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Analysis of Solar Energy System for the GSA Demonstration Office Building at Manchester, New Hampshire

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Final Report

Prepared for
Federal Energy Administration
New Post Office Buillding
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ABSTRACT

The energy conservation demonstration building of the General Services Administration to be built in Manchester, New Hampshire, has been planned to be partially heated and cooled by solar energy. Presented in this report are results of a study made at the National Bureau of Standards to determine the effect of solar collector sizes and the amount of storage on the overall energy consumption of the building. It was found that the fuel savings attainable by the use of solar energy for heating and cooling of the building will be less significant as the size of the collector and the amount of storage are increased beyond certain limits.

Key Words: Energy conservation; GSA/Manchester Building; solar collector; solar heating and cooling; thermal storage

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1. Introduction

The General Services Administration is constructing a seven-story office building in Manchester, New Hampshire, to demonstrate energy conservation features, architectural characteristics, HVAC system design and building operation. In addition to incorporating numerous conventional energy saving features, this building is to be equipped with a solar energy system to assist in reducing the fossil-fuel requirement for heating and cooling.

The application of a solar system to office buildings has not yet been widely practiced, although there is some evidence that this application will be given more and more emphasis for several reasons [1]*:

a. Office buildings usually have simultaneous heating and cooling requirements over long periods of the year, which results in a full utilization of the collected energy.

b. Most energy conserving designs for these buildings already include thermal storage, thus avoiding this incremental addition to the cost of the solar system.

c. Many systems will require a small thermal storage system (relative to the collector area) since less nighttime heating and cooling are typically needed.

d. Absorption cooling equipment is available in the 100-ton (351,680 W) range which can use the relatively low water temperatures (200 - 220 F (93.3 - 104.4 C)) available from some high performance flat-plate collectors.

e. There are fewer aesthetic and architectural constraints to utilizing solar collectors in commercial buildings compared with small houses, where the collector usually dominates the roof.

The National Bureau of Standards was asked by GSA to work with an architectural and engineering firm in analyzing the building's predicted energy consumption as a result of various alternative designs of the building exterior envelopes and HVAC systems. In a previous report [2], detailed computer analyses for heating and cooling loads for 43 different designs were described. This report deals mainly with the analysis of the solar system.

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* See references at end of narrative.

In the first part of this paper, a brief description of the HVAC system to be employed in the building is given, followed by the results of the calculation of predicted cooling-coil load and boiler load. Results of solar-assisted heating and cooling simulation studies are then given in which solar collector performance data reported by the University of Pennsylvania report [3, 4] are used. Only the energy consumption of the upper four floors is addressed in this report, since the lower three floors are not to be connected to the central air system and consequently will not utilize any of the collected energy.

2. HVAC Systems Used in the GSA/Manchester Building

Several different heating and air conditioning systems, which are known to have energy-conserving characteristics, will be used in this building to demonstrate energy conservation. The first three floors of the building will be equipped with a closed water-loop-type heat pump system so that the heat emitted by lights and occupants is used as the heat source for perimeter heating. The chilled air produced by the core zone heat pump will be distributed over the space via variable volume air diffusers.

The space heating and cooling for the fourth floor and above will be provided by a central air system connected to a combination of an electrically-driven water chiller and an absorption chiller located in the penthouse of the building. A 140-KW generator driven by a gas engine will provide power to the electric chiller. The absorption chiller will be driven by the heat received from the natural-gas engine jacket water cooling system. A representation of the penthouse plant is shown in Figure 1. As can be seen, there are supplementary boilers, a domestic hot water generator, and a solar energy collection system.

The electric chiller will be equipped with a double-bundle condenser so that a portion of heat rejected from the refrigeration process can be utilized to provide heating to perimeter zones, if required, while the core zone is being cooled. An evaporative cooler will be installed to keep the water loop of the heat pump system used on the first three floors from becoming too hot during the summer when perimeter heating is not required.

The chilled water produced at the electrical and absorption chillers will be delivered to the chilled water coil in the central air handling system to provide cooling air to the upper four floors. The perimeter heating for these upper floors will be done differently from the lower floors. On the fourth floor, baseboard units will be supplied with warm water from the double-bundle condenser. On the fifth floor, the perimeter zone temperature will be regulated by double-duct systems; the source for the hot air duct will be a fan-coil unit fed with the hot water from the double-bundle condenser. On the sixth and seventh floors, four-pipe fan-coil units will be installed to provide heating as well as cooling to the perimeter zone. Being a four-pipe system, the two upper floors can be heated or cooled simultaneously. The four-pipe fan-coil units of these floors can also be operated in the two-pipe mode.

3. Load Calculation for the Building

Heating and cooling loads for the space air conditioning were previously calculated on an hourly basis by using 1962 weather data provided by the National Weather Record Center in Asheville, North Carolina. In this calculation, a computer program called NBSLD [5] was used to determine hourly heating and cooling loads for four different zones and the data were recorded on four different magnetic tapes each for the top floor, middle floor, ground and second floors. This resulted in a total of sixteen magnetic tapes for the building analysis. The thermal loads for the 3rd, 4th, 5th and 6th floors were considered to be the same as that for a middle floor. These hourly loads were summarized independently for the heating and cooling parts for the upper four floors and the resultant summary loads were then balanced in a mathematical simulation against the heating and cooling capacities of the central equipment in the penthouse.

As mentioned previously, the central equipment will consist of a gas engine-generator unit, an electric chiller with a double-bundle condenser, a heat recovery unit for the engine jacket water, an absorption chiller operated by the engine waste heat, and a supplementary boiler to assist in the perimeter heating (which is done mostly by the warm water from the double-bundle condenser). The chilled water from the electrical and absorption chillers will be fed to the cooling coil in the central air handling unit. This air handling unit will supply the chilled air to the central or core zone of the upper four floors while the perimeter heating or reheating zone will be fed by the warm water from the double-bundle condenser. The air supply system to the core zone will be equipped with variable volume (VAV) outlets so that the supply airflow rates can be regulated to match the zone cooling load as long as it is larger than the minimum outdoor ventilation air rate.

For many days in Manchester, New Hampshire, heating becomes necessary even during the summer due to low outdoor air temperatures. In order to help minimize the heating load, an exhaust air heat recovery unit utilizing heat pipes will be used to recover heat from the toilet exhaust air. Although actual air handling systems are quite complex, a simplified schematic diagram such as Figure 2 was used to simulate the air-side performance for the upper four floors. Figure 3 shows the part-load power consumption characteristics of the electric chiller used to estimate the first requirement for the engine generator and the heat available from the engine jacket and exhaust-hood heat exchanger. Appendix A contains the computer algorithm used for simulating the air-side performance of the system depicted in Figure 2.

The hourly supplementary heating requirement was determined by summing the available heat from the double-bundle condenser and the stored heat in a 10,000-gallon water tank and subtracting from it the space heating and the ventilation air heating load.

The hourly value of cooling-coil load required by the central air conditioning system to provide 60 F (15.6 C) supply air temperature to the VAV units was also determined. In this simulation, whenever the outdoor air temperature was such that the 60 F (15.6 C) supply air temperature could be obtained by increasing the supply of outdoor air beyond the ventilation air requirement, the cooling coil was turned off or the coil load was set equal to zero to simulate the operation of an economizer cycle. The hourly coil load and supplementary heating requirement were next compared to the heating and cooling capacities available from the solar energy system.

4. Simulation of Flat-Plate 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

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 report was to develop an empirical routine based on the performance of double-glaze collectors reported by the University of Pennsylvania [3, 4].

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 (Figure 4). 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:

$$\eta = \frac{Q}{I} = \frac{\text{energy collected}}{\text{incident solar radiation}} \qquad (1)$$

$$\eta = \eta_o \left(\frac{\Delta t}{\Delta t_{max}}\right) \qquad (2)$$

where

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

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

t_c = absorber surface temperature

t_s = cover-plate surface temperature

η_o = intercept of the efficiency curve with the vertical axis

The value of Δt_{max} depends upon the incident radiation and the results of the experiments also show (Figure 5) that it is possible to approximate Δt_{max} by a linear function such that

$$\Delta t_{max} = b \cdot I \qquad (3)$$

The data on the double-glaze 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_s and the ambient temperature t_a if it is assumed that a heat loss from the collector takes place through the cover plate.

$$h\,(t_s - t_a) = I - Q = I\,(1 - \eta) \tag{4}$$

where h = surface heat transfer coefficient at the outer cover plate. Combining equations (2), (3), and (4), 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_c:

$$\eta = \eta_o \left\{ 1 - \frac{\frac{h}{I}\,(t_c - t_a) - (1 - \eta_o)}{\eta_o + hb} \right\} \tag{5}$$

Since the value of h is directly related to the wind speed over the cover plate, equation (5) accounts for the wind as well.

The value of solar collector efficiency can thus be evaluated for every hour throughout the day by knowing the hourly data on h, I, and t_a for given values of t_c, η_o, and b, which are the basic parameters of the specific collector. The available solar energy, I, impinging on the collector surface was estimated for Manchester by modifying the cloudless-day solar radiation data computed within NBSLD[5] by the cloud cover data taken from the weather tape. The cloudless solar radiation data for this particular locality were calculated according to the method described in the 1972 Handbook of Fundamentals [6], whereas the cloud cover modification was carried out by incorporating the Boeing solar transmissivity data [7].

