AVERAGE		58.	786.	1060.	284.	664.	531.	744.	175.	436.	615.	830.	230.	516.

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WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
5	1	71.	1819.	2088.	956.	1559.	1291.	1526.	594.	1083.	1384.	1617.	693.	1178.
	121		121		1957	5		1	13743					
5	2	63.	1536.	1859.	744.	1349.	1136.	1398.	539.	990.	1230.	1487.	632.	1084.
5	3	53.	1381.	1751.	639.	1255.	1033.	1333.	450.	938.	1123.	1422.	540.	1029.
5	4	50.	1214.	1616.	502.	1111.	926.	1231.	362.	847.	1011.	1312.	446.	931.
5	5	56.	1047.	1373.	427.	908.	800.	1044.	322.	687.	872.	1111.	382.	757.
5	6	62.	986.	1296.	372.	831.	826.	1052.	332.	701.	899.	1122.	400.	772.
5	7	65.	1766.	2062.	905.	1532.	1284.	1537.	608.	1093.	1363.	1614.	694.	1174.
5	8	70.	1845.	2105.	983.	1580.	1357.	1578.	659.	1133.	1433.	1653.	743.	1208.
5	9	73.	1553.	1832.	674.	1297.	1129.	1362.	454.	926.	1198.	1426.	526.	993.
5	10	75.	1183.	1460.	475.	962.	896.	1120.	299.	699.	950.	1172.	346.	757.
5	11	69.	304.	568.	0.	179.	259.	441.	0.	161.	292.	472.	0.	193.
5	12	68.	726.	960.	202.	560.	592.	769.	187.	463.	638.	813.	228.	508.
5	13	77.	1183.	1403.	542.	944.	996.	1169.	489.	813.	1057.	1225.	548.	873.
5	14	76.	1094.	1307.	499.	911.	1010.	1182.	461.	837.	1073.	1244.	524.	899.
5	15	76.	1088.	1313.	467.	891.	953.	1127.	395.	781.	1010.	1180.	448.	837.
5	16	68.	957.	1310.	222.	789.	738.	1015.	199.	629.	792.	1062.	249.	681.
5	17	64.	334.	567.	26.	232.	323.	510.	37.	221.	358.	943.	46.	255.
5	18	71.	1072.	1294.	482.	880.	978.	1140.	474.	809.	1034.	1193.	528.	865.
5	19	62.	214.	466.	0.	136.	203.	418.	0.	125.	233.	448.	0.	154.
5	20	58.	268.	485.	0.	172.	258.	439.	0.	162.	288.	467.	0.	191.
5	21	54.	195.	435.	0.	127.	187.	404.	0.	124.	216.	432.	0.	150.
5	22	61.	218.	469.	0.	137.	211.	424.	0.	134.	239.	451.	0.	159.
5	23	77.	1443.	1681.	661.	1212.	1187.	1408.	541.	992.	1234.	1446.	593.	1039.
5	24	76.	1309.	1573.	531.	1076.	1096.	1318.	467.	900.	1141.	1359.	519.	945.
5	25	70.	1485.	1791.	691.	1270.	1253.	1502.	658.	1080.	1305.	1547.	715.	1134.
5	26	76.	1080.	1331.	404.	856.	964.	1175.	417.	782.	1008.	1213.	461.	827.
5	27	72.	622.	885.	116.	448.	526.	736.	108.	384.	557.	762.	124.	414.
5	28	64.	1325.	1675.	476.	1152.	1044.	1352.	411.	909.	1083.	1384.	459.	952.
5	29	65.	995.	1325.	241.	797.	786.	1048.	234.	639.	820.	1073.	267.	673.
5	30	67.	641.	868.	205.	487.	643.	809.	253.	510.	679.	843.	287.	545.
5	31	68.	961.	1264.	263.	762.	775.	1021.	235.	624.	805.	1042.	270.	656.
MONTHLY TOTAL			31843.	40414.	12706.	26403.	25662.	32588.	10186.	21177.	27324.	34135.	11666.	22832.
AVERAGE		67.	1027.	1304.	410.	852.	828.	1051.	329.	683.	881.	1101.	376.	737.

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WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
6	1	71.	832.	1132.	84.	603.	584.	837.	79.	422.	608.	845.	96.	446.
	152		152		1957	6	1		13743					
6	2	74.	511.	795.	25.	322.	424.	626.	4.	270.	445.	639.	8.	291.
6	3	64.	204.	464.	0.	127.	214.	430.	0.	136.	236.	451.	0.	157.
6	4	66.	299.	518.	0.	185.	309.	478.	0.	196.	331.	499.	0.	217.
6	5	67.	269.	509.	0.	165.	281.	468.	0.	176.	302.	487.	0.	197.
6	6	70.	747.	1000.	183.	571.	673.	875.	197.	529.	701.	898.	222.	557.
6	7	76.	1279.	1503.	581.	1048.	1148.	1347.	545.	948.	1178.	1373.	580.	982.
6	8	60.	175.	428.	0.	109.	190.	417.	0.	123.	210.	437.	0.	143.
6	9	61.	570.	843.	58.	448.	546.	784.	84.	440.	573.	807.	109.	468.
6	10	68.	1434.	1712.	656.	1222.	1206.	1453.	577.	1031.	1234.	1467.	614.	1060.
6	11	71.	1263.	1554.	501.	1066.	1096.	1338.	451.	923.	1120.	1359.	484.	953.
6	12	80.	1189.	1441.	381.	909.	954.	1158.	346.	744.	974.	1172.	377.	765.
6	13	82.	1758.	1961.	860.	1443.	1378.	1581.	683.	1111.	1392.	1580.	716.	1127.
6	14	81.	1311.	1541.	535.	1027.	1141.	1333.	542.	909.	1166.	1353.	578.	933.
6	15	83.	1684.	1867.	859.	1356.	1406.	1561.	774.	1131.	1424.	1575.	807.	1154.
6	16	84.	1609.	1783.	887.	1319.	1415.	1541.	791.	1149.	1438.	1561.	824.	1171.
6	17	85.	1541.	1739.	755.	1240.	1367.	1538.	764.	1108.	1390.	1555.	804.	1142.
6	18	86.	1334.	1516.	618.	1029.	1196.	1350.	615.	948.	1220.	1371.	649.	977.
6	19	83.	912.	1153.	191.	642.	766.	963.	193.	551.	783.	973.	210.	572.
6	20	75.	1503.	1772.	611.	1242.	1184.	1436.	539.	978.	1199.	1442.	569.	997.
6	21	78.	1576.	1820.	697.	1291.	1288.	1510.	648.	1050.	1304.	1517.	684.	1074.
6	22	81.	1277.	1521.	499.	996.	1131.	1331.	542.	910.	1157.	1349.	576.	940.
6	23	82.	903.	1137.	313.	663.	853.	1026.	357.	664.	879.	1045.	385.	692.
6	24	81.	1077.	1313.	440.	867.	1027.	1202.	478.	844.	1057.	1226.	511.	873.
6	25	76.	689.	943.	147.	516.	650.	845.	176.	493.	672.	861.	194.	515.
6	26	77.	927.	1173.	362.	711.	898.	1065.	403.	740.	928.	1087.	433.	770.
6	27	79.	968.	1219.	387.	785.	962.	1143.	425.	802.	992.	1170.	457.	833.
6	28	80.	595.	833.	55.	398.	566.	771.	98.	410.	587.	788.	116.	433.
6	29	78.	1152.	1441.	412.	921.	1044.	1262.	446.	852.	1068.	1285.	479.	882.
6	30	75.	1143.	1398.	470.	928.	1090.	1290.	507.	903.	1120.	1317.	542.	933.
MONTHLY TOTAL			30730.	38028.	11569.	24150.	26987.	32962.	11266.	21490.	27689.	33492.	12025.	22254.
AVERAGE		76.	1024.	1268.	386.	805.	900.	1099.	376.	716.	923.	1116.	401.	742.

