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Solar integrates with almost any architectural style

A Paper Presented At The 1985 Meeting of the International Solar Energy Society

Performance Evaluation Of A Hybrid Solar Heating System Having A Radiant Panel Slab

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Abstract

This paper summarizes the results of performance monitoring of a simple hybrid solar heating system of the active charge/passive discharge type.

Conventional active hydronic flat plate solar collectors charge a massive radiant panel slab. Solar energy i stored and released to the building in a passive manner by radiation and conduction.

The Performance monitoring has demonstrated that this simple, low-cost hybrid solar heating system offers significant advantages in system efficiency, overall performance, comfort, and architectural flexibility.

Keywords

Hybrid solar heating; active charge/passive discharge; radiant panel heating.

Introduction

An objective of hybrid solar design is to combine the relative advantages of active and passive design approaches while minimizing their respective disadvantages.

Active design approaches tend to harvest solar energy with good efficiency and do not lose energy during periods when they are not operational as is the case with passive approaches. Cost and complexity, however has limited the application of active approaches.

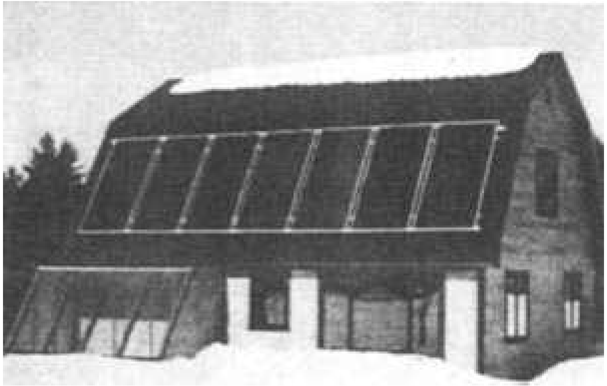

figure 1: Lyndonville Test Building

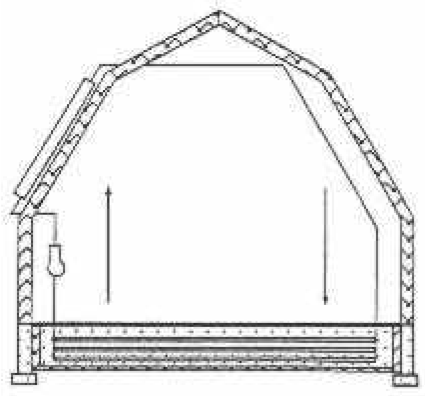

figure 2: Schematic of the Radiantec heating system

Many passive approaches reduce cost and complexity by using conventional building components to collect, store, and deliver solar energy. The usefulness of many passive methods, however, is compromised when the collection element is part of the building envelope. Heat loss during the night lowers overall efficiency and in cold and cloudy regions can result in negative energy gains.

The monitored design is a hydronic heating system using conventional flat plate solar collectors to heat a radiant panel slab and packed earth bed. The design was developed by Radiantec Company of Lyndonville Vermont, U.S.A.

Solar heated fluid is pumped in an active manner from the solar collectors throughout the radiant panel slab and packed earth bed. Heat is stored within the slab and earth bed. It is released to the heated space in a passive manner without controls by radiation and conduction. Solar energy which exceeds heating load requirments is diverted to the domestic hot water load.

The hypothesis was that the heating design would exhibit superior performance and efficiency as compared to representative active and passive approaches. Analytical study predicted that the active charging component would harvest the solar energy resource with very high efficiency due to its uniquely low operating temperature and minimal collector losses to the ambient air. It was hoped that the passive storage and release component, with its uniquely large thermal mass would enable prolonged solar storage and high solar heating fractions as well as radiant comfort.

Method

A test house using the Radiantec heating system was experimentally monitored to determine its energy-based performance in the 1982-1983 heating season. The test residence is located in Lyndonville, Vermont, an area which has a characteristically cold and cloudy climate. The two story residence has a floor area of about 1400 ft^2 (130 m^2) and was constructed on a 720 ft^2 (65 m^2) 5.5 inch (0.14m) thick floor slab. A 24 in. (0.6 m) packed gravel bed is located beneath the slab and the slab/gravel bed is insulated by 2 in. (0.05m) of polystyrene insulation.

The test building is of frame construction and uses insulation levels which have become commonplace. Windows were concentrated somewhat on the south side of the building and all but avoided on the north. A solar greenhouse was closed off from the structure permanently throughout the testing so as to better observe the solar heating invention without confounding variables. The monitoring equipment generated an internal gain of about 17,000 BTUs/day (5.0 KWH/day). Night window insulation was provided for all windows.