5. Solar-Assisted Heating

Figure 6 illustrates the results of calculations for typical winter days (January 18 and 19, 1962). The figure shows the hourly solar energy collected per unit area of collector at a temperature level of 140 F (60 C) together with the outdoor temperature and heating load of the top floor in the building. As can be seen, a mismatch exists between the heating load and the solar energy collected, resulting from the time difference between the occurrence of the maximum heating demand and the maximum solar energy availability. Thus, it is clear that some kind of storage device is necessary in order to be able to properly utilize the solar energy collected. The areas under the solar energy and heating load curves indicate total daily solar energy and total daily load requirements respectively. The total daily collected energy at 140 F (60.0 C) during January 18, 1962 was estimated to be 343 Btu/ft^2 (3.89 x 10^6 J/m^2) of collector, while the total daily heating load of the top floor during January 19 was 448,000 Btu (4.72 x 10^8 J). Therefore, if one installed a storage tank of 10,000 gallons (37.85 m^3) and a collector having an area of 1,000 ft^2 (92.9 m^2), it would be possible to supply 70% of the top-floor heating requirements, assuming that the temperature drop in the tank is limited to 5 F (2.8 C). The temperature change that would occur would increase linearly as the storage tank size is reduced.

Figure 7 shows the cumulative collected and stored solar energy as a result of using a double-glaze, south-facing collector tilted up at an angle of 60° during the month of January 1962. If the average collected energy was estimated on the basis of the 30-day total, the solar system could be sized assuming a daily collection of 360 Btu/ft^2 (4.09 x 10^6 J/m^2) of collector area if the fluid temperature were maintained at 100 F (37.8 C). The same figure indicates, however, that if a 140 F (60.0 C) fluid temperature is assumed, the collector should be sized on the basis of 240 Btu/ft^2 (2.72 J/m^2) of collector area.

The most important factor to be considered in the design of a solar system is the coincident nature of the collected and required energy. To demonstrate this, Figure 8 was prepared from the simulation of the top floor. The figure shows in shaded bars the collected energy by a 3,000 ft^2 (278.7 m^2) double-glaze collector during January. The white bars show the heating load. The figure shows clearly that there are days in which energy from storage and/or an auxiliary source would be required.

Figure 9 depicts the manner in which the solar energy is actually to be utilized to assist in the heating of the upper four floors of the GSA/Manchester Building. The energy produced in the double-bundle condenser will be used to supply the perimeter fan-coil units when the cooling system for the core zone is operating. This energy will be supplemented by solar energy as required, or if the energy from the solar system is inadequate, the supplementary gas-fired boiler will be operated to satisfy the need.

Figure 10 shows the heating requirement, energy available from the solar collector and the fuel consumed by the boiler for a selected period of 5 days in December 1962. The calculations were carried out hour-by-hour for all heating months in order to determine the boiler fuel requirement as a result of using various combinations of collectors and storage. The results are shown in Table 1.

6. Solar-Assisted Cooling

Figure 11 represents schematically the solar energy-assisted cooling system for the upper four floors of the GSA/Manchester Building. The energy collected at 220 F (104.4 C) will be used to operate the absorption chiller, which is assumed to have a coefficient of performance of 0.6. When solar energy is not available or is inadequate, the same absorption chiller will be operated by the waste heat recovered from the engine generator, which in turn drives the electric chiller.

Figure 12 shows, for a selective period of five days in August 1962, the hourly profiles of cooling requirements for the upper four floors, the solar energy collected at 220 F (104.4 C), and the engine fuel requirements. The collector size and the heat storage size were varied as shown in Table 2. The results are shown graphically in Figures 13 and 14. These tables and graphs show that more energy saving can be obtained by increasing the collector size (up to a certain point) than by increasing the storage capacity.

7. Summary

Annual energy consumption for the heating and cooling of the upper four floors of the GSA/Manchester Building was estimated by simulating the thermal performance of its HVAC system and solar energy system. By incorporating a 5,000 ft^2 (464 m^2) collector having a double-glaze cover plate and an absorber surface with a selective surface, in conjunction with 10,000 gallons of water storage, it is possible to reduce the fuel consumption by approximately 50% for both heating and cooling. The use of a larger collector and the amount of storage does not appear to be warranted, because of the diminishing return in the energy saving.

8. References

1. Dubin, F. S., "Statement to the Subcommittee on Energy of the House Science and Astronautics Committee", Congressional Record, June 12, 1973.

2. Kusuda, T., Hill, J. E., Liu, S. T., Barnett, J. P., and Bean, J. W., "Pre-Design Analysis of Energy Conservation Options for a Multi-Story Demonstration Office Building, NBS Building Science Series 78, November 1975.

3. Altman, M., "Conservation and Better Utilization of Electric Power by Means of Thermal Energy Storage and Solar Heating", Phase II Progress Report, No. NSF/RANN/SE/G127976/72/4, December 31, 1972.

4. Lorsch, H. G., "Performance of Flat Plate Solar Collectors", Proceedings of the Solar Heating and Cooling for Buildings Workshop, Part 1: Technical Sessions, The National Science Foundation, Washington, D.C., March 21-22, 1973.

5. Kusuda, T., "NBSLD, Heating and Cooling Load Calculation Program", NBSIR 74-574, November 1974.

6. ASHRAE Handbook of Fundamentals, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 345 East 47th Street, New York, New York 10017.

7. "Procedures for Determining Heating and Cooling Loads for Computerized Energy Calculations", ASHRAE Task Group on Energy Requirements for Heating and Cooling, American Society of Heating, Refrigerating and Air-Conditioning Engineers, 345 East 47th Street, New York, New York 10017.

9. Appendix A - Air System Simulation

Nomenclature Used for GSA/Manchester Air System - 4th-7th Floors

QLC: Zone cooling load

QLH: Zone heating load

QHCOIL: Heating coil load

OCCOIL: Cooling coil load

CFM: Airflow rate to the zone

CFMAX: Maximum fan capacity

CFMV: Outdoor air supply rate

CFMVO: Minimum outdoor air ventilation rate required

TAS1: Supply air temperature during the normal cooling cycle

TAS2: Supply air temperature during the economizer cycle

WAS1: Humidity ratio of the supply air during the normal cooling cycle

WAS2: Humidity ratio of the supply air during the economizer cycle

WA: Humidity ratio of outdoor air

WS: Humidity ratio of the air saturated at TAS1

RAW: Humidity ratio of return air

RAT: Return air temperature

DB: Outdoor air temperature

DBX: Temperature of outdoor air leaving the exhaust-heat-recovery heat exchanger

FTRS: Fan temperature rise

η: Heat-recovery heat-exchanger effectiveness

Computer Algorithms

a. IF QLC $\geq$ 0 and QLH = 0

$$CFM = \frac{QLC}{1.1 * (RAT - TAS1)} = CFM'$$

IF (CFM $\geq$ CFMAX) CFM = CFMAX

Zone temperature is expected to rise above the set point

CFMR = CFM - CFMVO

$$TEST = \frac{CFMVO * DB + CFMR * RAT}{CFM}$$

$$TESW = \frac{CFMVO * WA + CFMR * RAW}{CFM}$$

QCCOIL = CFM * (1.1 * (TEST + FTRS - TAS1) + 4.5 * 1061 * (TESW - WS)

IF CFMR $\leq$ 0, CFMR = 0

The room temperature begins to decrease below the set point unless the heating coil is activated to provide

QHCOIL = 1.1 * (CFMVO - CFM') * (RAT - TAS1)

b. IF QLC $\neq$ 0 QLH $\geq$ 0

QCCOIL = 0

QHCOIL = QLH + 1.1 * CFMVO * (RAT - (DBX + FTRS))

when DBX = DB + η * (RAT - DB)

η = heat-recovery heat-exchanger effectiveness

c. IF economizer cycle is employed when

$$QLC \geq 0 \text{ and } QLH = 0$$

The coil is shut off when

$$DB \leq TAS2 - FTRS = TEST$$

$$CFM = \frac{QLC}{1.1 * (RAT - TAS2)} = CFM'$$

$$IF\ (CFM \geq CFMAX),\ CFM = CFMAX$$

In this case the room temperature begins to rise above the set point unless the system is reverted to the normal operation as described in (a).

IF $CFMAX > CFM' > CFMVO$,

the zone is cooled by outdoor air and the zone humidity ratio floats as determined by the balance between the room latent load and 4.5 * CFMVO * (RAW - WA) * 1061.