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SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
7	1	74.	1331.	1656.	452.	1122.	1083.	1378.	411.	907.	1100.	1385.	446.	930.
	182		182		1957	7	1		13743					
7	2	71.	1621.	1932.	730.	1395.	1348.	1627.	668.	1166.	1376.	1638.	706.	1193.
7	3	76.	1673.	1926.	818.	1400.	1422.	1646.	742.	1199.	1448.	1660.	780.	1227.
7	4	82.	995.	1228.	392.	784.	964.	1124.	420.	777.	994.	1150.	452.	805.
7	5	85.	880.	1108.	266.	654.	837.	1015.	319.	647.	863.	1039.	350.	676.
7	6	78.	1746.	1975.	846.	1457.	1397.	1619.	705.	1154.	1415.	1629.	742.	1173.
7	7	80.	1225.	1434.	576.	972.	1142.	1314.	609.	931.	1174.	1341.	647.	967.
7	8	80.	398.	600.	6.	229.	402.	550.	0.	248.	422.	568.	3.	267.
7	9	83.	1166.	1386.	402.	894.	1015.	1216.	424.	806.	1043.	1234.	459.	839.
7	10	75.	1654.	1963.	765.	1418.	1375.	1638.	644.	1175.	1399.	1661.	687.	1207.
7	11	75.	1067.	1316.	339.	826.	832.	1054.	258.	634.	848.	1068.	279.	653.
7	12	81.	1002.	1195.	380.	760.	850.	1023.	309.	643.	875.	1039.	333.	667.
7	13	81.	538.	741.	58.	335.	503.	656.	73.	321.	524.	676.	88.	344.
7	14	84.	1147.	1375.	388.	855.	993.	1182.	419.	775.	1025.	1208.	458.	812.
7	15	83.	1389.	1620.	554.	1089.	1158.	1354.	522.	919.	1185.	1379.	563.	956.
7	16	76.	1550.	1800.	726.	1280.	1299.	1514.	678.	1071.	1332.	1541.	726.	1113.
7	17	77.	740.	958.	219.	546.	712.	867.	229.	540.	746.	898.	260.	573.
7	18	78.	531.	763.	75.	348.	491.	674.	68.	329.	518.	697.	77.	355.
7	19	78.	1493.	1716.	644.	1198.	1175.	1376.	468.	926.	1202.	1397.	508.	953.
7	20	81.	1806.	2044.	905.	1510.	1457.	1676.	744.	1205.	1494.	1706.	796.	1250.
7	21	87.	1814.	1991.	960.	1474.	1494.	1659.	784.	1194.	1527.	1692.	837.	1240.
7	22	87.	1159.	1373.	467.	886.	1064.	1214.	514.	830.	1110.	1255.	561.	876.
7	23	77.	471.	700.	45.	295.	405.	579.	20.	248.	429.	601.	25.	272.
7	24	74.	942.	1222.	303.	744.	847.	1081.	343.	696.	893.	1125.	390.	744.
7	25	74.	1135.	1414.	451.	909.	946.	1168.	396.	777.	986.	1206.	443.	823.
7	26	74.	399.	659.	0.	216.	326.	545.	0.	180.	354.	569.	0.	207.
7	27	77.	899.	1158.	292.	682.	794.	1001.	304.	631.	840.	1041.	343.	678.
7	28	77.	1080.	1340.	363.	837.	892.	1111.	368.	696.	937.	1152.	417.	747.
7	29	79.	844.	1077.	268.	641.	776.	961.	286.	603.	824.	1005.	332.	650.
7	30	79.	859.	1107.	194.	635.	727.	901.	210.	550.	772.	941.	251.	594.
7	31	80.	770.	995.	192.	541.	635.	789.	155.	438.	671.	823.	188.	478.
MONTHLY TOTAL			34327.	41770.	13075.	26931.	29359.	35511.	12092.	23218.	30325.	36325.	13150.	24271.
AVERAGE		79.	1107.	1347.	422.	869.	947.	1146.	390.	749.	978.	1172.	424.	783.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL				HORIZONTAL				12 DEG TILT			
MONTH	DAY	DB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
8	1	82.	1438.	1667.	640.	1146.	1166.	1359.	586.	936.	1222.	1414.	648.	998.
	213		213		1957	8	1		13743					
8	2	80.	1543.	1764.	718.	1260.	1260.	1458.	697.	1033.	1329.	1516.	768.	1104.
8	3	84.	1602.	1798.	790.	1283.	1279.	1448.	636.	1038.	1344.	1504.	704.	1103.
8	4	80.	412.	631.	5.	234.	341.	493.	0.	208.	372.	525.	5.	240.
8	5	74.	1393.	1680.	553.	1175.	1076.	1319.	375.	894.	1140.	1379.	443.	957.
8	6	70.	1308.	1601.	538.	1089.	1035.	1264.	451.	870.	1107.	1328.	522.	940.
8	7	73.	1276.	1570.	449.	1048.	963.	1214.	351.	792.	1032.	1275.	418.	859.
8	8	76.	588.	788.	91.	378.	484.	642.	66.	313.	527.	684.	91.	356.
8	9	80.	769.	955.	255.	584.	714.	856.	241.	554.	773.	914.	296.	612.
8	10	79.	398.	639.	25.	242.	360.	519.	31.	239.	400.	561.	49.	279.
8	11	79.	1382.	1592.	685.	1127.	1108.	1292.	540.	901.	1187.	1367.	619.	979.
8	12	82.	1037.	1262.	404.	820.	921.	1091.	393.	730.	998.	1166.	463.	805.
8	13	72.	1214.	1488.	525.	1008.	1006.	1218.	455.	845.	1091.	1302.	533.	930.
8	14	75.	1084.	1357.	354.	867.	850.	1079.	331.	695.	930.	1156.	403.	772.
8	15	79.	597.	819.	92.	395.	467.	634.	54.	301.	519.	684.	80.	349.
8	16	82.	1306.	1544.	566.	1046.	1060.	1241.	460.	852.	1150.	1327.	546.	941.
8	17	74.	631.	870.	129.	468.	518.	679.	114.	382.	577.	739.	163.	438.
8	18	72.	1082.	1328.	379.	865.	844.	1049.	313.	668.	931.	1131.	390.	753.
8	19	65.	161.	373.	0.	101.	155.	315.	0.	95.	193.	357.	0.	132.
8	20	70.	765.	947.	256.	600.	646.	799.	259.	504.	720.	873.	316.	576.
8	21	74.	1350.	1565.	623.	1105.	1001.	1187.	457.	800.	1100.	1282.	543.	896.
8	22	71.	662.	905.	172.	524.	548.	736.	169.	431.	621.	810.	226.	500.
8	23	70.	1174.	1454.	463.	967.	884.	1098.	330.	720.	985.	1198.	418.	819.
8	24	69.	472.	704.	65.	334.	359.	529.	53.	257.	419.	591.	88.	308.
8	25	67.	157.	375.	0.	98.	139.	303.	0.	80.	180.	350.	0.	121.
8	26	71.	415.	669.	41.	265.	270.	470.	0.	165.	328.	529.	4.	215.
8	27	77.	1361.	1588.	598.	1125.	992.	1191.	427.	802.	1109.	1305.	527.	916.
8	28	70.	1120.	1372.	472.	933.	843.	1046.	376.	694.	957.	1157.	467.	803.
8	29	72.	889.	1155.	285.	681.	666.	860.	237.	529.	764.	959.	318.	618.
8	30	79.	1419.	1596.	744.	1181.	1056.	1224.	475.	842.	1181.	1348.	593.	963.
8	31	79.	1161.	1348.	502.	938.	878.	1053.	357.	697.	995.	1168.	459.	809.
MONTHLY														
TOTAL			30166.	37406.	11419.	23889.	23890.	29666.	9233.	18867.	26182.	31898.	11104.	21091.
AVERAGE		75.	973.	1207.	368.	771.	771.	957.	298.	609.	845.	1029.	358.	680.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
9	1	78.	923.	1116.	384.	728.	743.	892.	315.	580.	849.	997.	404.	681.
	244		244		1957	9	1		13743					
9	2	78.	1139.	1359.	514.	943.	860.	1050.	323.	701.	981.	1171.	430.	818.
9	3	80.	705.	930.	170.	502.	524.	690.	110.	378.	609.	779.	183.	456.
9	4	78.	363.	573.	0.	197.	242.	395.	0.	122.	298.	456.	0.	175.
9	5	71.	1537.	1793.	745.	1328.	983.	1214.	378.	814.	1131.	1361.	510.	958.
9	6	70.	502.	712.	143.	382.	405.	544.	118.	299.	485.	626.	171.	377.
9	7	72.	398.	594.	9.	248.	257.	417.	0.	145.	322.	487.	2.	206.
9	8	72.	327.	529.	31.	223.	255.	388.	8.	164.	315.	456.	29.	222.
9	9	68.	183.	390.	0.	117.	128.	276.	0.	63.	181.	335.	0.	115.
9	10	75.	541.	738.	161.	419.	428.	567.	108.	310.	513.	656.	164.	394.
9	11	73.	781.	969.	265.	616.	474.	631.	114.	335.	569.	730.	156.	427.
9	12	77.	688.	867.	270.	545.	547.	665.	177.	415.	646.	769.	260.	512.
9	13	79.	889.	1109.	223.	675.	540.	727.	124.	381.	652.	843.	198.	484.
9	14	77.	693.	870.	220.	506.	472.	602.	121.	327.	569.	703.	193.	416.
9	15	78.	868.	1082.	325.	678.	606.	774.	196.	467.	728.	898.	299.	580.
9	16	76.	602.	807.	205.	466.	431.	587.	136.	346.	526.	691.	204.	426.
9	17	71.	144.	341.	0.	92.	108.	214.	0.	58.	145.	272.	0.	95.
9	18	70.	202.	395.	33.	151.	157.	259.	12.	108.	202.	324.	31.	152.
9	19	71.	882.	1077.	337.	684.	563.	716.	236.	422.	693.	847.	311.	543.
9	20	72.	145.	374.	0.	90.	100.	208.	0.	51.	139.	268.	0.	89.
9	21	78.	710.	937.	178.	515.	430.	590.	96.	304.	539.	705.	163.	404.
9	22	79.	770.	971.	219.	580.	474.	642.	129.	346.	598.	764.	201.	449.
9	23	69.	150.	344.	0.	89.	86.	198.	0.	42.	134.	262.	0.	81.
9	24	63.	1313.	1603.	556.	1149.	662.	906.	172.	535.	845.	1085.	300.	714.
9	25	63.	1386.	1625.	643.	1188.	751.	954.	273.	614.	936.	1140.	432.	793.
9	26	66.	356.	568.	92.	264.	226.	349.	54.	155.	300.	436.	82.	223.
9	27	54.	934.	1237.	350.	812.	460.	686.	105.	373.	616.	846.	207.	517.
9	28	52.	297.	527.	47.	235.	148.	279.	12.	106.	218.	366.	37.	174.
9	29	55.	103.	274.	0.	71.	46.	144.	0.	15.	88.	200.	0.	57.
9	30	60.	106.	288.	0.	73.	48.	147.	0.	15.	90.	203.	0.	57.
MONTHLY TOTAL			18636.	24999.	6119.	14569.	12155.	16715.	3317.	8992.	14919.	19675.	4968.	11595.
MONTHLY AVERAGE		71.	621.	833.	204.	486.	405.	557.	111.	300.	497.	656.	166.	387.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
10	1	61.	122.	307.	0.	82.	61.	155.	0.	23.	104.	214.	0.	65.
	274		274		1957	10	1		13743					
10	2	63.	959.	1221.	388.	816.	520.	710.	138.	420.	681.	884.	255.	570.
10	3	58.	860.	1158.	288.	738.	416.	637.	90.	339.	568.	799.	177.	479.
10	4	57.	608.	922.	144.	511.	220.	452.	17.	167.	344.	588.	52.	273.
10	5	58.	56.	283.	0.	28.	14.	99.	0.	4.	31.	159.	0.	18.
10	6	55.	21.	148.	0.	17.	0.	42.	0.	0.	15.	80.	0.	11.
10	7	57.	365.	615.	79.	233.	137.	260.	39.	100.	206.	356.	65.	144.
10	8	61.	73.	315.	0.	33.	14.	86.	0.	3.	31.	154.	0.	18.
10	9	66.	1017.	1288.	368.	860.	428.	644.	31.	320.	606.	828.	121.	484.
10	10	62.	440.	722.	51.	329.	129.	304.	4.	76.	223.	420.	31.	150.
10	11	53.	779.	1095.	213.	692.	238.	484.	0.	175.	389.	650.	26.	324.
10	12	49.	1278.	1594.	628.	1169.	530.	786.	99.	459.	747.	1020.	258.	664.
10	13	51.	1466.	1682.	875.	1291.	656.	845.	257.	532.	894.	1086.	428.	750.
10	14	54.	1458.	1636.	902.	1264.	690.	839.	296.	554.	916.	1077.	501.	765.
10	15	55.	637.	862.	107.	505.	180.	371.	0.	97.	308.	513.	0.	212.
10	16	57.	377.	624.	0.	258.	55.	234.	0.	11.	147.	343.	0.	73.
10	17	61.	3.	175.	0.	0.	0.	24.	0.	0.	0.	69.	0.	0.
10	18	61.	6.	162.	0.	0.	0.	18.	0.	0.	0.	61.	0.	0.
10	19	53.	85.	370.	0.	59.	0.	84.	0.	0.	2.	168.	0.	0.
10	20	54.	1220.	1529.	530.	1127.	444.	696.	39.	379.	663.	942.	182.	594.
10	21	53.	1330.	1533.	785.	1163.	557.	730.	177.	448.	799.	966.	380.	665.
10	22	56.	698.	932.	161.	573.	210.	385.	0.	141.	352.	547.	34.	273.
10	23	60.	372.	606.	41.	281.	91.	243.	0.	48.	180.	351.	0.	118.
10	24	63.	0.	141.	0.	0.	0.	8.	0.	0.	0.	45.	0.	0.
10	25	51.	287.	610.	0.	235.	15.	183.	0.	8.	66.	303.	0.	45.
10	26	43.	249.	510.	2.	225.	41.	167.	0.	26.	111.	261.	0.	95.
10	27	42.	208.	532.	0.	180.	0.	131.	0.	0.	42.	249.	0.	34.
10	28	42.	421.	758.	36.	380.	6.	199.	0.	0.	87.	342.	0.	66.
10	29	50.	660.	937.	182.	566.	128.	311.	0.	85.	258.	478.	8.	194.
10	30	52.	0.	141.	0.	0.	0.	0.	0.	0.	0.	26.	0.	0.
10	31	53.	0.	158.	0.	0.	0.	0.	0.	0.	0.	28.	0.	0.
MONTHLY														
TOTAL			16055.	23568.	5781.	13613.	5779.	10129.	1187.	4419.	8769.	14005.	2518.	7086.
AVERAGE		55.	518.	760.	186.	439.	186.	327.	38.	143.	283.	452.	81.	229.

FB, FLAT BLACK SURFACE
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BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
11	1	58.	0.	116.	0.	0.	0.	0.	0.	0.	0.	25.	0.	0.
	305		305	1957		11	1	13743						
11	2	59.	0.	126.	0.	0.	0.	0.	0.	0.	0.	28.	0.	0.
11	3	61.	254.	470.	0.	189.	37.	132.	0.	11.	100.	223.	0.	62.
11	4	55.	371.	656.	0.	297.	25.	187.	0.	4.	115.	320.	0.	70.
11	5	51.	319.	528.	6.	239.	40.	157.	0.	17.	104.	268.	0.	70.
11	6	47.	1112.	1415.	460.	1040.	271.	512.	0.	232.	505.	757.	79.	454.
11	7	48.	871.	1089.	366.	743.	243.	400.	39.	175.	424.	592.	122.	332.
11	8	57.	0.	120.	0.	0.	0.	0.	0.	0.	0.	23.	0.	0.
11	9	46.	678.	982.	202.	622.	103.	295.	0.	83.	249.	481.	22.	216.
11	10	37.	747.	1103.	246.	741.	151.	364.	0.	151.	313.	566.	16.	314.
11	11	37.	1109.	1389.	524.	1032.	258.	469.	23.	219.	487.	710.	128.	433.
11	12	38.	751.	1029.	271.	673.	138.	329.	0.	101.	320.	527.	1.	271.
11	13	44.	161.	316.	13.	110.	14.	61.	0.	0.	53.	128.	0.	28.
11	14	56.	0.	119.	0.	0.	0.	0.	0.	0.	0.	17.	0.	0.
11	15	60.	489.	712.	122.	378.	93.	192.	0.	49.	187.	314.	12.	132.
11	16	54.	0.	148.	0.	0.	0.	0.	0.	0.	0.	17.	0.	0.
11	17	55.	379.	614.	55.	306.	58.	171.	0.	35.	144.	294.	0.	99.
11	18	52.	0.	89.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
11	19	61.	0.	157.	0.	0.	0.	0.	0.	0.	0.	28.	0.	0.
11	20	46.	331.	632.	0.	288.	0.	117.	0.	0.	49.	245.	0.	34.
11	21	48.	793.	1078.	324.	724.	184.	344.	0.	150.	343.	552.	55.	305.
11	22	45.	0.	78.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
11	23	40.	0.	59.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	24	47.	346.	586.	70.	288.	21.	109.	0.	4.	91.	216.	0.	50.
11	25	43.	0.	82.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
11	26	40.	129.	315.	0.	103.	0.	36.	0.	0.	9.	88.	0.	3.
11	27	43.	425.	629.	153.	381.	72.	179.	0.	53.	179.	309.	6.	156.
11	28	53.	0.	97.	0.	0.	0.	0.	0.	0.	0.	5.	0.	0.
11	29	57.	319.	538.	29.	231.	1.	82.	0.	0.	41.	189.	0.	15.
11	30	44.	0.	59.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
MONTHLY TOTAL			9584.	15331.	2839.	8385.	1707.	4137.	62.	1285.	3710.	6925.	440.	3044.
AVERAGE		49.	319.	511.	95.	279.	57.	138.	2.	43.	124.	231.	15.	101.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	12 DEG TILT 140 FB	12 DEG TILT 140 SB	12 DEG TILT 220 FB	12 DEG TILT 220 SB
12	1	36.	797.	1163.	256.	785.	80.	279.	0.	75.	246.	517.	0.	242.
	335		335		1957	12	1		13743					
12	2	48.	931.	1211.	426.	843.	171.	344.	0.	126.	375.	571.	34.	319.
12	3	39.	0.	83.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	4	32.	0.	18.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	5	30.	770.	1151.	225.	775.	44.	255.	0.	53.	216.	499.	0.	229.
12	6	38.	0.	39.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	7	50.	0.	68.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	8	47.	0.	56.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	9	43.	0.	47.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	10	38.	0.	31.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	11	30.	0.	9.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	12	19.	32.	297.	0.	55.	0.	2.	0.	0.	0.	46.	0.	0.
12	13	27.	378.	682.	68.	390.	1.	108.	0.	2.	81.	253.	0.	87.
12	14	40.	407.	657.	91.	361.	8.	87.	0.	2.	53.	218.	0.	37.
12	15	43.	881.	1143.	372.	805.	117.	285.	0.	86.	307.	515.	13.	260.
12	16	45.	0.	94.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	17	43.	372.	589.	27.	319.	0.	92.	0.	0.	64.	234.	0.	37.
12	18	42.	0.	55.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	19	53.	0.	111.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
12	20	58.	0.	93.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	21	53.	944.	1200.	396.	865.	113.	308.	0.	79.	320.	554.	0.	270.
12	22	46.	904.	1112.	455.	798.	137.	290.	0.	87.	344.	520.	31.	269.
12	23	50.	545.	801.	83.	474.	25.	165.	0.	2.	148.	330.	0.	103.
12	24	51.	0.	93.	0.	0.	0.	0.	0.	0.	0.	1.	0.	0.
12	25	37.	26.	133.	0.	21.	0.	7.	0.	0.	0.	27.	0.	0.
12	26	44.	0.	71.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
12	27	42.	743.	1036.	245.	698.	68.	223.	0.	52.	215.	444.	0.	196.
12	28	43.	0.	74.	0.	0.	0.	0.	0.	0.	0.	2.	0.	0.
12	29	40.	685.	969.	179.	662.	30.	211.	0.	24.	176.	420.	0.	166.
12	30	38.	254.	441.	35.	212.	0.	79.	0.	0.	51.	178.	0.	28.
12	31	40.	220.	339.	67.	183.	1.	52.	0.	0.	56.	108.	0.	34.
MONTHLY														
TOTAL			8889.	13863.	2927.	8245.	795.	2787.	0.	590.	2652.	5440.	79.	2279.
AVERAGE		41.	287.	447.	94.	266.	26.	90.	0.	19.	86.	175.	3.	74.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