If, however, $CFM' \leq CFMVO$

the zone temperature begins to decrease below the set point unless the heating coil is activated to provide

$$QHCOIL = 1.1 * (CFMVO - CFM') * (TEST - DB)$$

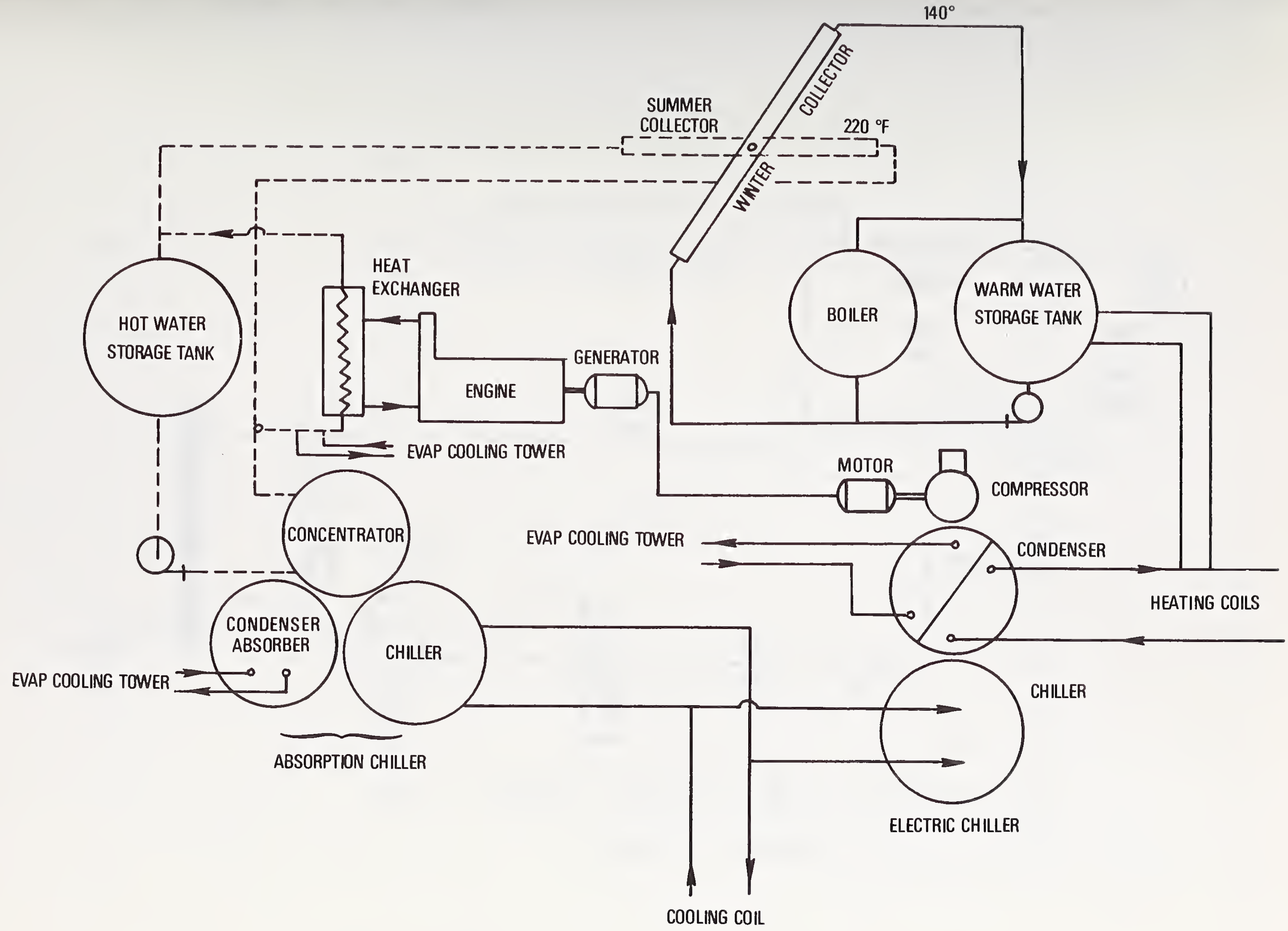


Figure 1 Schematic Drawing of the Solar-Assisted Heating and Cooling System of the GSA/Manchester Building

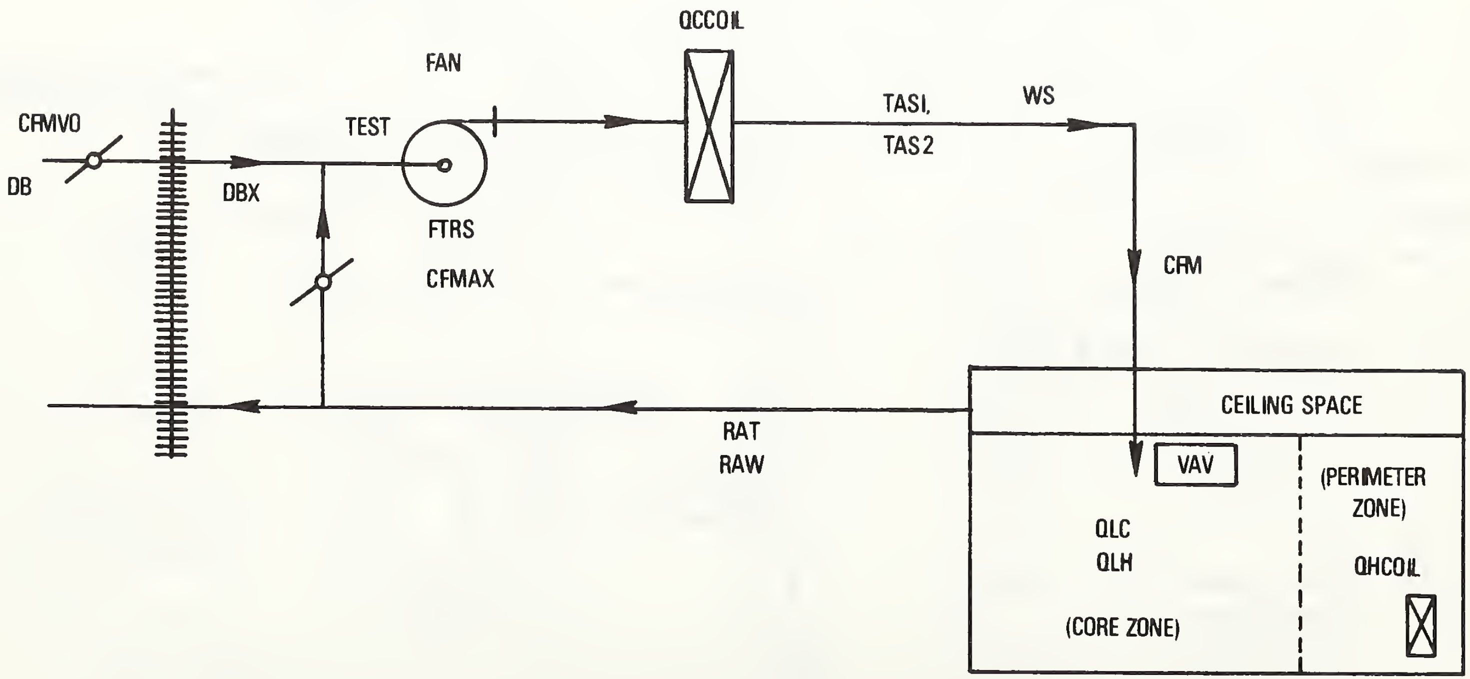


Figure 2 Air System Employed in the Upper Four Floors of the GSA/Manchester Building

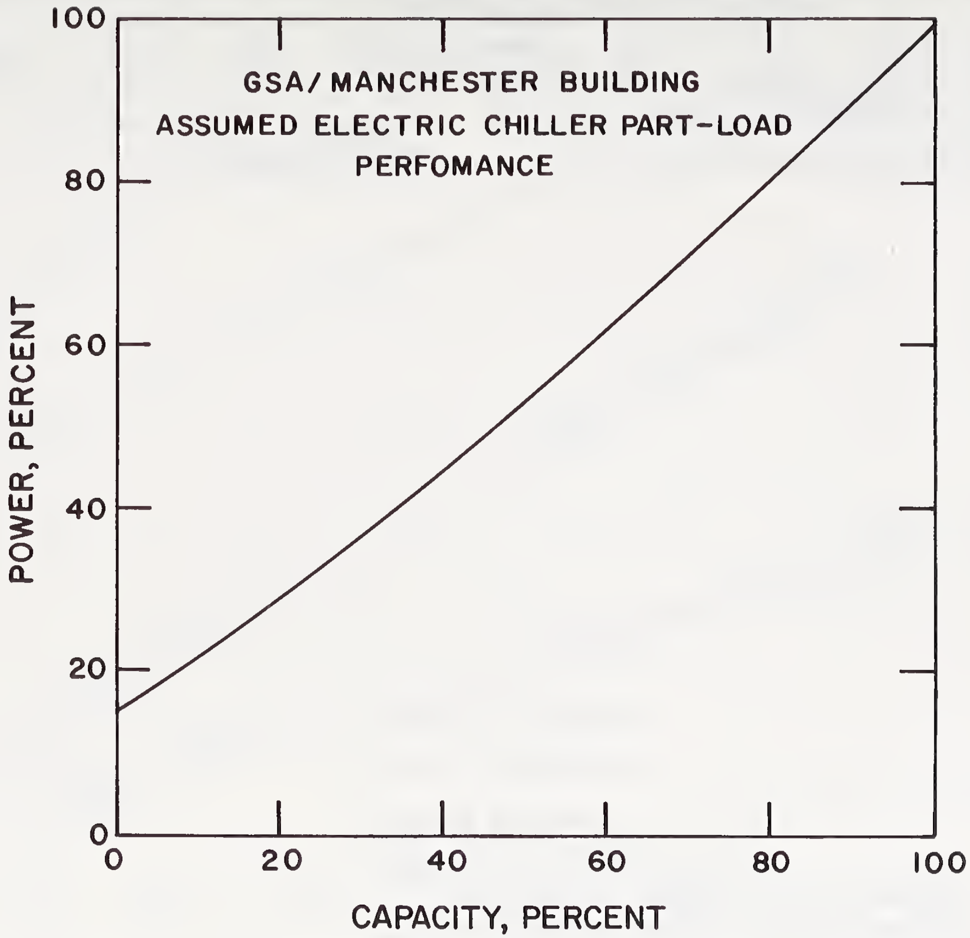


Figure 3 Part-Load Performance of the Electric Chiller Used for the Solar Energy Simulation Analysis