Table C2

Thermal Output for the Year 1957 and a 50° Tilt Angle

The following twelve pages show the day by day thermal output in Btu for double-glazed flat-plate solar collectors for the year 1957, Washington, D.C., under all combinations of the following conditions:

absorber surface; flat black and selective black

fluid temperature; 60 °C (140 °F) and 104.4 °C (220 °F)

inclination; normal to the sun, horizontal, and at a tilt angle of 50° from the horizon

1 Btu = 1054.35 J

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 FB	NORMAL x 10^{-3} 140 SB	NORMAL x 10^{-3} 220 FB	NORMAL x 10^{-3} 220 SB	HORIZONTAL x 10^{-3} 140 FB	HORIZONTAL x 10^{-3} 140 SB	HORIZONTAL x 10^{-3} 220 FB	HORIZONTAL x 10^{-3} 220 SB	50 DEG TILT x 10^{-3} 140 FB	50 DEG TILT x 10^{-3} 140 SB	50 DEG TILT x 10^{-3} 220 FB	50 DEG TILT x 10^{-3} 220 SB
1	1	33.	.250000	.333333	.000000	.250000	0.	38.	0.	0.	212.	502.	0.	214.
1	2	24.	.291667	.333333	.208333	.291667	22.	228.	0.	36.	661.	994.	201.	683.
1	3	29.	.250000	.291667	.125000	.250000	0.	101.	0.	0.	317.	587.	25.	315.
1	4	42.	.250000	.291667	.166667	.250000	25.	187.	0.	8.	510.	755.	127.	474.
1	5	36.	.041667	.208333	.000000	.041667	0.	2.	0.	0.	20.	87.	0.	16.
1	6	31.	.000000	.166667	.000000	.000000	0.	0.	0.	0.	0.	46.	0.	0.
1	7	36.	.041667	.208333	.041667	.041667	3.	38.	0.	0.	98.	184.	29.	91.
1	8	36.	.041667	.208333	.000000	.041667	0.	0.	0.	0.	2.	104.	0.	0.
1	9	37.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	83.	0.	0.
1	10	38.	.250000	.250000	.000000	.250000	0.	26.	0.	0.	111.	353.	0.	98.
1	11	28.	.083333	.250000	.000000	.083333	0.	19.	0.	0.	76.	208.	0.	72.
1	12	33.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	70.	0.	0.
1	13	38.	.250000	.291667	.000000	.208333	0.	24.	0.	0.	121.	370.	0.	98.
1	14	24.	.291667	.333333	.166667	.291667	55.	248.	0.	67.	651.	982.	248.	660.
1	15	17.	.000000	.125000	.000000	.000000	0.	0.	0.	0.	0.	22.	0.	0.
1	16	23.	.208333	.291667	.125000	.208333	57.	213.	0.	62.	527.	812.	198.	529.
1	17	14.	.083333	.250000	.000000	.083333	0.	3.	0.	0.	59.	189.	0.	61.
1	18	18.	.208333	.291667	.083333	.208333	18.	117.	0.	19.	325.	618.	94.	333.
1	19	25.	.291667	.333333	.250000	.291667	123.	334.	0.	113.	801.	1078.	361.	773.
1	20	33.	.041667	.208333	.000000	.000000	0.	0.	0.	0.	1.	116.	0.	0.
1	21	40.	.041667	.208333	.000000	.041667	0.	8.	0.	0.	27.	153.	0.	20.
1	22	49.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	94.	0.	0.
1	23	49.	.166667	.291667	.000000	.166667	0.	42.	0.	0.	114.	340.	0.	100.
1	24	25.	.083333	.291667	.041667	.083333	0.	25.	0.	0.	80.	217.	2.	68.
1	25	30.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	104.	0.	0.
1	26	38.	.083333	.291667	.000000	.083333	0.	13.	0.	0.	52.	188.	0.	39.
1	27	41.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	73.	0.	0.
1	28	37.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	68.	0.	0.
1	29	38.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	72.	0.	0.
1	30	38.	.041667	.250000	.000000	.041667	0.	4.	0.	0.	20.	112.	0.	13.
1	31	35.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	71.	0.	0.
MONTHLY TOTAL			5418.	10783.	1291.	5268.	302.	1670.	0.	306.	4785.	9653.	1285.	4658.
AVERAGE		33.	175.	348.	42.	170.	10.	54.	0.	10.	154.	311.	41.	150.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR OATA FOR
WASHINGTON O.C.

			NORMAL x 10^{-3}				HORIZONTAL x 10^{-3}				50 DEG TILT x 10^{-3}			
MONTH	OAY	OB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
2	1	38.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	70.	0.	0.
2	2	40.	.291667	.333333	.208333	.291667	91.	259.	0.	56.	584.	805.	174.	511.
2	3	41.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	114.	0.	0.
2	4	51.	.083333	.291667	.000000	.083333	0.	34.	0.	0.	69.	238.	0.	45.
2	5	38.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	80.	0.	0.
2	6	35.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	76.	0.	0.
2	7	40.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	92.	0.	0.
2	8	42.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	102.	0.	0.
2	9	44.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	88.	0.	0.
2	10	51.	.333333	.333333	.000000	.291667	30.	212.	0.	10.	378.	654.	0.	321.
2	11	36.	.000000	.166667	.000000	.000000	0.	0.	0.	0.	0.	52.	0.	0.
2	12	31.	.333333	.375000	.125000	.291667	84.	246.	0.	63.	468.	747.	138.	428.
2	13	37.	.250000	.291667	.041667	.250000	17.	169.	0.	6.	293.	515.	5.	254.
2	14	36.	.083333	.291667	.000000	.083333	0.	28.	0.	0.	53.	202.	0.	49.
2	15	34.	.041667	.250000	.000000	.000000	0.	1.	0.	0.	6.	87.	0.	0.
2	16	39.	.208333	.291667	.000000	.208333	0.	104.	0.	0.	144.	341.	0.	122.
2	17	35.	.291667	.333333	.041667	.291667	15.	235.	0.	16.	347.	681.	18.	354.
2	18	41.	.291667	.375000	.208333	.291667	285.	503.	9.	255.	805.	1093.	361.	758.
2	19	43.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	101.	0.	0.
2	20	32.	.333333	.375000	.250000	.333333	296.	587.	0.	301.	901.	1252.	380.	901.
2	21	35.	.333333	.416667	.250000	.333333	454.	684.	109.	400.	1118.	1370.	629.	1042.
2	22	38.	.291667	.375000	.041667	.291667	57.	246.	0.	39.	377.	635.	63.	319.
2	23	45.	.208333	.291667	.000000	.125000	6.	68.	0.	0.	113.	275.	0.	56.
2	24	47.	.333333	.375000	.208333	.333333	284.	501.	43.	229.	760.	998.	296.	673.
2	25	49.	.041667	.250000	.000000	.000000	0.	11.	0.	0.	3.	136.	0.	0.
2	26	56.	.041667	.291667	.000000	.000000	0.	19.	0.	0.	1.	142.	0.	0.
2	27	55.	.166667	.333333	.000000	.083333	15.	87.	0.	0.	104.	264.	0.	64.
2	28	34.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	56.	0.	0.
MONTHLY TOTAL			7877.	13349.	2394.	7137.	1634.	3995.	162.	1375.	6524.	11267.	2063.	5898.
AVERAGE		41.	281.	477.	85.	255.	58.	143.	6.	49.	233.	402.	74.	211.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASEO UPON OATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 OEG F ANO 220 OEG F
.BASIC COLLECTOR- OOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL x 10^{-3}				HORIZONTAL x 10^{-3}				50 DEG TILT x 10^{-3}			
MONTH	DAY	DB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
3	1	35.	.000000	.291667	.000000	.000000	0.	0.	0.	0.	0.	98.	0.	0.
3	2	43.	.166667	.291667	.000000	.125000	42.	159.	0.	30.	182.	384.	0.	161.
3	3	36.	.333333	.416667	.250000	.333333	446.	747.	56.	424.	1027.	1354.	489.	991.
3	4	34.	.333333	.375000	.208333	.333333	397.	661.	95.	369.	892.	1200.	417.	848.
3	5	37.	.291667	.375000	.208333	.291667	378.	611.	39.	338.	818.	1084.	364.	768.
3	6	41.	.041667	.250000	.000000	.041667	2.	41.	0.	0.	41.	148.	0.	35.
3	7	40.	.041667	.250000	.000000	.041667	2.	41.	0.	0.	40.	151.	0.	35.
3	8	42.	.083333	.250000	.000000	.083333	2.	77.	0.	0.	75.	193.	0.	66.
3	9	41.	.125000	.291667	.000000	.125000	24.	133.	0.	23.	110.	294.	0.	108.
3	10	40.	.291667	.375000	.208333	.291667	416.	707.	51.	404.	838.	1168.	371.	821.
3	11	42.	.250000	.291667	.041667	.250000	126.	323.	18.	100.	358.	577.	83.	310.
3	12	54.	.250000	.333333	.041667	.208333	78.	226.	0.	46.	221.	427.	16.	156.
3	13	53.	.333333	.375000	.208333	.333333	443.	686.	88.	362.	816.	1080.	310.	716.
3	14	57.	.375000	.375000	.250000	.375000	603.	832.	202.	501.	1021.	1258.	490.	888.
3	15	59.	.166667	.333333	.000000	.125000	69.	183.	0.	32.	170.	346.	0.	126.
3	16	54.	.375000	.416667	.291667	.375000	637.	904.	168.	551.	1069.	1352.	492.	968.
3	17	54.	.333333	.416667	.250000	.333333	463.	707.	73.	378.	793.	1073.	277.	689.
3	18	49.	.208333	.291667	.041667	.208333	96.	247.	0.	73.	222.	419.	43.	184.
3	19	43.	.125000	.250000	.000000	.125000	8.	124.	0.	3.	89.	229.	0.	81.
3	20	43.	.125000	.291667	.000000	.125000	7.	128.	0.	1.	90.	239.	0.	81.
3	21	46.	.333333	.416667	.208333	.333333	506.	773.	112.	459.	813.	1127.	366.	757.
3	22	44.	.125000	.250000	.000000	.125000	51.	148.	0.	27.	132.	257.	0.	106.
3	23	49.	.375000	.416667	.291667	.375000	689.	963.	210.	605.	1044.	1332.	489.	950.
3	24	53.	.333333	.333333	.125000	.291667	377.	599.	65.	296.	618.	834.	196.	513.
3	25	42.	.166667	.250000	.000000	.166667	19.	170.	0.	11.	113.	272.	0.	99.
3	26	45.	.208333	.250000	.166667	.208333	337.	485.	86.	288.	514.	668.	221.	459.
3	27	47.	.208333	.250000	.083333	.166667	177.	352.	18.	151.	299.	500.	74.	270.
3	28	46.	.166667	.250000	.000000	.166667	92.	209.	0.	52.	182.	312.	0.	140.
3	29	46.	.208333	.333333	.125000	.208333	320.	504.	59.	283.	474.	684.	174.	427.
3	30	45.	.291667	.375000	.166667	.291667	308.	590.	28.	275.	479.	792.	130.	437.
3	31	44.	.375000	.416667	.291667	.375000	810.	1088.	330.	729.	1101.	1374.	578.	1010.
MONTHLY														
TOTAL			17580.	25631.	6162.	15819.	7925.	13417.	1696.	6813.	14641.	21228.	5579.	13204.
AVERAGE		45.	567.	827.	199.	510.	256.	433.	55.	220.	472.	685.	180.	426.

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ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	HORIZONTAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	50 DEG TILT x 10^{-3} 140 FB	140 SB	220 FB	220 SB
4	1	46.	.166667	.250000	.000000	.166667	74.	203.	0.	43.	152.	295.	0.	120.
4	2	61.	.333333	.375000	.125000	.291667	411.	635.	64.	319.	574.	805.	158.	475.
4	3	48.	.208333	.333333	.041667	.208333	204.	359.	43.	145.	301.	475.	78.	240.
4	4	44.	.208333	.208333	.000000	.208333	36.	224.	0.	25.	113.	306.	0.	96.
4	5	54.	.208333	.291667	.000000	.208333	137.	276.	0.	80.	219.	363.	0.	160.
4	6	50.	.208333	.250000	.041667	.208333	132.	316.	24.	111.	215.	404.	53.	191.
4	7	57.	.375000	.416667	.250000	.333333	746.	1032.	198.	641.	925.	1204.	353.	814.
4	8	49.	.208333	.250000	.000000	.208333	72.	250.	0.	42.	143.	324.	0.	110.
4	9	46.	.291667	.375000	.250000	.291667	579.	896.	92.	547.	726.	1043.	218.	692.
4	10	50.	.375000	.416667	.250000	.375000	748.	1070.	229.	672.	904.	1217.	373.	825.
4	11	55.	.333333	.375000	.250000	.333333	837.	1104.	311.	751.	988.	1252.	450.	899.
4	12	59.	.291667	.333333	.208333	.291667	689.	887.	236.	582.	801.	995.	332.	693.
4	13	42.	.291667	.333333	.208333	.250000	497.	775.	112.	462.	605.	885.	213.	568.
4	14	43.	.291667	.375000	.208333	.250000	516.	809.	123.	483.	620.	912.	216.	584.
4	15	45.	.375000	.416667	.291667	.375000	953.	1253.	397.	865.	1068.	1355.	517.	978.
4	16	51.	.250000	.333333	.083333	.250000	218.	458.	0.	165.	273.	510.	1.	219.
4	17	58.	.250000	.291667	.000000	.208333	195.	333.	0.	121.	239.	378.	0.	163.
4	18	63.	.250000	.333333	.041667	.250000	297.	462.	43.	196.	344.	506.	57.	241.
4	19	61.	.291667	.333333	.041667	.250000	297.	460.	12.	170.	296.	495.	21.	211.
4	20	63.	.291667	.333333	.125000	.250000	440.	615.	110.	343.	484.	658.	137.	389.
4	21	75.	.375000	.458333	.250000	.333333	972.	1183.	437.	776.	1017.	1200.	496.	823.
4	22	65.	.250000	.375000	.208333	.250000	484.	730.	83.	411.	527.	763.	128.	454.
4	23	64.	.250000	.333333	.125000	.208333	377.	558.	75.	281.	409.	585.	101.	314.
4	24	76.	.375000	.375000	.208333	.291667	881.	1064.	387.	692.	905.	1078.	429.	730.
4	25	65.	.291667	.333333	.000000	.208333	198.	403.	0.	112.	209.	406.	0.	131.
4	26	67.	.291667	.375000	.166667	.291667	552.	726.	157.	403.	539.	710.	160.	408.
4	27	76.	.416667	.416667	.291667	.333333	1197.	1380.	618.	971.	1169.	1344.	627.	968.
4	28	77.	.375000	.375000	.291667	.291667	1054.	1192.	527.	843.	1045.	1183.	537.	843.
4	29	71.	.333333	.416667	.250000	.291667	914.	1141.	377.	757.	880.	1096.	384.	745.
4	30	69.	.375000	.458333	.291667	.375000	1266.	1510.	594.	1068.	1198.	1417.	575.	1022.
MONTHLY														
TOTAL			23571.	31804.	8530.	19926.	15934.	22307.	5250.	13078.	17888.	24162.	6613.	15108.
AVERAGE		58.	786.	1060.	284.	664.	531.	744.	175.	436.	596.	805.	220.	504.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR OATA FOR
WASHINGTON O.C.