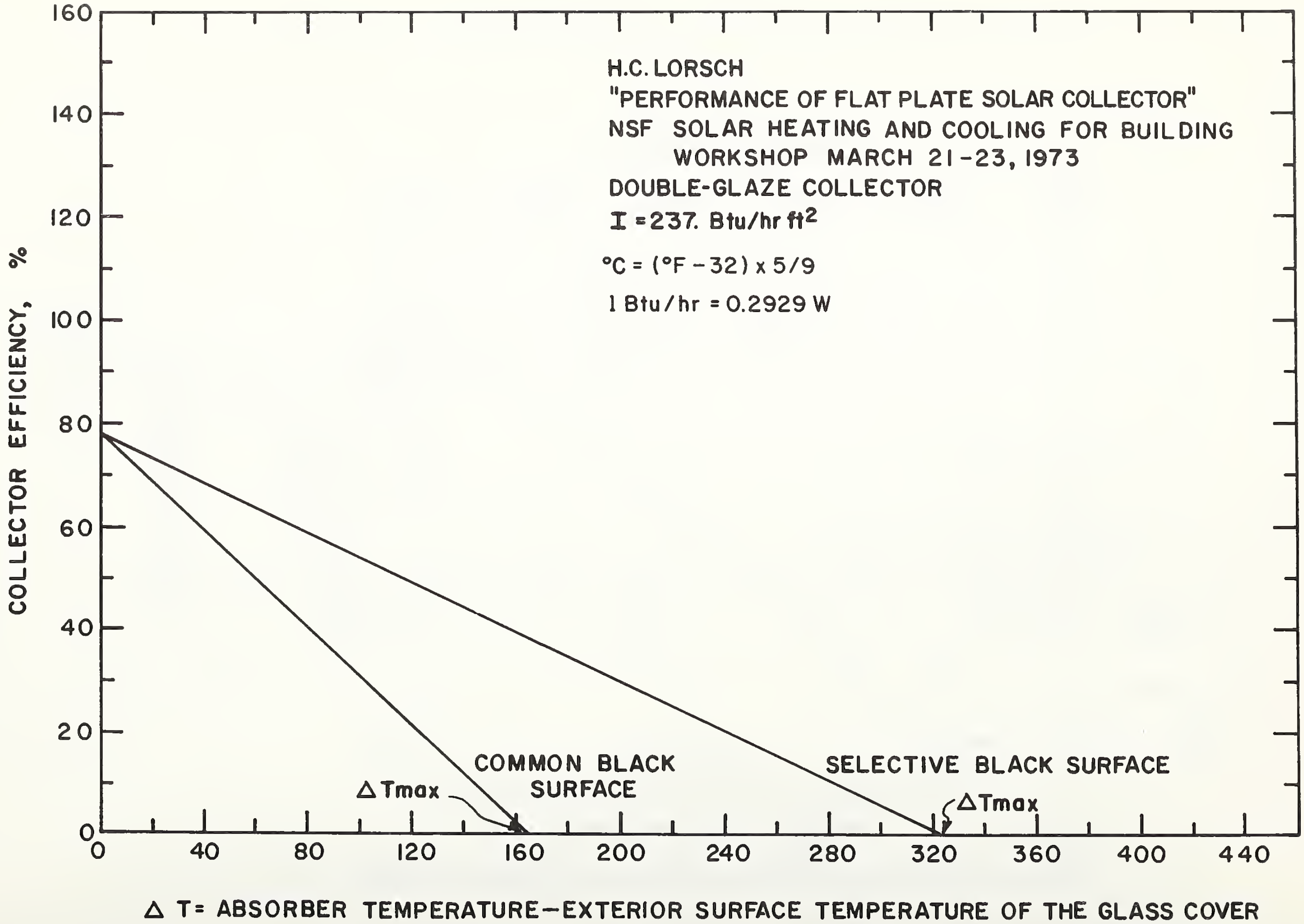


Figure 4 Typical Solar Collector Efficiency as a Function of Temperature Difference Between the Absorber Surface and Cover Plate

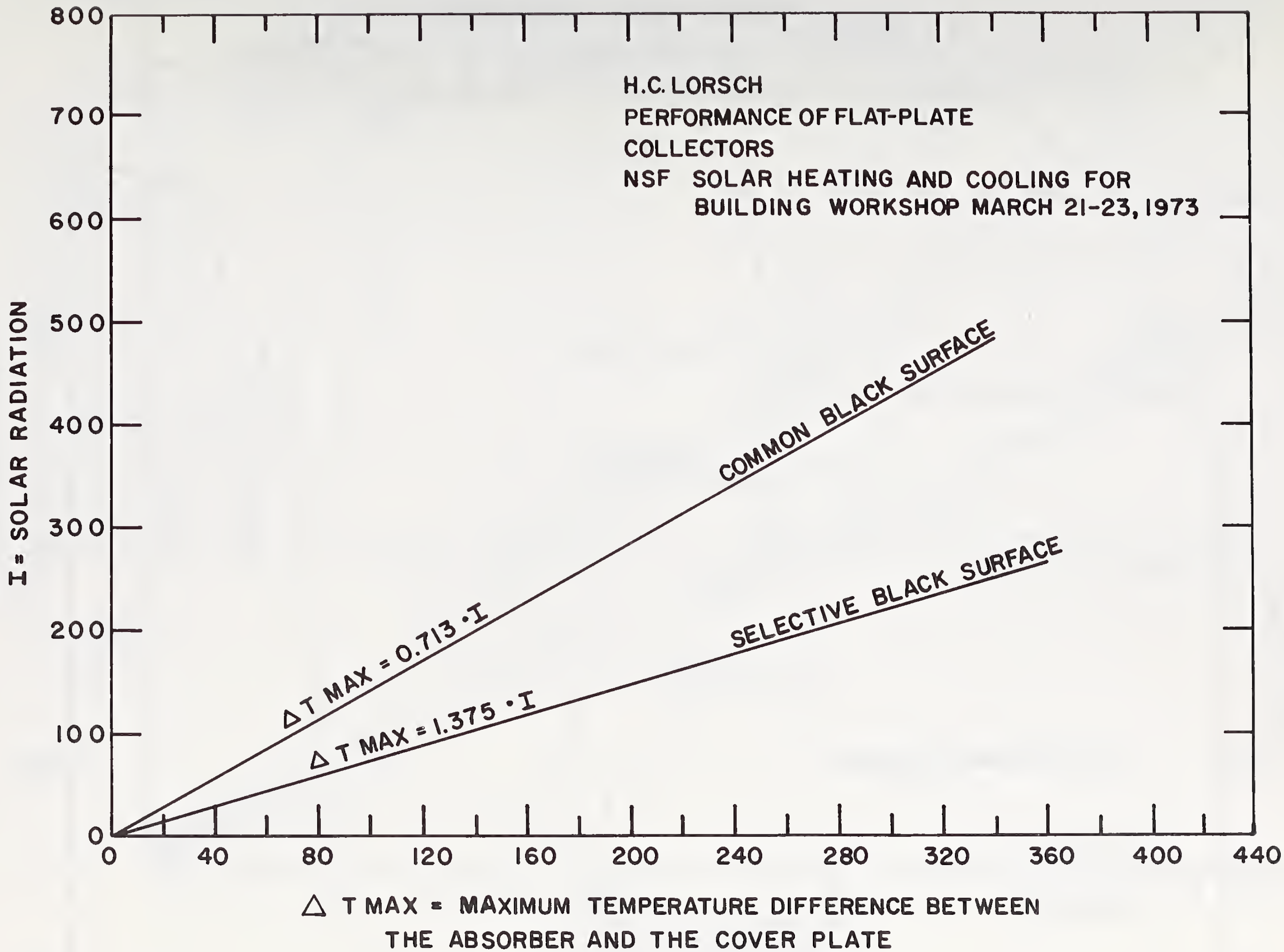


Figure 5 Maximum Temperature Difference Between the Absorber Surface and the Cover Plate as a Function of Incident Solar Radiation