MONTH	OAY	08	NORMAL x 10^{-3} 140 F8	140 S8	220 F8	220 S8	HORIZONTAL x 10^{-3} 140 F8	140 S8	220 F8	220 S8	50 OEG TILT x 10^{-3} 140 F8	140 S8	220 F8	220 S8
5	1	71.	.416667	.458333	.291667	.375000	1291.	1526.	594.	1083.	1205.	1421.	569.	1021.
5	2	63.	.375000	.416667	.250000	.375000	1136.	1398.	539.	990.	1075.	1305.	526.	933.
5	3	53.	.333333	.416667	.291667	.333333	1033.	1333.	450.	938.	976.	1244.	420.	889.
5	4	50.	.333333	.375000	.208333	.333333	926.	1231.	362.	847.	868.	1141.	334.	790.
5	5	56.	.333333	.375000	.208333	.333333	800.	1044.	322.	687.	740.	953.	298.	629.
5	6	62.	.291667	.375000	.250000	.291667	826.	1052.	332.	701.	772.	977.	301.	661.
5	7	65.	.375000	.458333	.291667	.375000	1284.	1537.	608.	1093.	1140.	1369.	542.	977.
5	8	70.	.375000	.458333	.291667	.375000	1357.	1578.	659.	1133.	1185.	1400.	588.	1001.
5	9	73.	.375000	.416667	.250000	.375000	1129.	1362.	454.	926.	986.	1198.	387.	804.
5	10	75.	.375000	.416667	.166667	.333333	896.	1120.	299.	699.	773.	976.	253.	603.
5	11	69.	.250000	.333333	.000000	.208333	259.	441.	0.	161.	229.	389.	0.	134.
5	12	68.	.291667	.333333	.208333	.250000	592.	769.	187.	463.	525.	679.	143.	403.
5	13	77.	.333333	.375000	.250000	.333333	996.	1169.	489.	813.	891.	1034.	419.	711.
5	14	76.	.333333	.375000	.291667	.291667	1010.	1182.	461.	837.	902.	1065.	370.	741.
5	15	76.	.333333	.375000	.250000	.333333	953.	1127.	395.	781.	836.	995.	319.	666.
5	16	68.	.291667	.375000	.166667	.291667	738.	1015.	199.	629.	635.	869.	144.	539.
5	17	64.	.291667	.291667	.041667	.208333	323.	510.	37.	221.	263.	450.	28.	177.
5	18	71.	.333333	.333333	.250000	.291667	978.	1140.	474.	809.	852.	1004.	383.	698.
5	19	62.	.208333	.291667	.000000	.208333	203.	418.	0.	125.	144.	358.	0.	88.
5	20	58.	.291667	.291667	.000000	.208333	258.	439.	0.	162.	193.	374.	0.	107.
5	21	54.	.250000	.291667	.000000	.208333	187.	404.	0.	124.	131.	338.	0.	81.
5	22	61.	.250000	.291667	.000000	.208333	211.	424.	0.	134.	150.	356.	0.	86.
5	23	77.	.375000	.416667	.291667	.333333	1187.	1408.	541.	992.	968.	1166.	382.	797.
5	24	76.	.333333	.416667	.250000	.333333	1096.	1318.	467.	900.	883.	1092.	328.	725.
5	25	70.	.375000	.375000	.291667	.333333	1253.	1502.	658.	1080.	1028.	1233.	492.	865.
5	26	76.	.333333	.375000	.250000	.291667	964.	1175.	417.	782.	796.	979.	296.	645.
5	27	72.	.333333	.333333	.125000	.250000	526.	736.	108.	384.	402.	590.	49.	285.
5	28	64.	.375000	.375000	.250000	.375000	1044.	1352.	411.	909.	810.	1060.	266.	684.
5	29	65.	.333333	.375000	.166667	.291667	786.	1048.	234.	639.	592.	816.	122.	472.
5	30	67.	.291667	.333333	.166667	.250000	643.	809.	253.	510.	527.	676.	178.	404.
5	31	68.	.333333	.375000	.208333	.291667	775.	1021.	235.	624.	596.	786.	110.	454.
MONTHLY TOTAL			31843.	40414.	12706.	26403.	25662.	32588.	10186.	21177.	22073.	28293.	8247.	18068.
AVERAGE		67.	1027.	1304.	410.	852.	828.	1051.	329.	683.	712.	913.	266.	583.

F8, FLAT 8LACK SURFACE
SB, SELECTIVE 8LACK SURFACE (8ASEO UPON OATA OF UNIV. OF PENNSYLVANIA)
A8SOR8ER TEMPERATURES 140 OEG F AND 220 OEG F
8ASIC COLLECTOR- OOU8LE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	HORIZONTAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	50 DEG TILT x 10^{-3} 140 FB	140 SB	220 FB	220 SB
6	1	71.	.333333	.375000	.083333	.291667	584.	837.	79.	422.	420.	622.	22.	285.
6	2	74.	.291667	.333333	.000000	.291667	424.	626.	4.	270.	303.	474.	0.	168.
6	3	64.	.250000	.291667	.000000	.208333	214.	430.	0.	136.	127.	339.	0.	70.
6	4	66.	.291667	.291667	.000000	.208333	309.	478.	0.	196.	214.	381.	0.	112.
6	5	67.	.291667	.291667	.000000	.208333	281.	468.	0.	176.	185.	369.	0.	96.
6	6	70.	.333333	.333333	.208333	.250000	673.	875.	197.	529.	506.	689.	84.	383.
6	7	76.	.375000	.416667	.291667	.333333	1148.	1347.	545.	948.	886.	1064.	348.	713.
6	8	60.	.208333	.291667	.000000	.208333	190.	417.	0.	123.	105.	320.	0.	58.
6	9	61.	.250000	.333333	.125000	.250000	546.	784.	84.	440.	403.	615.	23.	321.
6	10	68.	.333333	.416667	.291667	.333333	1206.	1453.	577.	1031.	901.	1117.	346.	758.
6	11	71.	.375000	.375000	.291667	.333333	1096.	1338.	451.	923.	815.	1035.	249.	671.
6	12	80.	.375000	.416667	.250000	.291667	954.	1158.	346.	744.	704.	880.	195.	525.
6	13	82.	.416667	.458333	.291667	.333333	1378.	1581.	683.	1111.	1006.	1179.	455.	788.
6	14	81.	.375000	.416667	.291667	.291667	1141.	1333.	542.	909.	857.	1032.	347.	677.
6	15	83.	.375000	.458333	.291667	.333333	1406.	1561.	774.	1131.	1062.	1196.	509.	833.
6	16	84.	.375000	.416667	.291667	.333333	1415.	1541.	791.	1149.	1079.	1205.	538.	847.
6	17	85.	.375000	.416667	.291667	.333333	1367.	1538.	764.	1108.	1058.	1202.	539.	849.
6	18	86.	.375000	.375000	.291667	.291667	1196.	1350.	615.	948.	924.	1053.	410.	715.
6	19	83.	.375000	.416667	.125000	.291667	766.	963.	193.	551.	553.	723.	101.	373.
6	20	75.	.375000	.458333	.291667	.333333	1184.	1436.	539.	978.	867.	1060.	321.	699.
6	21	78.	.375000	.416667	.291667	.291667	1288.	1510.	648.	1050.	952.	1134.	427.	764.
6	22	81.	.333333	.416667	.250000	.291667	1131.	1331.	542.	910.	866.	1032.	344.	684.
6	23	82.	.291667	.375000	.208333	.291667	853.	1026.	357.	664.	660.	808.	205.	497.
6	24	81.	.333333	.333333	.291667	.291667	1027.	1202.	478.	844.	801.	952.	280.	640.
6	25	76.	.291667	.333333	.125000	.291667	650.	845.	176.	493.	478.	650.	84.	341.
6	26	77.	.291667	.333333	.250000	.291667	898.	1065.	403.	740.	711.	851.	243.	560.
6	27	79.	.291667	.375000	.250000	.291667	962.	1143.	425.	802.	758.	915.	237.	610.
6	28	80.	.291667	.333333	.125000	.250000	566.	771.	98.	410.	420.	589.	29.	281.
6	29	78.	.333333	.416667	.291667	.291667	1044.	1262.	446.	852.	790.	983.	245.	635.
6	30	75.	.333333	.375000	.291667	.291667	1090.	1290.	507.	903.	840.	1023.	301.	681.
MONTHLY TOTAL			30730.	38028.	11569.	24150.	26987.	32962.	11266.	21490.	20250.	25491.	6881.	15633.
AVERAGE		76.	1024.	1268.	386.	805.	900.	1099.	376.	716.	675.	850.	229.	521.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL x 10^{-3}				HORIZONTAL x 10^{-3}				50 DEG TILT x 10^{-3}			
MONTH	DAY	08	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
7	1	74.	.375000	.416667	.250000	.333333	1083.	1378.	411.	907.	785.	1017.	224.	643.
7	2	71.	.375000	.416667	.291667	.333333	1348.	1627.	668.	1166.	992.	1231.	415.	842.
7	3	76.	.416667	.416667	.291667	.333333	1422.	1646.	742.	1199.	1070.	1267.	483.	883.
7	4	82.	.333333	.375000	.250000	.291667	964.	1124.	420.	777.	754.	904.	241.	587.
7	5	85.	.333333	.375000	.208333	.250000	837.	1015.	319.	647.	653.	810.	187.	494.
7	6	78.	.416667	.458333	.291667	.333333	1397.	1619.	705.	1154.	1033.	1222.	451.	833.
7	7	80.	.333333	.416667	.291667	.291667	1142.	1314.	609.	931.	905.	1049.	411.	728.
7	8	80.	.291667	.333333	.000000	.291667	402.	550.	0.	248.	302.	431.	0.	150.
7	9	83.	.333333	.416667	.250000	.333333	1015.	1216.	424.	806.	795.	956.	258.	611.
7	10	75.	.416667	.416667	.291667	.375000	1375.	1638.	644.	1175.	1021.	1261.	412.	859.
7	11	75.	.375000	.375000	.208333	.333333	832.	1054.	258.	634.	597.	786.	129.	426.
7	12	81.	.375000	.375000	.166667	.291667	850.	1023.	309.	643.	642.	798.	209.	453.
7	13	81.	.291667	.375000	.125000	.250000	503.	656.	73.	321.	377.	520.	18.	227.
7	14	84.	.333333	.416667	.250000	.291667	993.	1182.	419.	775.	791.	948.	285.	603.
7	15	83.	.375000	.416667	.291667	.375000	1158.	1354.	522.	919.	907.	1071.	352.	696.
7	16	76.	.375000	.416667	.291667	.333333	1299.	1514.	678.	1071.	1017.	1200.	493.	834.
7	17	77.	.333333	.333333	.125000	.291667	712.	867.	229.	540.	570.	722.	154.	416.
7	18	78.	.333333	.333333	.041667	.250000	491.	674.	68.	329.	375.	542.	30.	235.
7	19	78.	.416667	.458333	.291667	.375000	1175.	1376.	468.	926.	890.	1078.	302.	688.
7	20	81.	.416667	.416667	.291667	.375000	1457.	1676.	744.	1205.	1158.	1339.	540.	945.
7	21	87.	.416667	.458333	.291667	.375000	1494.	1659.	784.	1194.	1198.	1341.	602.	947.
7	22	87.	.375000	.375000	.250000	.291667	1064.	1214.	514.	830.	895.	1035.	403.	689.
7	23	77.	.333333	.333333	.041667	.333333	405.	579.	20.	248.	300.	467.	11.	146.
7	24	74.	.333333	.416667	.250000	.250000	847.	1081.	343.	696.	711.	909.	244.	581.
7	25	74.	.333333	.375000	.250000	.333333	946.	1168.	396.	777.	783.	965.	291.	626.
7	26	74.	.333333	.375000	.000000	.250000	326.	545.	0.	180.	246.	436.	0.	130.
7	27	77.	.291667	.375000	.208333	.291667	794.	1001.	304.	631.	675.	854.	225.	532.
7	28	77.	.333333	.375000	.250000	.291667	892.	1111.	368.	696.	752.	930.	286.	600.
7	29	79.	.333333	.375000	.250000	.250000	776.	961.	286.	603.	672.	833.	211.	522.
7	30	79.	.333333	.333333	.208333	.291667	727.	901.	210.	550.	626.	779.	160.	464.
7	31	80.	.291667	.375000	.166667	.291667	635.	789.	155.	438.	539.	671.	118.	374.
MONTHLY														
TOTAL			34327.	41770.	13075.	26931.	29359.	35511.	12092.	23218.	23032.	28370.	8146.	17767.
AVERAGE		79.	1107.	1347.	422.	869.	947.	1146.	390.	749.	743.	915.	263.	573.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON, D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 F8	140 S8	220 F8	220 S8	HORIZONTAL x 10^{-3} 140 F8	140 S8	220 F8	220 S8	50 DEG TILT x 10^{-3} 140 F8	140 S8	220 F8	220 S8
8	1	82.	.375000	.458333	.250000	.375000	1166.	1359.	586.	936.	1011.	1173.	512.	802.
8	2	80.	.375000	.416667	.250000	.333333	1260.	1458.	697.	1033.	1117.	1275.	612.	918.
8	3	84.	.375000	.416667	.333333	.375000	1279.	1448.	636.	1038.	1120.	1269.	522.	896.
8	4	80.	.250000	.375000	.000000	.250000	341.	493.	0.	208.	305.	431.	0.	179.
8	5	74.	.416667	.416667	.291667	.375000	1076.	1319.	375.	894.	923.	1165.	298.	758.
8	6	70.	.375000	.416667	.291667	.333333	1035.	1264.	451.	870.	928.	1137.	385.	770.
8	7	73.	.375000	.416667	.250000	.333333	963.	1214.	351.	792.	867.	1076.	297.	697.
8	8	76.	.333333	.375000	.083333	.250000	484.	642.	66.	313.	437.	587.	56.	277.
8	9	80.	.291667	.375000	.250000	.291667	714.	856.	241.	554.	681.	809.	217.	522.
8	10	79.	.250000	.333333	.083333	.250000	360.	519.	31.	239.	347.	495.	28.	227.
8	11	79.	.375000	.416667	.291667	.333333	1108.	1292.	540.	901.	1041.	1193.	507.	847.
8	12	82.	.333333	.375000	.250000	.291667	921.	1091.	393.	730.	889.	1053.	383.	708.
8	13	72.	.333333	.416667	.250000	.333333	1006.	1218.	455.	845.	970.	1163.	450.	817.
8	14	75.	.333333	.416667	.250000	.291667	850.	1079.	331.	695.	834.	1037.	331.	679.
8	15	79.	.333333	.375000	.125000	.250000	467.	634.	54.	301.	456.	610.	49.	302.
8	16	82.	.375000	.375000	.291667	.333333	1060.	1241.	460.	852.	1040.	1210.	464.	832.
8	17	74.	.291667	.375000	.208333	.250000	518.	679.	114.	382.	524.	671.	127.	396.
8	18	72.	.375000	.416667	.250000	.291667	844.	1049.	313.	668.	846.	1037.	337.	684.
8	19	65.	.208333	.291667	.000000	.208333	155.	315.	0.	95.	173.	330.	0.	112.
8	20	70.	.291667	.375000	.166667	.250000	646.	799.	259.	504.	674.	815.	292.	532.
8	21	74.	.375000	.416667	.250000	.375000	1001.	1187.	457.	800.	1023.	1181.	498.	821.
8	22	71.	.291667	.375000	.166667	.250000	548.	736.	169.	431.	587.	763.	209.	474.
8	23	70.	.375000	.416667	.250000	.333333	884.	1098.	330.	720.	924.	1128.	385.	760.
8	24	69.	.250000	.333333	.125000	.208333	359.	529.	53.	257.	395.	564.	81.	297.
8	25	67.	.208333	.291667	.000000	.208333	139.	303.	0.	80.	173.	339.	0.	114.
8	26	71.	.291667	.333333	.000000	.250000	270.	470.	0.	165.	310.	505.	0.	204.
8	27	77.	.375000	.416667	.250000	.375000	992.	1191.	427.	802.	1076.	1260.	515.	884.
8	28	70.	.375000	.375000	.208333	.291667	843.	1046.	376.	694.	936.	1137.	468.	788.
8	29	72.	.333333	.416667	.208333	.250000	666.	860.	237.	529.	758.	943.	323.	618.
8	30	79.	.375000	.416667	.333333	.333333	1056.	1224.	475.	842.	1165.	1329.	589.	958.
8	31	79.	.375000	.416667	.250000	.333333	878.	1053.	357.	697.	995.	1163.	468.	813.
MONTHLY														
TOTAL			30166.	37406.	11419.	23889.	23890.	29666.	9233.	18867.	23527.	28849.	9403.	18685.
AVERAGE		75.	973.	1207.	368.	771.	771.	957.	298.	609.	759.	931.	303.	603.

F8, FLAT BLACK SURFACE
S8, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	HORIZONTAL x 10^{-3} 140 FB	140 SB	220 FB	220 SB	50 DEG TILT x 10^{-3} 140 FB	140 SB	220 FB	220 SB
9	1	78.	.333333	.333333	.208333	.291667	743.	892.	315.	580.	862.	1009.	422.	696.
9	2	78.	.333333	.375000	.250000	.333333	860.	1050.	323.	701.	998.	1185.	453.	834.
9	3	80.	.291667	.375000	.208333	.250000	524.	690.	110.	378.	629.	795.	204.	476.
9	4	78.	.250000	.333333	.000000	.250000	242.	395.	0.	122.	315.	472.	0.	192.
9	5	71.	.416667	.416667	.291667	.375000	983.	1214.	378.	814.	1162.	1384.	553.	994.
9	6	70.	.250000	.291667	.125000	.250000	405.	544.	118.	299.	519.	659.	196.	410.
9	7	72.	.291667	.333333	.041667	.250000	257.	417.	0.	145.	349.	514.	7.	233.
9	8	72.	.208333	.333333	.083333	.208333	255.	388.	8.	164.	345.	488.	43.	252.
9	9	68.	.208333	.291667	.000000	.208333	128.	276.	0.	63.	209.	367.	0.	143.
9	10	75.	.250000	.333333	.125000	.250000	428.	567.	108.	310.	562.	706.	198.	442.
9	11	73.	.291667	.375000	.166667	.291667	474.	631.	114.	335.	623.	783.	187.	480.
9	12	77.	.250000	.333333	.208333	.250000	547.	665.	177.	415.	711.	836.	320.	576.
9	13	79.	.375000	.416667	.166667	.291667	540.	727.	124.	381.	725.	916.	250.	555.
9	14	77.	.333333	.375000	.166667	.291667	472.	602.	121.	327.	640.	774.	247.	481.
9	15	78.	.333333	.375000	.208333	.291667	606.	774.	196.	467.	822.	992.	379.	669.
9	16	76.	.250000	.375000	.166667	.208333	431.	587.	136.	346.	603.	774.	265.	492.
9	17	71.	.125000	.291667	.000000	.125000	108.	214.	0.	58.	177.	320.	0.	125.
9	18	70.	.125000	.291667	.041667	.125000	157.	259.	12.	108.	241.	381.	48.	190.
9	19	71.	.333333	.375000	.166667	.291667	563.	716.	236.	422.	810.	964.	392.	651.
9	20	72.	.166667	.291667	.000000	.125000	100.	208.	0.	51.	177.	324.	0.	124.
9	21	78.	.333333	.375000	.166667	.250000	430.	590.	96.	304.	646.	816.	230.	500.
9	22	79.	.333333	.333333	.208333	.291667	474.	642.	129.	346.	720.	884.	277.	556.
9	23	69.	.166667	.291667	.000000	.166667	86.	198.	0.	42.	183.	327.	0.	122.
9	24	63.	.375000	.416667	.250000	.375000	662.	906.	172.	535.	1038.	1277.	451.	903.
9	25	63.	.375000	.458333	.250000	.333333	751.	954.	273.	614.	1142.	1347.	603.	986.
9	26	66.	.208333	.291667	.041667	.166667	226.	349.	54.	155.	384.	532.	113.	297.
9	27	54.	.333333	.375000	.208333	.333333	460.	686.	105.	373.	797.	1031.	336.	694.
9	28	52.	.208333	.333333	.041667	.166667	148.	279.	12.	106.	299.	475.	66.	253.
9	29	55.	.125000	.291667	.000000	.125000	46.	144.	0.	15.	138.	273.	0.	106.
9	30	60.	.125000	.291667	.000000	.125000	48.	147.	0.	15.	141.	282.	0.	107.
MONTHLY TOTAL			18636.	24999.	6119.	14569.	12155.	16715.	3317.	8992.	16967.	21887.	6240.	13539.
AVERAGE		71.	621.	833.	204.	486.	405.	557.	111.	300.	566.	730.	208.	451.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL x 10^{-3}				HORIZONTAL x 10^{-3}				50 DEG TILT x 10^{-3}			
MONTH	DAY	DB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
10	1	61.	.125000	.291667	.000000	.125000	61.	155.	0.	23.	157.	297.	0.	116.
10	2	63.	.333333	.375000	.250000	.291667	520.	710.	138.	420.	885.	1106.	422.	770.
10	3	58.	.333333	.375000	.208333	.333333	416.	637.	90.	339.	782.	1018.	312.	679.
10	4	57.	.333333	.375000	.083333	.291667	220.	452.	17.	167.	518.	773.	118.	441.
10	5	58.	.125000	.333333	.000000	.083333	14.	99.	0.	4.	66.	245.	0.	44.
10	6	55.	.041667	.250000	.000000	.041667	0.	42.	0.	0.	35.	143.	0.	30.
10	7	57.	.250000	.375000	.083333	.166667	137.	260.	39.	100.	323.	501.	117.	234.
10	8	61.	.125000	.333333	.000000	.083333	14.	86.	0.	3.	69.	254.	0.	45.
10	9	66.	.333333	.375000	.250000	.333333	428.	644.	31.	320.	864.	1095.	308.	738.
10	10	62.	.291667	.375000	.041667	.250000	129.	304.	4.	76.	372.	599.	70.	285.
10	11	53.	.333333	.375000	.208333	.333333	238.	484.	0.	175.	636.	909.	121.	557.
10	12	49.	.375000	.375000	.291667	.375000	530.	786.	99.	459.	1111.	1376.	542.	1009.
10	13	51.	.375000	.375000	.291667	.375000	656.	845.	257.	532.	1276.	1457.	746.	1118.
10	14	54.	.375000	.375000	.291667	.375000	690.	839.	296.	554.	1297.	1447.	832.	1118.
10	15	55.	.333333	.375000	.166667	.333333	180.	371.	0.	97.	532.	745.	65.	415.
10	16	57.	.291667	.375000	.000000	.291667	55.	234.	0.	11.	310.	536.	0.	218.
10	17	61.	.125000	.291667	.000000	.000000	0.	24.	0.	0.	13.	153.	0.	0.
10	18	61.	.083333	.291667	.000000	.000000	0.	18.	0.	0.	2.	146.	0.	0.
10	19	53.	.208333	.333333	.000000	.166667	0.	84.	0.	0.	75.	310.	0.	40.
10	20	54.	.375000	.375000	.291667	.375000	444.	696.	39.	379.	1061.	1351.	479.	971.
10	21	53.	.333333	.375000	.250000	.333333	557.	730.	177.	448.	1201.	1376.	714.	1056.
10	22	56.	.333333	.375000	.166667	.250000	210.	385.	0.	141.	603.	834.	176.	503.
10	23	60.	.250000	.333333	.083333	.250000	91.	243.	0.	48.	363.	549.	48.	281.
10	24	63.	.000000	.291667	.000000	.000000	0.	8.	0.	0.	0.	130.	0.	0.
10	25	51.	.291667	.375000	.000000	.291667	15.	183.	0.	8.	256.	516.	0.	211.
10	26	43.	.166667	.333333	.041667	.166667	41.	167.	0.	26.	248.	467.	21.	226.
10	27	42.	.291667	.333333	.000000	.291667	0.	131.	0.	0.	188.	454.	0.	161.
10	28	42.	.333333	.375000	.000000	.291667	6.	199.	0.	0.	312.	620.	0.	280.
10	29	50.	.333333	.375000	.166667	.333333	128.	311.	0.	85.	541.	794.	134.	454.
10	30	52.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	109.	0.	0.
10	31	53.	.000000	.291667	.000000	.000000	0.	0.	0.	0.	0.	128.	0.	0.
MONTHLY														
TOTAL			16055.	23568.	5781.	13613.	5779.	10129.	1187.	4419.	14097.	20437.	5226.	12000.
AVERAGE		55.	518.	760.	186.	439.	186.	327.	38.	143.	455.	659.	169.	387.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

			NORMAL x 10^{-3}				HORIZONTAL x 10^{-3}				50 DEG TILT x 10^{-3}			
MONTH	DAY	DB	140		220		140		220		140		220	
			FB	SB	FB	SB	FB	SB	FB	SB	FB	SB	FB	SB
11	1	58.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	109.	0.	0.
11	2	59.	.000000	.291667	.000000	.000000	0.	0.	0.	0.	0.	117.	0.	0.
11	3	61.	.166667	.333333	.083333	.166667	37.	132.	0.	11.	234.	411.	5.	180.
11	4	55.	.291667	.333333	.041667	.291667	25.	187.	0.	4.	333.	578.	2.	269.
11	5	51.	.250000	.291667	.083333	.250000	40.	157.	0.	17.	295.	488.	32.	229.
11	6	47.	.333333	.375000	.250000	.333333	271.	512.	0.	232.	958.	1260.	426.	896.
11	7	48.	.291667	.375000	.208333	.291667	243.	400.	39.	175.	793.	984.	374.	686.
11	8	57.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	110.	0.	0.
11	9	46.	.333333	.333333	.125000	.333333	103.	295.	0.	83.	585.	862.	179.	530.
11	10	37.	.250000	.333333	.166667	.250000	151.	364.	0.	151.	684.	1006.	272.	678.
11	11	37.	.291667	.375000	.291667	.291667	258.	469.	23.	219.	960.	1234.	481.	895.
11	12	38.	.291667	.375000	.208333	.291667	138.	329.	0.	101.	695.	918.	267.	630.
11	13	44.	.166667	.291667	.041667	.125000	14.	61.	0.	0.	157.	299.	22.	108.
11	14	56.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	109.	0.	0.
11	15	60.	.291667	.375000	.125000	.208333	93.	192.	0.	49.	416.	615.	140.	336.
11	16	54.	.000000	.291667	.000000	.000000	0.	0.	0.	0.	0.	115.	0.	0.
11	17	55.	.250000	.333333	.083333	.208333	58.	171.	0.	35.	365.	567.	84.	305.
11	18	52.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	84.	0.	0.
11	19	61.	.041667	.291667	.000000	.000000	0.	0.	0.	0.	2.	140.	0.	0.
11	20	46.	.291667	.333333	.000000	.250000	0.	117.	0.	0.	275.	547.	0.	240.
11	21	48.	.291667	.333333	.166667	.291667	184.	344.	0.	150.	752.	991.	352.	687.
11	22	45.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	66.	0.	0.
11	23	40.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	56.	0.	0.
11	24	47.	.208333	.333333	.083333	.166667	21.	109.	0.	4.	293.	495.	44.	241.
11	25	43.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	84.	0.	0.
11	26	40.	.166667	.291667	.000000	.083333	0.	36.	0.	0.	102.	257.	0.	81.
11	27	43.	.208333	.250000	.125000	.208333	72.	179.	0.	53.	425.	596.	175.	384.
11	28	53.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	91.	0.	0.
11	29	57.	.250000	.333333	.041667	.208333	1.	82.	0.	0.	255.	456.	8.	188.
11	30	44.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	63.	0.	0.
MONTHLY														
TOTAL			9584.	15331.	2839.	8385.	1707.	4137.	62.	1285.	8577.	13707.	2865.	7563.
AVERAGE		49.	319.	511.	95.	279.	57.	138.	2.	43.	286.	457.	95.	252.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

SOLAR COLLECTOR DATA FOR
WASHINGTON D.C.