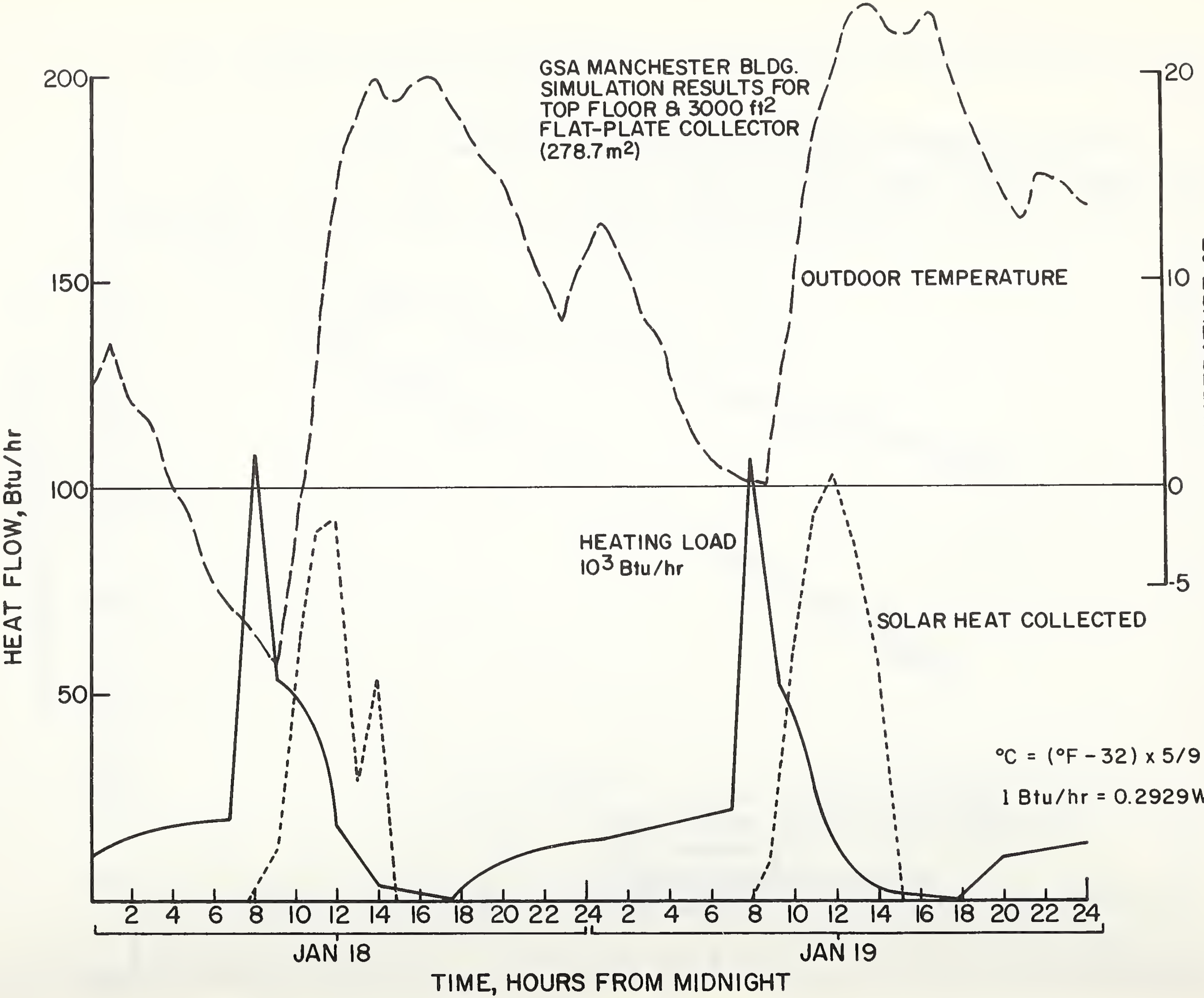


Figure 6 Calculated Hourly Heating Requirement and Collected Solar Energy During January 18 and 19, 1962

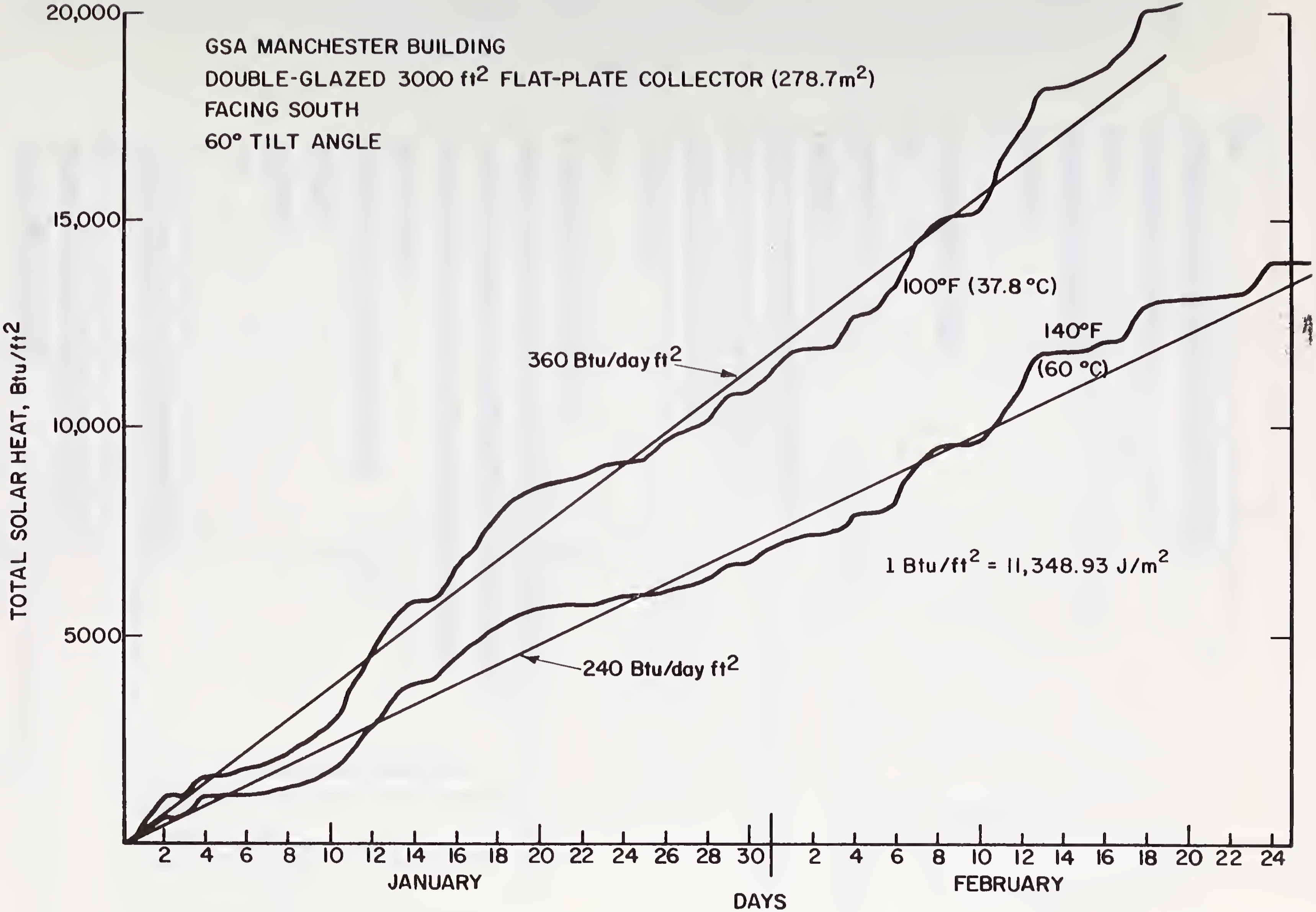


Figure 7 Calculated Cumulative Collected Solar Energy During January and February 1962

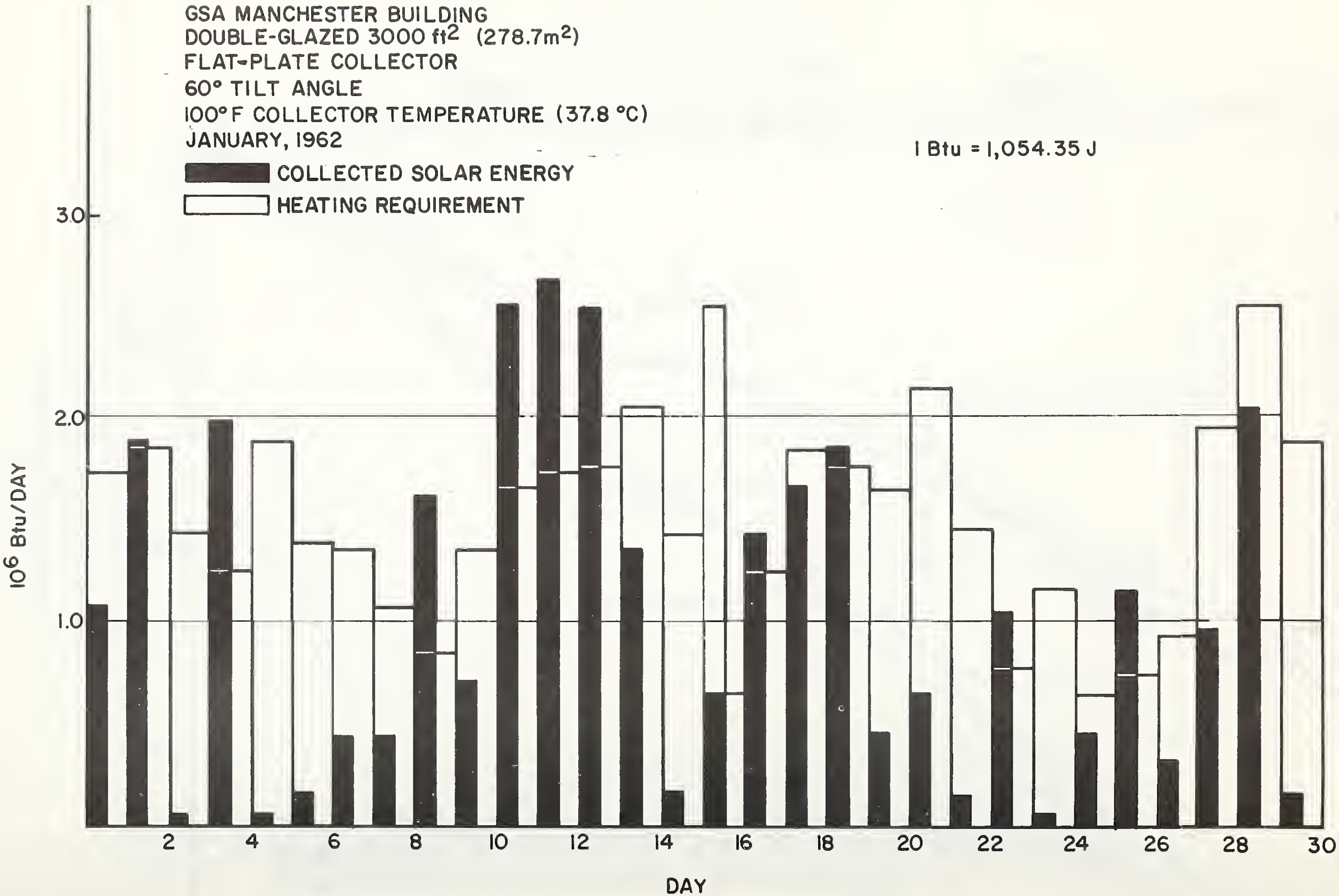


Figure 8 Calculated Daily Collected Solar Energy and Daily Heating Requirement for the Top Floor During January 1962

GSA/MANCHESTER BUILDING
UPPER FOUR FLOORS
SOLAR HEATING SYSTEM ANALYSIS

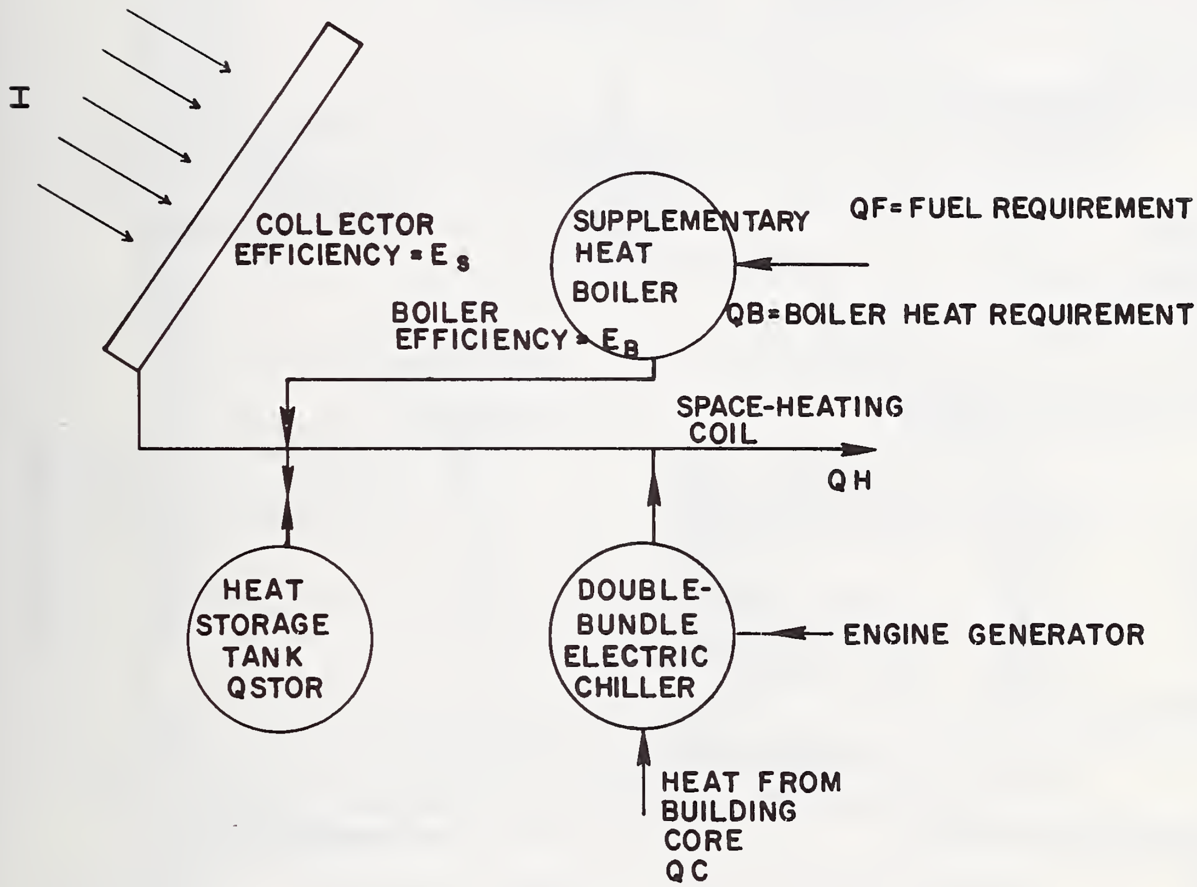


Figure 9 Energy Balance for the Solar-Assisted Heating System

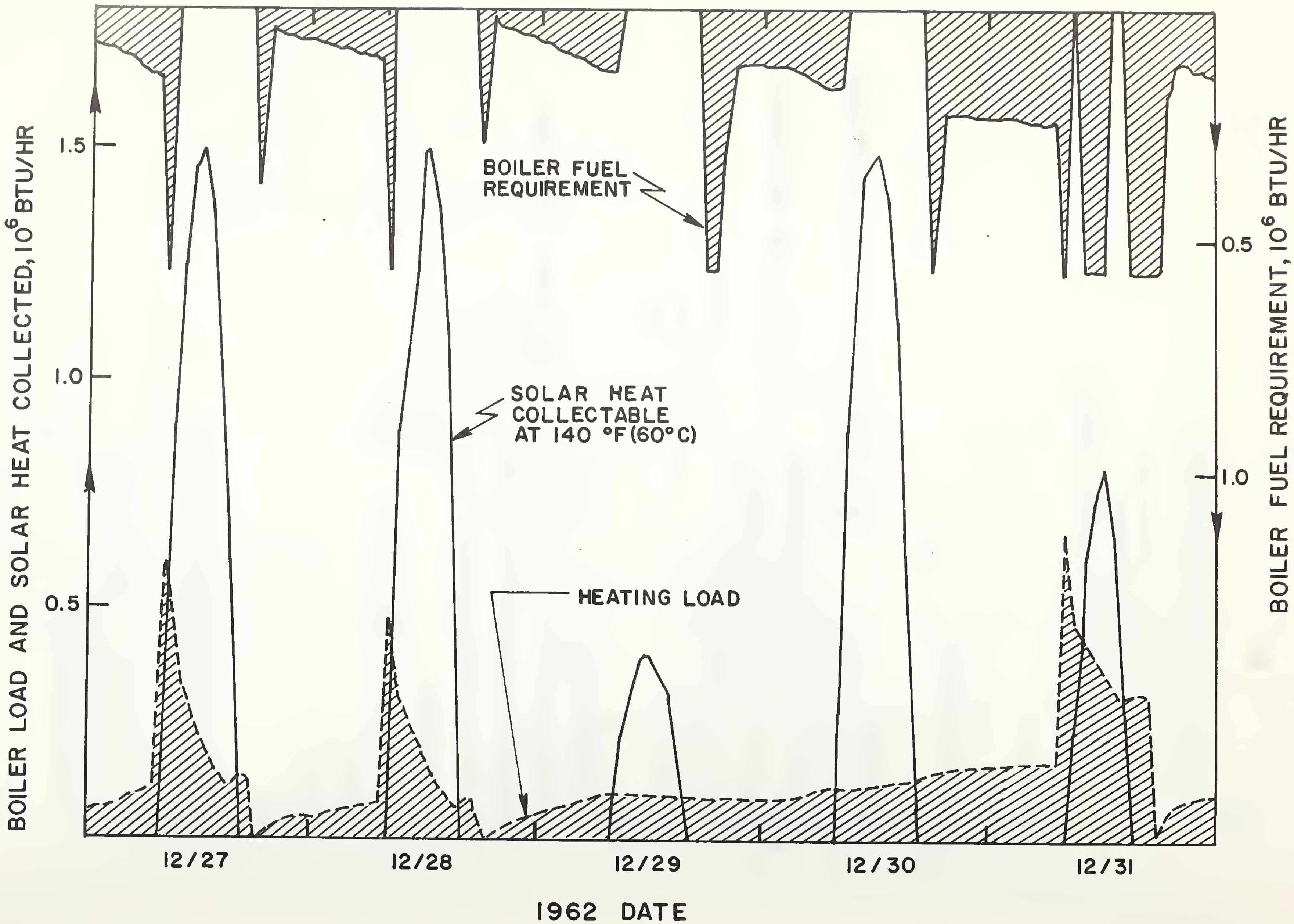
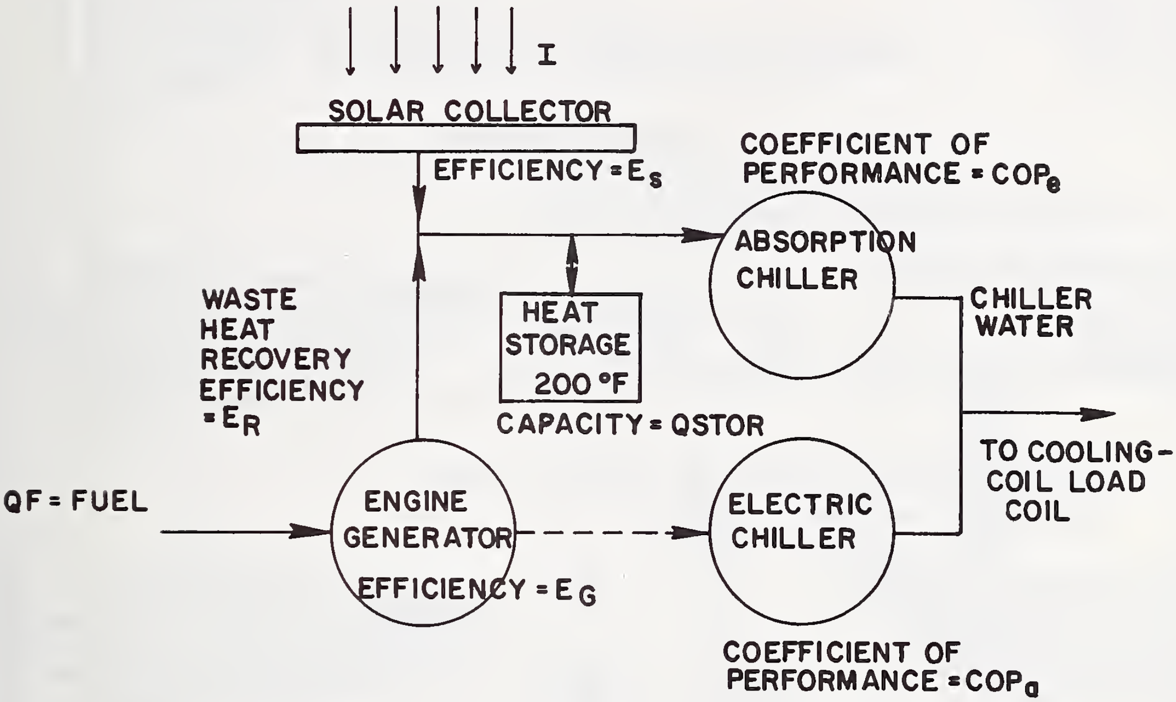