MONTH	DAY	DB	NORMAL x 10^{-3} 140 FB	NORMAL 140 SB	NORMAL 220 FB	NORMAL 220 SB	HORIZONTAL x 10^{-3} 140 FB	HORIZONTAL 140 SB	HORIZONTAL 220 FB	HORIZONTAL 220 SB	50 DEG TILT x 10^{-3} 140 FB	50 DEG TILT 140 SB	50 DEG TILT 220 FB	50 DEG TILT 220 SB
12	1	36.	.291667	.375000	.166667	.291667	80.	279.	0.	75.	728.	1021.	254.	716.
12	2	48.	.291667	.375000	.208333	.291667	171.	344.	0.	126.	844.	1082.	405.	771.
12	3	39.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	70.	0.	0.
12	4	32.	.000000	.125000	.000000	.000000	0.	0.	0.	0.	0.	26.	0.	0.
12	5	30.	.291667	.333333	.208333	.291667	44.	255.	0.	53.	701.	1010.	222.	711.
12	6	38.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	43.	0.	0.
12	7	50.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	68.	0.	0.
12	8	47.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	58.	0.	0.
12	9	43.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	51.	0.	0.
12	10	38.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	34.	0.	0.
12	11	30.	.000000	.125000	.000000	.000000	0.	0.	0.	0.	0.	18.	0.	0.
12	12	19.	.083333	.291667	.000000	.125000	0.	2.	0.	0.	28.	252.	0.	47.
12	13	27.	.208333	.291667	.125000	.208333	1.	108.	0.	2.	345.	630.	77.	354.
12	14	40.	.208333	.333333	.041667	.208333	8.	87.	0.	2.	323.	554.	46.	292.
12	15	43.	.291667	.333333	.250000	.291667	117.	285.	0.	86.	798.	1031.	346.	735.
12	16	45.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	78.	0.	0.
12	17	43.	.250000	.250000	.083333	.250000	0.	92.	0.	0.	349.	537.	30.	300.
12	18	42.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	57.	0.	0.
12	19	53.	.000000	.250000	.000000	.000000	0.	0.	0.	0.	0.	98.	0.	0.
12	20	58.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	84.	0.	0.
12	21	53.	.291667	.333333	.250000	.291667	113.	308.	0.	79.	851.	1093.	335.	783.
12	22	46.	.291667	.333333	.250000	.291667	137.	290.	0.	87.	844.	1012.	403.	744.
12	23	50.	.291667	.333333	.166667	.291667	25.	165.	0.	2.	495.	719.	96.	426.
12	24	51.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	87.	0.	0.
12	25	37.	.041667	.250000	.000000	.041667	0.	7.	0.	0.	34.	121.	0.	29.
12	26	44.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	67.	0.	0.
12	27	42.	.291667	.333333	.166667	.291667	68.	223.	0.	52.	670.	930.	244.	633.
12	28	43.	.000000	.208333	.000000	.000000	0.	0.	0.	0.	0.	74.	0.	0.
12	29	40.	.291667	.291667	.166667	.291667	30.	211.	0.	24.	621.	893.	179.	599.
12	30	38.	.166667	.250000	.041667	.166667	0.	79.	0.	0.	255.	409.	28.	223.
12	31	40.	.125000	.250000	.083333	.083333	1.	52.	0.	0.	183.	306.	57.	151.
MONTHLY TOTAL			8889.	13863.	2927.	8245.	795.	2787.	0.	590.	8069.	12510.	2721.	7512.
AVERAGE		41.	287.	447.	94.	266.	26.	90.	0.	19.	260.	404.	88.	242.

FB, FLAT BLACK SURFACE
SB, SELECTIVE BLACK SURFACE (BASED UPON DATA OF UNIV. OF PENNSYLVANIA)
ABSORBER TEMPERATURES 140 DEG F AND 220 DEG F
BASIC COLLECTOR- DOUBLE GLAZE

Appendix D

Computer Predictions for the Day by Day Performance of a Solar Heating and Cooling System in the NBS Test House for a Typical Weather Year (1957) in Washington, D.C.