Figure 10 Hourly Profiles of Solar Heat Collected at 140 F (60 C), Space Heating Requirement, and Boiler Fuel Energy Consumption

GSA/MANCHESTER BUILDING
UPPER FOUR FLOORS
SOLAR COOLING SYSTEM ANALYSIS



$$QCOIL = QF \cdot E_G \cdot COP_e + QF \cdot (1 - E_G) \cdot E_R \cdot COP_a + I \cdot E_S \cdot COP_a + QSTOR \cdot COP_a$$

$$Q_F = \frac{Q\,COIL - (I \cdot E_S + QSTOR) \cdot COP_a}{E_G \cdot COP_e + (1 - EG) \cdot E_R \cdot COP_a}$$

ASSUMPTION = E_S = CALCULATED AS A FUNCTION OF I, AMBIENT TEMPERATURE AND COLLECTOR TEMPERATURE

E_G = .28
E_R = 0.5
COP_e = 3.0
COP_a = 0.6

Figure 11 Energy Balance for the Solar-Assisted Cooling System

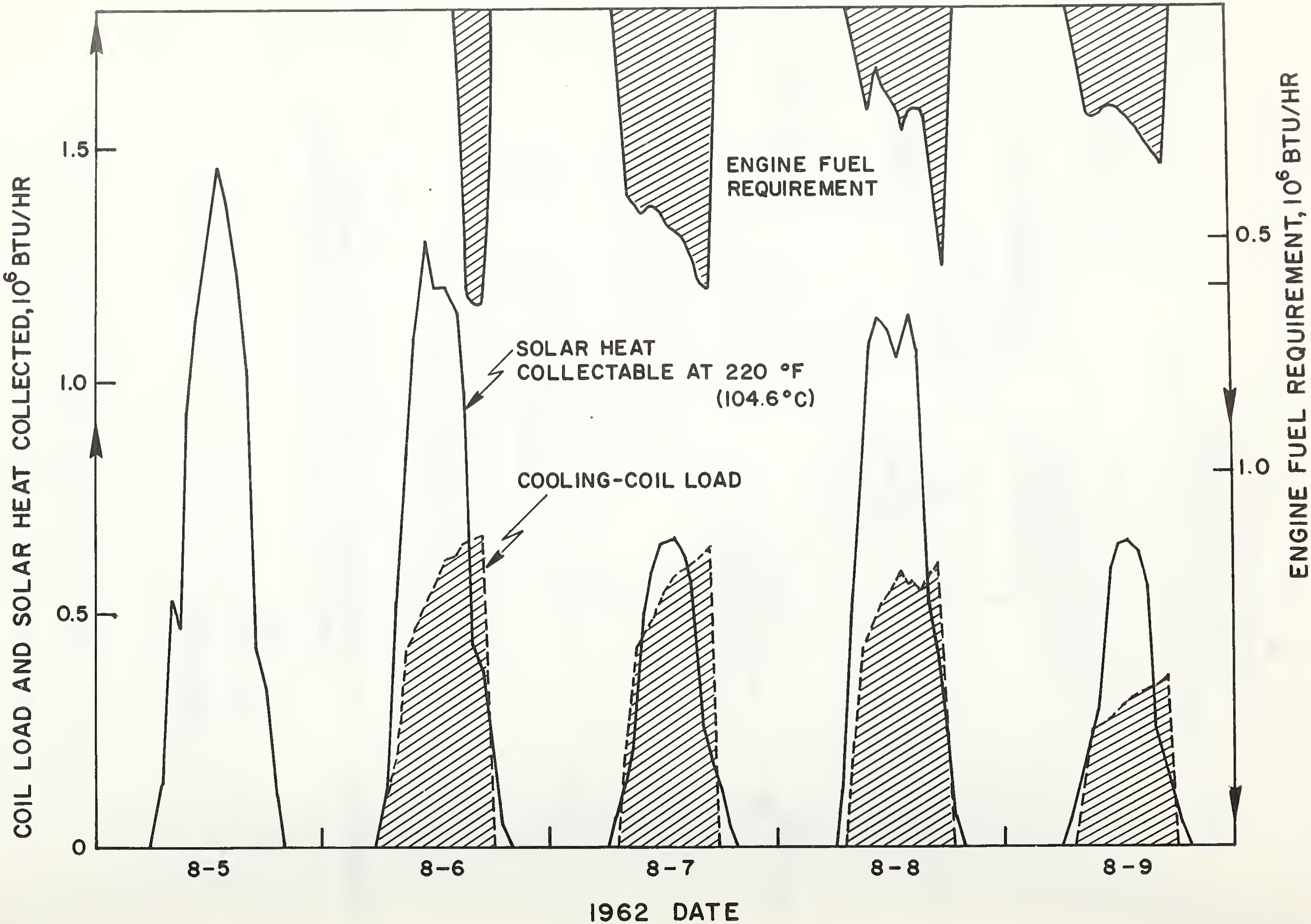


Figure 12 Hourly Profiles of Solar Heat Collected at 220 F (104.4 C), Cooling-Coil Load, and Fuel Energy Requirement at the Engine-Driven Generator

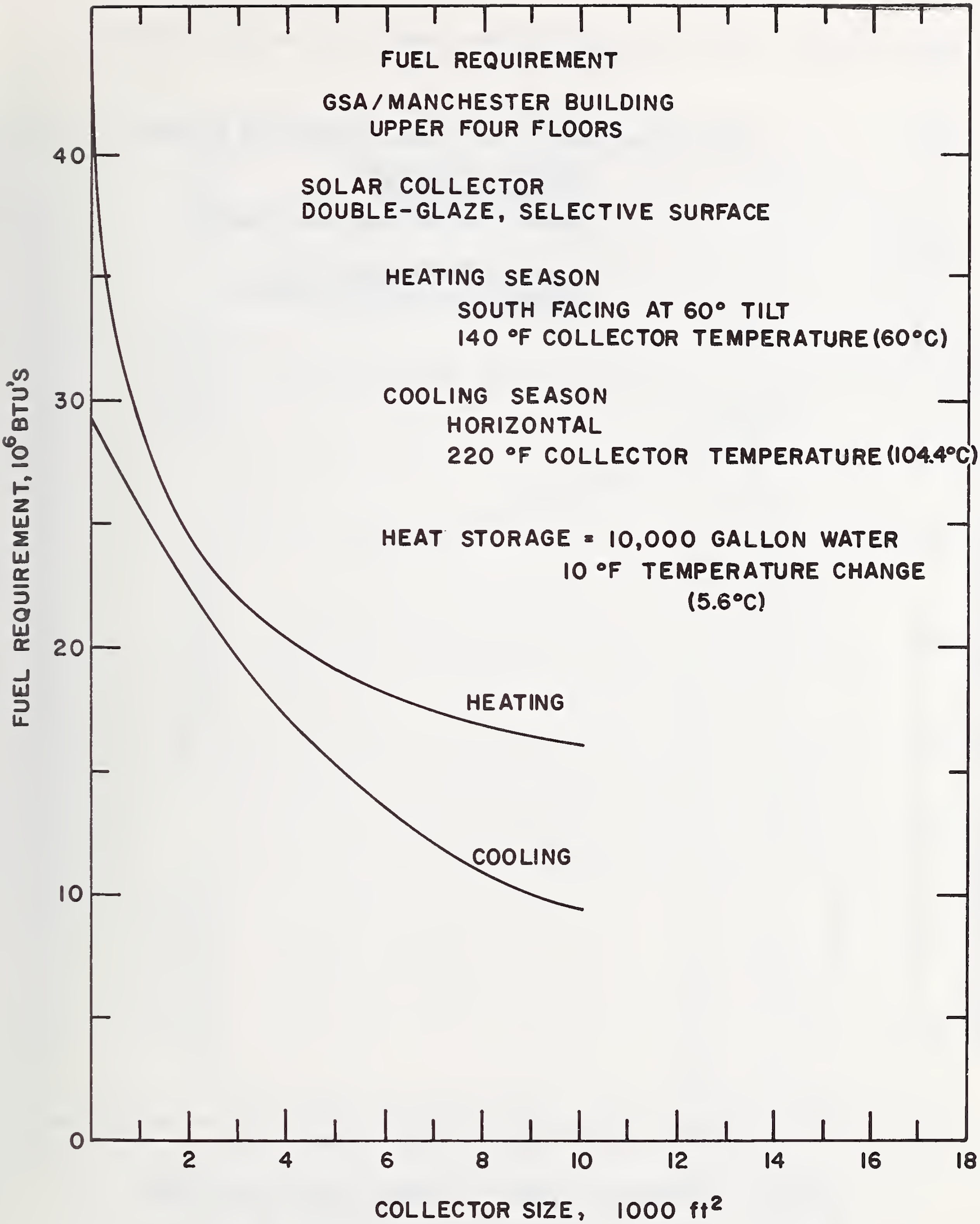


Figure 13 Effect of Collector Size on the Energy Consumption for Heating and Cooling of the Upper Four Floors in the GSA/Manchester Building

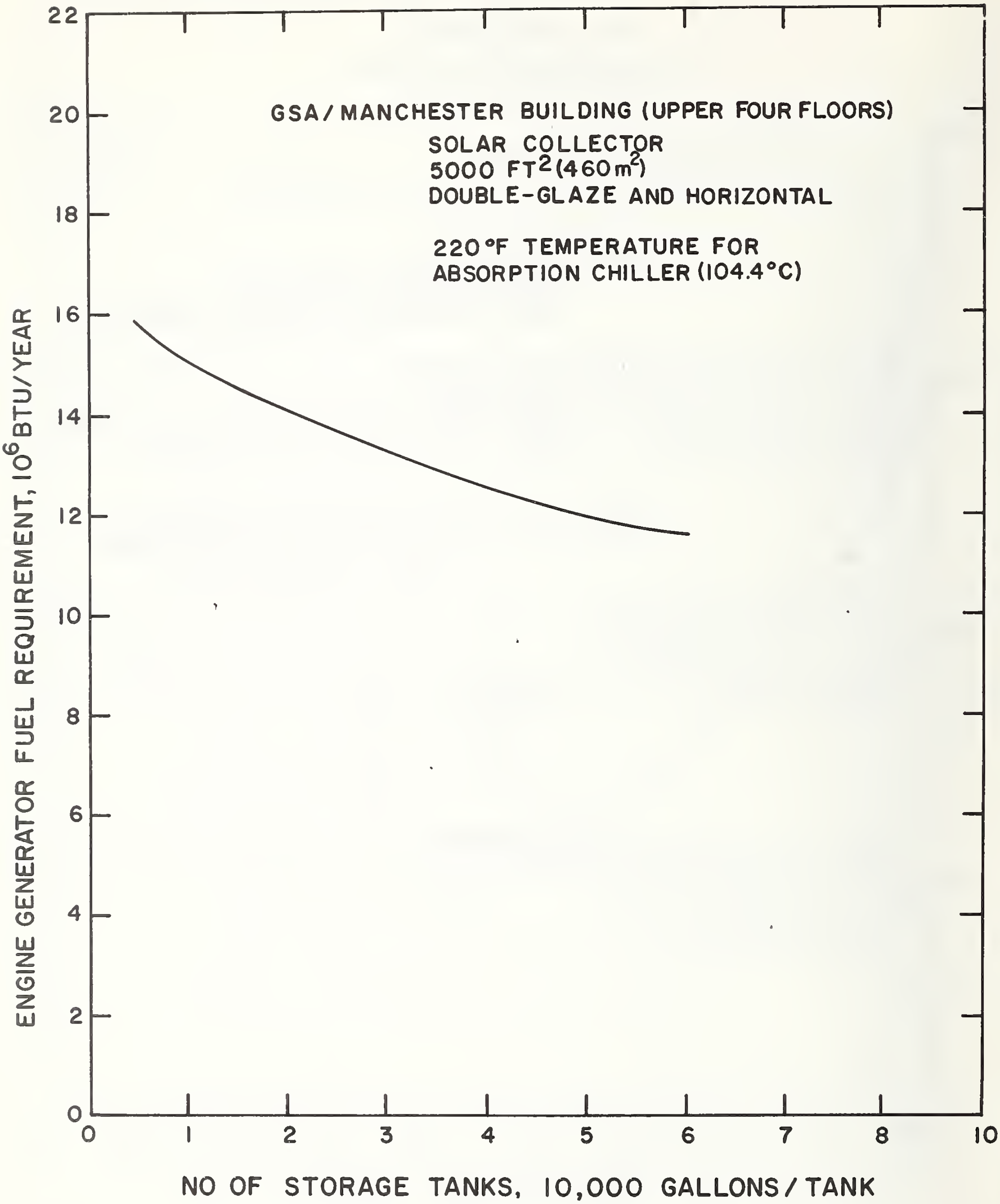


Figure 14 Effect of Thermal Storage Size on the Energy Consumption for Heating and Cooling of the Upper Four Floors in the GSA/Manchester Building

Table 1 Results of the Solar-Assisted Heating System Analysis

Collector Size (ft^2)	No. of 10,000 Gallon Water Heat Storage Tanks	Maximum Boiler Capacity (1,000 Btu/hr)	Total Fuel Requirement 10^6 Btu's	Remarks
3,000	1	968	218	
5,000	1/2	968	234	
5,000	1	968	189	
5,000	1	402	206	1
5,000	1	402	292	2
5,000	1	1,192	296	3
5,000	2	968	134	
10,000	1	968	160	
0		1,042	439	

1 Boiler of 402,000 Btu/hr capacity is to be fired only when the supplementary heating is needed.

2 Boiler of 402,000 Btu/hr is used to heat up the heat storage tank whenever the storage is less than its maximum capacity.

3 The same as 2 except that the boiler capacity is not limited.

$1\ ft^2 = 0.0929\ m^2$
1 Btu/hr = 0.2929 W
1 Btu = 1,054.35 J

Table 2 Results of the Solar-Assisted Cooling System Analysis

Collector Size (ft^2)	No. of 10,000 Gallon Water Heat Storage Tanks	Max. Engines (KVA)	Max. Elec. Chiller Cap. (Tons)	Max. Abs. Chiller Cap. (Tons)	Total Fund Requirement 10^6 Btu's
3,000	1	53	45	12	197
5,000	1/2	53	45	12	158
	1	53	45	12	150
	2	53	45	12	140
	3	53	45	12	132
	4	53	45	12	126
	5	52	45	12	120
	6	50	43	11	115
10,000	1	53	45	12	94
0	0	53	45	12	289

$1\ ft^2 = 0.0929\ m^2$
$1\ Btu = 1{,}054.35\ J$

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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.)*

The energy conservation demonstration building of the General Services Administration to be built in Manchester, New Hampshire, has been planned to be partially heated and cooled by solar energy. Presented in this report are results of a study made at the National Bureau of Standards to determine the effect of solar collector sizes and the amount of storage on the overall energy consumption of the building. It was found that the fuel savings attainable by the use of solar energy for heating and cooling of the building will be less significant as the size of the collector and the amount of storage are increased beyond certain limits.

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)* Energy conservation; GSA/Manchester Building; solar collector; solar heating and cooling; thermal storage

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