1 Btu = 1054.34 J

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
JAN	1	79120.00	.00	184160.00	HEAT	.00	105040.00	184160.00	105040.00
JAN	2	211600.00	93840.00	253280.00	HEAT	.00	41680.00	437440.00	146720.00
JAN	3	107180.00	26220.00	214880.00	HEAT	.00	107700.00	652320.00	254420.00
JAN	4	161920.00	62560.00	115040.00	HEAT	42192.00	.00	767360.00	254420.00
JAN	5	9200.00	.00	161120.00	HEAT	.00	109728.00	928480.00	364148.00
JAN	6	.00	.00	199520.00	HEAT	.00	199520.00	1128000.00	563668.00
JAN	7	31740.00	13340.00	161120.00	HEAT	.00	129380.00	1289120.00	693048.00
JAN	8	2760.00	.00	161120.00	HEAT	.00	158360.00	1450240.00	851408.00
JAN	9	.00	.00	153440.00	HEAT	.00	153440.00	1603680.00	1004848.00
JAN	10	54280.00	.00	145760.00	HEAT	.00	91480.00	1749440.00	1096328.00
JAN	11	28060.00	1840.00	222560.00	HEAT	.00	194500.00	1972000.00	1290828.00
JAN	12	2300.00	.00	184160.00	HEAT	.00	181860.00	2156160.00	1472688.00
JAN	13	53820.00	.00	145760.00	HEAT	.00	91940.00	2301920.00	1564628.00
JAN	14	213900.00	106260.00	253280.00	HEAT	.00	39380.00	2555200.00	1604008.00
JAN	15	.00	.00	307040.00	HEAT	.00	307040.00	2862240.00	1911048.00
JAN	16	178940.00	86940.00	260960.00	HEAT	.00	82020.00	3123200.00	1993068.00
JAN	17	20700.00	.00	330080.00	HEAT	.00	309380.00	3453280.00	2302448.00
JAN	18	117760.00	41400.00	299360.00	HEAT	.00	181600.00	3752640.00	2484048.00
JAN	19	258520.00	144440.00	245600.00	HEAT	11628.00	.00	3998240.00	2484048.00
JAN	20	7360.00	.00	184160.00	HEAT	.00	165172.00	4182400.00	2649220.00
JAN	21	14260.00	.00	130400.00	HEAT	.00	116140.00	4312800.00	2765360.00
JAN	22	1380.00	.00	61280.00	HEAT	.00	59900.00	4374080.00	2825260.00
JAN	23	56580.00	.00	61280.00	HEAT	.00	4700.00	4435360.00	2829960.00
JAN	24	32200.00	3220.00	245600.00	HEAT	.00	213400.00	4680960.00	3043360.00
JAN	25	.00	.00	207200.00	HEAT	.00	207200.00	4888160.00	3250560.00
JAN	26	22540.00	.00	145760.00	HEAT	.00	123220.00	5033920.00	3373780.00
JAN	27	460.00	.00	122720.00	HEAT	.00	122260.00	5156640.00	3496040.00
JAN	28	.00	.00	153440.00	HEAT	.00	153440.00	5310080.00	3649480.00
JAN	29	460.00	.00	145760.00	HEAT	.00	145300.00	5455840.00	3794780.00
JAN	30	9660.00	.00	145760.00	HEAT	.00	136100.00	5601600.00	3930880.00
JAN	31	.00	.00	168800.00	HEAT	.00	168800.00	5770400.00	4099680.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
FEB	1	.00	.00	145760.00	HEAT	.00	145760.00	145760.00	145760.00
FEB	2	201480.00	81420.00	130400.00	HEAT	63972.00	.00	276160.00	145760.00
FEB	3	5060.00	.00	122720.00	HEAT	.00	53688.00	398880.00	199448.00
FEB	4	39100.00	.00	45920.00	HEAT	.00	6820.00	444800.00	206268.00
FEB	5	1840.00	.00	145760.00	HEAT	.00	143920.00	590560.00	350188.00
FEB	6	920.00	.00	168800.00	HEAT	.00	167880.00	759360.00	518068.00
FEB	7	3220.00	.00	130400.00	HEAT	.00	127180.00	889760.00	645248.00
FEB	8	5980.00	.00	115040.00	HEAT	.00	109060.00	1004800.00	754308.00
FEB	9	3680.00	.00	99680.00	HEAT	.00	96000.00	1104480.00	850308.00
FEB	10	167900.00	43240.00	45920.00	HEAT	109782.00	.00	1150400.00	850308.00
FEB	11	.00	.00	161120.00	HEAT	.00	51338.00	1311520.00	901646.00
FEB	12	191820.00	70380.00	199520.00	HEAT	.00	7700.00	1511040.00	909346.00
FEB	13	132020.00	28060.00	153440.00	HEAT	.00	21420.00	1664480.00	930766.00
FEB	14	31280.00	3220.00	161120.00	HEAT	.00	129840.00	1825600.00	1060606.00
FEB	15	7360.00	.00	176480.00	HEAT	.00	169120.00	2002080.00	1229726.00
FEB	16	86480.00	11040.00	138080.00	HEAT	.00	51600.00	2140160.00	1281326.00
FEB	17	179400.00	48300.00	168800.00	HEAT	9540.00	.00	2308960.00	1281326.00
FEB	18	326600.00	198260.00	122720.00	HEAT	193032.00	.00	2431680.00	1281326.00
FEB	19	10580.00	.00	107360.00	HEAT	96252.00	.00	2539040.00	1281326.00
FEB	20	381800.00	234140.00	191840.00	HEAT	267215.99	.00	2730880.00	1281326.00
FEB	21	429640.00	286580.00	168800.00	HEAT	501971.99	.00	2899680.00	1281326.00
FEB	22	177100.00	51980.00	145760.00	HEAT	530177.98	.00	3045440.00	1281326.00
FEB	23	66240.00	5520.00	92000.00	HEAT	504417.98	.00	3137440.00	1281326.00
FEB	24	317860.00	172500.00	76640.00	HEAT	658618.41	.00	3214080.00	1281326.00
FEB	25	24840.00	.00	61280.00	HEAT	622178.41	.00	3275360.00	1281326.00
FEB	26	27140.00	.00	7520.00	HEAT	622178.41	.00	3282880.00	1281326.00
FEB	27	64400.00	8740.00	15200.00	HEAT	627520.12	.00	3298080.00	1281326.00
FEB	28	1840.00	.00	176480.00	HEAT	452880.12	.00	3474560.00	1281326.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
MAR	1	9660.00	.00	168800.00	HEAT	293740.12	.00	168800.00	.00
MAR	2	112700.00	35880.00	107360.00	HEAT	298546.12	.00	276160.00	.00
MAR	3	451260.00	298540.00	161120.00	HEAT	559672.12	.00	437280.00	.00
MAR	4	402500.00	259900.00	176480.00	HEAT	693608.54	.00	613760.00	.00
MAR	5	367080.00	234600.00	153440.00	HEAT	802838.01	.00	767200.00	.00
MAR	6	35880.00	5980.00	122720.00	HEAT	715998.01	.00	889920.00	.00
MAR	7	36800.00	6440.00	130400.00	HEAT	622398.01	.00	1020320.00	.00
MAR	8	55200.00	11500.00	115040.00	HEAT	562558.01	.00	1135360.00	.00
MAR	9	89700.00	23000.00	122720.00	HEAT	529538.01	.00	1258080.00	.00
MAR	10	414460.00	266800.00	130400.00	HEAT	705967.55	.00	1388480.00	.00
MAR	11	199180.00	81420.00	115040.00	HEAT	733483.07	.00	1503520.00	.00
MAR	12	143060.00	40940.00	22880.00	HEAT	760996.95	.00	1526400.00	.00
MAR	13	396060.00	237820.00	30560.00	HEAT	936572.78	.00	1556960.00	.00
MAR	14	470580.00	308660.00	.00		1183500.77	.00	1556960.00	.00
MAR	15	117760.00	34960.00	.00		1211468.75	.00	1556960.00	.00
MAR	16	509680.00	340860.00	22880.00	HEAT	1400000.00	.00	1579840.00	.00
MAR	17	403420.00	241040.00	22880.00	HEAT	1400000.00	.00	1602720.00	.00
MAR	18	149960.00	56580.00	61280.00	HEAT	1400000.00	.00	1664000.00	.00
MAR	19	78200.00	17480.00	107360.00	HEAT	1370840.00	.00	1771360.00	.00
MAR	20	81880.00	18400.00	107360.00	HEAT	1345360.00	.00	1878720.00	.00
MAR	21	436540.00	276460.00	84320.00	HEAT	1400000.00	.00	1963040.00	.00
MAR	22	92000.00	30820.00	99680.00	HEAT	1392320.00	.00	2062720.00	.00
MAR	23	530380.00	358800.00	61280.00	HEAT	1400000.00	.00	2124000.00	.00
MAR	24	332120.00	187220.00	30560.00	HEAT	1400000.00	.00	2154560.00	.00
MAR	25	101660.00	24840.00	115040.00	HEAT	1386620.00	.00	2269600.00	.00
MAR	26	268180.00	174800.00	92000.00	HEAT	1400000.00	.00	2361600.00	.00
MAR	27	199640.00	99360.00	76640.00	HEAT	1400000.00	.00	2438240.00	.00
MAR	28	121900.00	46460.00	84320.00	HEAT	1400000.00	.00	2522560.00	.00
MAR	29	279220.00	166060.00	84320.00	HEAT	1400000.00	.00	2606880.00	.00
MAR	30	327060.00	169740.00	92000.00	HEAT	1400000.00	.00	2698880.00	.00
MAR	31	581440.00	414000.00	99680.00	HEAT	1400000.00	.00	2798560.00	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
APR	1	118680.00	40940.00	84320.00	HEAT	1400000.00	.00	84320.00	.00
APR	2	342240.00	191360.00	.00		1400000.00	.00	84320.00	.00
APR	3	200560.00	95220.00	68960.00	HEAT	1400000.00	.00	153280.00	.00
APR	4	127420.00	30820.00	99680.00	HEAT	1400000.00	.00	252960.00	.00
APR	5	153640.00	61640.00	22880.00	HEAT	1400000.00	.00	275840.00	.00
APR	6	172960.00	75440.00	53600.00	HEAT	1400000.00	.00	329440.00	.00
APR	7	538200.00	355120.00	.00		1400000.00	.00	329440.00	.00
APR	8	140300.00	42320.00	61280.00	HEAT	1400000.00	.00	390720.00	.00
APR	9	470120.00	304980.00	84320.00	HEAT	1400000.00	.00	475040.00	.00
APR	10	555220.00	371680.00	53600.00	HEAT	1400000.00	.00	528640.00	.00
APR	11	570860.00	406180.00	15200.00	HEAT	1400000.00	.00	543840.00	.00
APR	12	457240.00	315560.00	.00		1400000.00	.00	543840.00	.00
APR	13	405260.00	257140.00	115040.00	HEAT	1400000.00	.00	658880.00	.00
APR	14	422280.00	266340.00	107360.00	HEAT	1400000.00	.00	766240.00	.00
APR	15	639860.00	460920.00	92000.00	HEAT	1400000.00	.00	858240.00	.00
APR	16	241040.00	102580.00	45920.00	HEAT	1400000.00	.00	904160.00	.00
APR	17	176640.00	76360.00	.00		1400000.00	.00	904160.00	.00
APR	18	240580.00	114540.00	.00		1400000.00	.00	904160.00	.00
APR	19	239200.00	102580.00	.00		1400000.00	.00	904160.00	.00
APR	20	315560.00	187680.00	.00		1400000.00	.00	904160.00	.00
APR	21	590640.00	404340.00	166666.67	A/C	1400000.00	.00	1070826.66	.00
APR	22	372140.00	221720.00	.00		1400000.00	.00	1070826.66	.00
APR	23	285200.00	155940.00	.00		1400000.00	.00	1070826.66	.00
APR	24	530840.00	358340.00	193950.00	A/C	1400000.00	.00	1264776.66	.00
APR	25	207000.00	70840.00	.00		1400000.00	.00	1264776.66	.00
APR	26	362480.00	212980.00	.00		1400000.00	.00	1264776.66	.00
APR	27	679880.00	491740.00	193950.00	A/C	1400000.00	.00	1458726.66	.00
APR	28	589720.00	428260.00	221233.33	A/C	1400000.00	.00	1679959.98	.00
APR	29	563040.00	384100.00	57533.33	A/C	1400000.00	.00	1737493.31	.00
APR	30	737840.00	536360.00	2966.67	A/C	1400000.00	.00	1740459.97	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	YPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
MAY	1	743820.00	541880.00	57533.33	A/C	1400000.00	.00	57533.33	.00
MAY	2	684020.00	498640.00	.00		1400000.00	.00	57533.33	.00
MAY	3	654120.00	473340.00	30560.00	HEAT	1400000.00	.00	88093.33	.00
MAY	4	603520.00	428260.00	53600.00	HEAT	1400000.00	.00	141693.33	.00
MAY	5	511060.00	348220.00	7520.00	HEAT	1400000.00	.00	149213.33	.00
MAY	6	516120.00	355120.00	.00		1400000.00	.00	149213.33	.00
MAY	7	742440.00	540040.00	.00		1400000.00	.00	149213.33	.00
MAY	8	760380.00	555680.00	30250.00	A/C	1400000.00	.00	179463.33	.00
MAY	9	655960.00	456780.00	112100.00	A/C	1400000.00	.00	291563.33	.00
MAY	10	539120.00	348220.00	166666.67	A/C	1400000.00	.00	458230.00	.00
MAY	11	217120.00	88780.00	2966.67	A/C	1400000.00	.00	461196.66	.00
MAY	12	373980.00	233680.00	.00		1400000.00	.00	461196.66	.00
MAY	13	563500.00	401580.00	221233.33	A/C	1400000.00	.00	682429.99	.00
MAY	14	572240.00	413540.00	193950.00	A/C	1400000.00	.00	876379.99	.00
MAY	15	542800.00	385020.00	193950.00	A/C	1400000.00	.00	1070329.98	.00
MAY	16	488520.00	313260.00	.00		1400000.00	.00	1070329.98	.00
MAY	17	249780.00	117300.00	.00		1400000.00	.00	1070329.98	.00
MAY	18	548780.00	397900.00	57533.33	A/C	1400000.00	.00	1127863.31	.00
MAY	19	206080.00	70840.00	.00		1400000.00	.00	1127863.31	.00
MAY	20	214820.00	87860.00	.00		1400000.00	.00	1127863.31	.00
MAY	21	198720.00	69000.00	22880.00	HEAT	1400000.00	.00	1150743.31	.00
MAY	22	207460.00	73140.00	.00		1400000.00	.00	1150743.31	.00
MAY	23	665160.00	477940.00	221233.33	A/C	1400000.00	.00	1371976.64	.00
MAY	24	625140.00	434700.00	193950.00	A/C	1400000.00	.00	1565926.64	.00
MAY	25	711620.00	521640.00	30250.00	A/C	1400000.00	.00	1596176.64	.00
MAY	26	557980.00	380420.00	193950.00	A/C	1400000.00	.00	1790126.64	.00
MAY	27	350520.00	190440.00	84816.67	A/C	1400000.00	.00	1874943.30	.00
MAY	28	636640.00	437920.00	.00		1400000.00	.00	1874943.30	.00
MAY	29	493580.00	309580.00	.00		1400000.00	.00	1874943.30	.00
MAY	30	387780.00	250700.00	.00		1400000.00	.00	1874943.30	.00
MAY	31	479320.00	301760.00	.00		1400000.00	.00	1874943.30	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
JUN	1	388700.00	205160.00	65866.67	A/C	1400000.00	.00	65866.67	.00
JUN	2	293940.00	133860.00	147716.67	A/C	1386143.34	.00	213583.33	.00
JUN	3	207460.00	72220.00	.00		1400000.00	.00	213583.33	.00
JUN	4	229540.00	99820.00	.00		1400000.00	.00	213583.33	.00
JUN	5	224020.00	90620.00	.00		1400000.00	.00	213583.33	.00
JUN	6	413080.00	256220.00	38583.33	A/C	1400000.00	.00	252166.66	.00
JUN	7	631580.00	451720.00	202283.33	A/C	1400000.00	.00	454450.00	.00
JUN	8	201020.00	65780.00	.00		1400000.00	.00	454450.00	.00
JUN	9	371220.00	215280.00	.00		1400000.00	.00	454450.00	.00
JUN	10	674820.00	487600.00	.00		1400000.00	.00	454450.00	.00
JUN	11	625140.00	438380.00	65866.67	A/C	1400000.00	.00	520316.66	.00
JUN	12	539120.00	351900.00	311416.66	A/C	1400000.00	.00	831733.32	.00
JUN	13	726800.00	518420.00	365983.33	A/C	1400000.00	.00	1197716.64	.00
JUN	14	622380.00	429180.00	338700.00	A/C	1400000.00	.00	1536416.64	.00
JUN	15	724500.00	530840.00	393266.66	A/C	1400000.00	.00	1929683.30	.00
JUN	16	718060.00	538660.00	420550.00	A/C	1400000.00	.00	2350233.28	.00
JUN	17	715300.00	525320.00	447833.33	A/C	1400000.00	.00	2798066.59	.00
JUN	18	630660.00	449420.00	475116.67	A/C	1374303.34	.00	3273183.25	.00
JUN	19	447580.00	263120.00	393266.66	A/C	1244156.69	.00	3666449.91	.00
JUN	20	663320.00	458620.00	175000.00	A/C	1400000.00	.00	3841449.91	.00
JUN	21	697820.00	494040.00	256850.00	A/C	1400000.00	.00	4098299.91	.00
JUN	22	620540.00	432400.00	338700.00	A/C	1400000.00	.00	4436999.87	.00
JUN	23	480700.00	318320.00	365983.33	A/C	1352336.67	.00	4802983.19	.00
JUN	24	563960.00	401580.00	338700.00	A/C	1400000.00	.00	5141683.19	.00
JUN	25	396060.00	236900.00	202283.33	A/C	1400000.00	.00	5343966.50	.00
JUN	26	500020.00	354200.00	229566.67	A/C	1400000.00	.00	5573533.12	.00
JUN	27	538200.00	383180.00	284133.33	A/C	1400000.00	.00	5857666.44	.00
JUN	28	362480.00	199180.00	311416.66	A/C	1287763.34	.00	6169083.06	.00
JUN	29	591100.00	405720.00	256850.00	A/C	1400000.00	.00	6425933.06	.00
JUN	30	605820.00	429180.00	175000.00	A/C	1400000.00	.00	6600933.06	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
JUL	1	637100.00	427800.00	147716.67	A/C	1400000.00	.00	147716.67	.00
JUL	2	753480.00	548780.00	65866.67	A/C	1400000.00	.00	213583.33	.00
JUL	3	763600.00	564420.00	202283.33	A/C	1400000.00	.00	415866.66	.00
JUL	4	529000.00	370300.00	365983.33	A/C	1400000.00	.00	781849.99	.00
JUL	5	477940.00	310960.00	447833.33	A/C	1263126.67	.00	1229683.31	.00
JUL	6	749340.00	539580.00	256850.00	A/C	1400000.00	.00	1486533.31	.00
JUL	7	616860.00	444820.00	311416.66	A/C	1400000.00	.00	1797949.97	.00
JUL	8	261280.00	122820.00	311416.66	A/C	1211403.34	.00	2109366.62	.00
JUL	9	567640.00	385940.00	393266.66	A/C	1204076.69	.00	2502633.28	.00
JUL	10	764060.00	555220.00	175000.00	A/C	1400000.00	.00	2677633.28	.00
JUL	11	491280.00	300380.00	175000.00	A/C	1400000.00	.00	2852633.28	.00
JUL	12	477940.00	306820.00	338700.00	A/C	1368120.00	.00	3191333.28	.00
JUL	13	310960.00	158240.00	338700.00	A/C	1187660.00	.00	3530033.28	.00
JUL	14	555680.00	373520.00	420550.00	A/C	1140630.00	.00	3950583.28	.00
JUL	15	634340.00	439760.00	393266.66	A/C	1177824.66	.00	4343849.94	.00
JUL	16	708860.00	511980.00	202283.33	A/C	1400000.00	.00	4546133.25	.00
JUL	17	413080.00	263580.00	229566.67	A/C	1400000.00	.00	4775699.87	.00
JUL	18	320620.00	163300.00	256850.00	A/C	1306450.00	.00	5032549.87	.00
JUL	19	642620.00	438380.00	256850.00	A/C	1400000.00	.00	5289399.87	.00
JUL	20	784760.00	575000.00	338700.00	A/C	1400000.00	.00	5628099.87	.00
JUL	21	778320.00	570400.00	502400.00	A/C	1400000.00	.00	6130499.87	.00
JUL	22	577300.00	402960.00	502400.00	A/C	1300560.00	.00	6632899.87	.00
JUL	23	276460.00	125120.00	229566.67	A/C	1196113.34	.00	6862466.50	.00
JUL	24	517500.00	342240.00	147716.67	A/C	1351732.00	.00	7010183.12	.00
JUL	25	554760.00	378580.00	147716.67	A/C	1400000.00	.00	7157899.75	.00
JUL	26	261740.00	95220.00	147716.67	A/C	1347503.34	.00	7305616.37	.00
JUL	27	478860.00	311880.00	229566.67	A/C	1400000.00	.00	7535183.00	.00
JUL	28	529920.00	343620.00	229566.67	A/C	1400000.00	.00	7764749.62	.00
JUL	29	462300.00	299000.00	284133.33	A/C	1400000.00	.00	8048882.94	.00
JUL	30	432860.00	273240.00	284133.33	A/C	1389106.67	.00	8333016.25	.00
JUL	31	378580.00	219880.00	311416.66	A/C	1297570.02	.00	8644432.87	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F. SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
AUG	1	650440.00	459080.00	365983.33	A/C	1372047.34	.00	365983.33	.00
AUG	2	697360.00	507840.00	311416.66	A/C	1400000.00	.00	677399.99	.00
AUG	3	691840.00	507380.00	420550.00	A/C	1400000.00	.00	1097949.98	.00
AUG	4	241500.00	110400.00	311416.66	A/C	1198983.34	.00	1409366.64	.00
AUG	5	634340.00	440220.00	147716.67	A/C	1400000.00	.00	1557083.30	.00
AUG	6	610880.00	432400.00	38583.33	A/C	1400000.00	.00	1595666.62	.00
AUG	7	586500.00	395140.00	120433.33	A/C	1400000.00	.00	1716099.95	.00
AUG	8	314640.00	163760.00	202283.33	A/C	1361476.67	.00	1918383.28	.00
AUG	9	420440.00	281520.00	311416.66	A/C	1331580.02	.00	2229799.94	.00
AUG	10	258060.00	128340.00	284133.33	A/C	1175786.69	.00	2513933.25	.00
AUG	11	628820.00	450340.00	284133.33	A/C	1308752.02	.00	2798066.56	.00
AUG	12	536360.00	370300.00	365983.33	A/C	1312205.34	.00	3164049.87	.00
AUG	13	598920.00	427800.00	93150.00	A/C	1400000.00	.00	3257199.87	.00
AUG	14	531760.00	355120.00	175000.00	A/C	1400000.00	.00	3432199.87	.00
AUG	15	314640.00	160540.00	284133.33	A/C	1276406.67	.00	3716333.19	.00
AUG	16	610420.00	432860.00	365983.33	A/C	1329908.00	.00	4082316.50	.00
AUG	17	339940.00	201480.00	147716.67	A/C	1372918.66	.00	4230033.12	.00
AUG	18	520260.00	346380.00	93150.00	A/C	1400000.00	.00	4323183.12	.00
AUG	19	164220.00	60720.00	.00		1400000.00	.00	4323183.12	.00
AUG	20	401580.00	264960.00	38583.33	A/C	1400000.00	.00	4361766.44	.00
AUG	21	589720.00	412160.00	147716.67	A/C	1400000.00	.00	4509483.06	.00
AUG	22	372600.00	230000.00	65866.67	A/C	1400000.00	.00	4575349.69	.00
AUG	23	551080.00	376740.00	38583.33	A/C	1400000.00	.00	4613933.00	.00
AUG	24	271860.00	141680.00	11300.00	A/C	1400000.00	.00	4625233.00	.00
AUG	25	161000.00	55660.00	.00		1400000.00	.00	4625233.00	.00
AUG	26	243340.00	98900.00	65866.67	A/C	1400000.00	.00	4691099.62	.00
AUG	27	600300.00	421360.00	229566.67	A/C	1400000.00	.00	4920666.25	.00
AUG	28	532220.00	369380.00	38583.33	A/C	1400000.00	.00	4959249.56	.00
AUG	29	441140.00	284280.00	93150.00	A/C	1400000.00	.00	5052399.56	.00
AUG	30	620080.00	442980.00	284133.33	A/C	1400000.00	.00	5336532.87	.00
AUG	31	537280.00	372140.00	284133.33	A/C	1400000.00	.00	5620666.19	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
SEP	1	458620.00	313260.00	248516.67	A/C	1400000.00	.00	248516.67	.00
SEP	2	538660.00	376280.00	248516.67	A/C	1400000.00	.00	497033.33	.00
SEP	3	358340.00	209760.00	303083.33	A/C	1306676.67	.00	800116.66	.00
SEP	4	209760.00	80500.00	248516.67	A/C	1138660.02	.00	1048633.33	.00
SEP	5	626060.00	440680.00	57533.33	A/C	1400000.00	.00	1106166.66	.00
SEP	6	287960.00	173420.00	30250.00	A/C	1400000.00	.00	1136416.66	.00
SEP	7	224020.00	94760.00	84816.67	A/C	1400000.00	.00	1221233.31	.00
SEP	8	209760.00	102120.00	84816.67	A/C	1400000.00	.00	1306049.97	.00
SEP	9	154100.00	52900.00	.00		1400000.00	.00	1306049.97	.00
SEP	10	301760.00	181240.00	166666.67	A/C	1400000.00	.00	1472716.62	.00
SEP	11	335800.00	196420.00	112100.00	A/C	1400000.00	.00	1584816.62	.00
SEP	12	353740.00	235520.00	221233.33	A/C	1400000.00	.00	1806049.95	.00
SEP	13	387780.00	222640.00	275800.00	A/C	1346840.00	.00	2081849.95	.00
SEP	14	323380.00	191360.00	221233.33	A/C	1316966.67	.00	2303083.28	.00
SEP	15	413080.00	266800.00	248516.67	A/C	1331593.33	.00	2551599.94	.00
SEP	16	317860.00	195960.00	193950.00	A/C	1333201.33	.00	2745549.94	.00
SEP	17	125120.00	43700.00	57533.33	A/C	1319368.00	.00	2803083.25	.00
SEP	18	149040.00	69920.00	30250.00	A/C	1351104.00	.00	2833333.25	.00
SEP	19	389620.00	249780.00	57533.33	A/C	1400000.00	.00	2890866.56	.00
SEP	20	123280.00	40940.00	84816.67	A/C	1356123.34	.00	2975683.22	.00
SEP	21	324300.00	185840.00	248516.67	A/C	1293446.69	.00	3224199.87	.00
SEP	22	351440.00	206540.00	275800.00	A/C	1224186.69	.00	3499999.87	.00
SEP	23	120520.00	37260.00	2966.67	A/C	1251621.34	.00	3502966.53	.00
SEP	24	499100.00	328440.00	.00		1400000.00	.00	3502966.53	.00
SEP	25	524400.00	364780.00	.00		1400000.00	.00	3502966.53	.00
SEP	26	200560.00	102580.00	.00		1400000.00	.00	3502966.53	.00
SEP	27	389160.00	237820.00	22880.00	HEAT	1400000.00	.00	3525846.53	.00
SEP	28	168360.00	80040.00	38240.00	HEAT	1400000.00	.00	3564086.53	.00
SEP	29	92000.00	26220.00	15200.00	HEAT	1400000.00	.00	3579286.53	.00
SEP	30	93380.00	26720.00	.00		1400000.00	.00	3579286.53	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
OCT	1	98440.00	29900.00	.00		1400000.00	.00	.00	.00
OCT	2	406640.00	262200.00	.00		1400000.00	.00	.00	.00
OCT	3	367540.00	220340.00	.00		1400000.00	.00	.00	.00
OCT	4	270480.00	125580.00	.00		1400000.00	.00	.00	.00
OCT	5	73140.00	8280.00	.00		1400000.00	.00	.00	.00
OCT	6	36800.00	5060.00	15200.00	HEAT	1400000.00	.00	15200.00	.00
OCT	7	163760.00	66240.00	.00		1400000.00	.00	15200.00	.00
OCT	8	70840.00	8280.00	.00		1400000.00	.00	15200.00	.00
OCT	9	380880.00	222640.00	.00		1400000.00	.00	15200.00	.00
OCT	10	193200.00	69000.00	.00		1400000.00	.00	15200.00	.00
OCT	11	299000.00	149040.00	30560.00	HEAT	1400000.00	.00	45760.00	.00
OCT	12	469200.00	305440.00	61280.00	HEAT	1400000.00	.00	107040.00	.00
OCT	13	499560.00	345000.00	45920.00	HEAT	1400000.00	.00	152960.00	.00
OCT	14	495420.00	351900.00	22880.00	HEAT	1400000.00	.00	175840.00	.00
OCT	15	235980.00	97520.00	15200.00	HEAT	1400000.00	.00	191040.00	.00
OCT	16	157780.00	33580.00	.00		1400000.00	.00	191040.00	.00
OCT	17	31740.00	.00	.00		1400000.00	.00	191040.00	.00
OCT	18	28060.00	.00	.00		1400000.00	.00	191040.00	.00
OCT	19	77280.00	.00	30560.00	HEAT	1400000.00	.00	221600.00	.00
OCT	20	433320.00	273240.00	22880.00	HEAT	1400000.00	.00	244480.00	.00
OCT	21	444360.00	305900.00	30560.00	HEAT	1400000.00	.00	275040.00	.00
OCT	22	251620.00	125580.00	7520.00	HEAT	1400000.00	.00	282560.00	.00
OCT	23	161460.00	54280.00	.00		1400000.00	.00	282560.00	.00
OCT	24	20700.00	.00	.00		1400000.00	.00	282560.00	.00
OCT	25	139380.00	20700.00	45920.00	HEAT	1400000.00	.00	328480.00	.00
OCT	26	120060.00	43700.00	107360.00	HEAT	1400000.00	.00	435840.00	.00
OCT	27	114540.00	15640.00	115040.00	HEAT	1399500.00	.00	550880.00	.00
OCT	28	157320.00	30360.00	115040.00	HEAT	1400000.00	.00	665920.00	.00
OCT	29	219880.00	89240.00	53600.00	HEAT	1400000.00	.00	719520.00	.00
OCT	30	11960.00	.00	38240.00	HEAT	1373720.00	.00	757760.00	.00
OCT	31	12880.00	.00	30560.00	HEAT	1356040.00	.00	788320.00	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	COLLECTOR OUTPUT(BTU) 220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
NOV	1	11500.00	.00	.00		1356040.00	.00	.00	.00
NOV	2	12880.00	.00	.00		1356040.00	.00	.00	.00
NOV	3	102580.00	28520.00	.00		1378855.98	.00	.00	.00
NOV	4	147200.00	32200.00	15200.00	HEAT	1400000.00	.00	15200.00	.00
NOV	5	123280.00	32200.00	45920.00	HEAT	1400000.00	.00	61120.00	.00
NOV	6	348220.00	208840.00	76640.00	HEAT	1400000.00	.00	137760.00	.00
NOV	7	272320.00	152720.00	68960.00	HEAT	1400000.00	.00	206720.00	.00
NOV	8	10580.00	.00	.00		1400000.00	.00	206720.00	.00
NOV	9	221260.00	99360.00	84320.00	HEAT	1400000.00	.00	291040.00	.00
NOV	10	260360.00	144440.00	153440.00	HEAT	1400000.00	.00	444480.00	.00
NOV	11	326600.00	199180.00	153440.00	HEAT	1400000.00	.00	597920.00	.00
NOV	12	242420.00	124660.00	145760.00	HEAT	1400000.00	.00	743680.00	.00
NOV	13	58880.00	12880.00	99680.00	HEAT	1359200.00	.00	843360.00	.00
NOV	14	7820.00	.00	7520.00	HEAT	1359200.00	.00	850880.00	.00
NOV	15	144440.00	60720.00	.00		1400000.00	.00	850880.00	.00
NOV	16	7820.00	.00	22880.00	HEAT	1384940.00	.00	873760.00	.00
NOV	17	135240.00	45540.00	15200.00	HEAT	1400000.00	.00	888960.00	.00
NOV	18	920.00	.00	38240.00	HEAT	1362680.00	.00	927200.00	.00
NOV	19	12880.00	.00	.00		1362680.00	.00	927200.00	.00
NOV	20	112700.00	15640.00	84320.00	HEAT	1365830.75	.00	1011520.00	.00
NOV	21	253920.00	140300.00	68960.00	HEAT	1400000.00	.00	1080480.00	.00
NOV	22	460.00	.00	92000.00	HEAT	1308460.00	.00	1172480.00	.00
NOV	23	.00	.00	130400.00	HEAT	1178060.00	.00	1302880.00	.00
NOV	24	99360.00	23000.00	76640.00	HEAT	1182267.41	.00	1379520.00	.00
NOV	25	.00	.00	107360.00	HEAT	1074907.41	.00	1486880.00	.00
NOV	26	40480.00	1380.00	130400.00	HEAT	984987.41	.00	1617280.00	.00
NOV	27	142140.00	71760.00	107360.00	HEAT	999034.47	.00	1724640.00	.00
NOV	28	2300.00	.00	30560.00	HEAT	970774.47	.00	1755200.00	.00
NOV	29	86940.00	6900.00	.00		976294.46	.00	1755200.00	.00
NOV	30	.00	.00	99680.00	HEAT	876614.46	.00	1854880.00	.00

MONTH	DAY	COLLECTOR OUTPUT(BTU) 140F SB	220F SB	LOAD BTU	TYPE BTU	STORAGE BTU	AUX HEAT BTU	TOTAL LOAD	TOTAL AUX.
DEC	1	237820.00	111320.00	161120.00	HEAT	905336.16	.00	161120.00	.00
DEC	2	262660.00	146740.00	68960.00	HEAT	991907.50	.00	230080.00	.00
DEC	3	.00	.00	138080.00	HEAT	853827.50	.00	368160.00	.00
DEC	4	.00	.00	191840.00	HEAT	661987.50	.00	560000.00	.00
DEC	5	229540.00	105340.00	207200.00	HEAT	670189.27	.00	767200.00	.00
DEC	6	.00	.00	145760.00	HEAT	524429.27	.00	912960.00	.00
DEC	7	.00	.00	53600.00	HEAT	470829.27	.00	966560.00	.00
DEC	8	.00	.00	76640.00	HEAT	394189.27	.00	1043200.00	.00
DEC	9	.00	.00	107360.00	HEAT	286829.27	.00	1150560.00	.00
DEC	10	.00	.00	145760.00	HEAT	141069.27	.00	1296320.00	.00
DEC	11	.00	.00	207200.00	HEAT	.00	66130.73	1503520.00	66130.73
DEC	12	21160.00	.00	291680.00	HEAT	.00	270520.00	1795200.00	336650.73
DEC	13	116380.00	40020.00	230240.00	HEAT	.00	113860.00	2025440.00	450510.73
DEC	14	100280.00	17020.00	130400.00	HEAT	.00	30120.00	2155840.00	480630.73
DEC	15	236900.00	119600.00	107360.00	HEAT	116586.00	.00	2263200.00	480630.73
DEC	16	.00	.00	92000.00	HEAT	24586.00	.00	2355200.00	480630.73
DEC	17	107640.00	17020.00	107360.00	HEAT	24838.00	.00	2462560.00	480630.73
DEC	18	.00	.00	115040.00	HEAT	.00	90202.00	2577600.00	570832.73
DEC	19	920.00	.00	30560.00	HEAT	.00	29640.00	2608160.00	600472.73
DEC	20	.00	.00	.00		2200000.00	2200000.00	2608160.00	2800472.72
DEC	21	254840.00	124200.00	30560.00	HEAT	1400000.00	.00	2638720.00	2800472.72
DEC	22	239200.00	123740.00	84320.00	HEAT	1400000.00	.00	2723040.00	2800472.72
DEC	23	151800.00	47380.00	53600.00	HEAT	1400000.00	.00	2776640.00	2800472.72
DEC	24	460.00	.00	45920.00	HEAT	1354540.00	.00	2822560.00	2800472.72
DEC	25	12420.00	.00	153440.00	HEAT	1213520.00	.00	2976000.00	2800472.72
DEC	26	.00	.00	99680.00	HEAT	1113840.00	.00	3075680.00	2800472.72
DEC	27	204240.00	90160.00	115040.00	HEAT	1145341.25	.00	3190720.00	2800472.72
DEC	28	920.00	.00	107360.00	HEAT	1038901.25	.00	3298080.00	2800472.72
DEC	29	193200.00	76360.00	130400.00	HEAT	1058758.00	.00	3428480.00	2800472.72
DEC	30	81880.00	12880.00	145760.00	HEAT	994878.00	.00	3574240.00	2800472.72
DEC	31	49680.00	15640.00	130400.00	HEAT	914158.00	.00	3704640.00	2800472.72

TOTAL ANNUAL LOAD (BTU) 46452081.00

TOTAL ANNUAL AUXILIARY HEAT 8181478.69

NBS-114A (REV. 7-73)

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7. AUTHOR(S) James E. Hill and Thomas E. Richtmyer			8. Performing Organ. Report No.
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			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

During 1972 and 1973, the National Bureau of Standards conducted controlled laboratory tests on a factory-built four-bedroom house having a floor area of 110 m^2 (1200 ft^2) equipped with a conventional gas furnace and central electric air conditioner incorporated into a forced air distribution system. During 1974, the house was moved onto the NBS grounds and a solar heating and cooling system was designed to be added to the house. Calculations have been made to show that more than 75% of the yearly energy needs for heating, cooling, and supplying domestic hot water could be obtained from the sun.

This report deals with the design and construction of the retrofitted system. It consists of 45 m^2 (485 ft^2) of double-glazed, flat-plate solar collector, 5.7 m^3 (1500 gallons) of water storage, and a 10,000 W (3 ton) lithium bromide absorption air cooling unit.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Retrofitted solar residence; solar collector; solar heating and cooling system; solar-powered absorption refrigeration.

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