The analytically predicted heat loss characteristics of the structure are 204 BTU/hr/F (107.6 W/C) during the daytime and 169 BTU/hr/F (89.1 W/C) during the nighttime. More explicit details of the building construction are given in the references (Starr and McGowan and others, 1984).

The active solar collection component uses 210 ft^2 (19.52 m^2) of single-glazed hydronic solar collectors (Grumman 332A) which are connected to 800 ft (244 m) of heat exchanger tubing within the slab and 600 ft (183 m) of tubing within the packed gravel bed. The heat exchanger tubing is high-density polyethylene pipe with a nominal outside diameter of 1 in. (0.025 m) and is evenly distributed throughout the slab and packed earth bed. A proportional differential controller is used to turn on the collector loop flow when a positive temperature differential is detected between the collectors and the storage mass.

Passive solar energy is supplied to the building by 40 ft^2 (3.7 m^2) of south-facing glazing and also by 72 ft^2 (6.6 m^2) of east and west facing glazing.

Auxiliary energy was provided by an electrical baseboard resistance heater which was set to maintain an inside temperature of 65° F (18.3°C) for eight hours during the day and 55 °F (12.8°C) for sixteen hours during the night.

Vermont has climate which is characteristically cold and cloudy. The relative opportunity to meet a heating load at a given location with the available solar resource can be judged by the relationship HS/DD for the location (solar radiation/degree days). Table 1 references Balcomb and others (1983) and presents the average HS/DD at several North American locations for the month of December. Lower numbers represent the less favorable location. It is seen that the testing program was conducted in one of the least favorable locations for solar heating in North America.

Table 1: Solar Resource versus Heating Requirements for Selected Locations (Average December Values)

Location		**HS**	**DD**	**Location**		**HS**	**DD**
Burlington, VT	283/1314	=	.22	Toronto, ONT	354/1198	=	.30
Buffalo, NY	283/1150	=	.25	Denver, CO	732/1004	=	.73
Seattle, WA	211/760	=	.28	Washington, DC	481/961	=	.50

The residence was fitted with numerous temperature and energy sensors. Temperature readings from 16 RTD sensors were read manually at the beginning and end of each heating day as well as the readings from the BTU meter and the electric energy meters. Temperature data from the thermocouples and the pyranometer were continuously recorded on a Fluke Model 2240A Data Logger coupled to a Texas Instruments 733 ASR/KSR Electronic Data Terminal. Data collected from this system was processed and reduced by the university of Massachusetts Control Data Cyber 175 system.

Table 2: Summary of Experimental Instrumentation Sensors

1. Temperature
8 -RTD Sensors in Cement Slab
6 -RTD Sensors in Gravel Bed
4 -Thermocouples in Slab
2 -Thermocouples Outside House
2 -Thermocouples in Solar Loop
3 -Thermocouples Inside Residence
2 -RTD Sensors Within the Ground

2. Flow Rate - Brooks Rotameter

3. Energy
1 -Eppley Pryanometer Model 8-48
1 -Hollis Laboratory Recording Pyramometer System
{ LM-3000 (Recorder) ; MR-5A (Pyranometer)}
1 -Li-Cor Model LI-175 Solar Meter/Integrator
1 -Ista BTU Meter Model WMZ 2/50
2 -Electrical Energy Meters
1 -Electrical Power Meter

Results

System Efficiency

System efficiency as discussed here refers to the amount of solar energy which is harvested and delivered to the building relative to the total amount of solar insolation which is available at the site. Table 3 is a summary of the monthly measured efficiencies which were observed at the test building in Vermont. Table 4 is a summary of the monthly efficiencies which were observed at a test building having an active solar heating system with hydronic flat plate collectors located at Colorado State University. This system was designed, installed, and operated by solar specialists in a closely controlled measurement program and is representative of the efficiency of a quality active solar heating system operating in a favorable climate (Lof, 1981).

Table 3: Summary of Hybrid System Efficiency (Vermont)

Month	Solar Input (MBTU)	Measured Output (MBTU)	Average Efficiency (%)
November	3.358	1.668	49.7
December	3.926	1.972	50.2
January	4.915	2.350	47.9
February	6.632	3.334	50.3
March	6.390	3.104	48.6
April	6.035	2.967	49.2

Table 4: Summary of Active System Efficiency (Colorado)

Month	Average Efficiency (%)
November	35.0
December	38.0
January	31.0
February	33.5
March	34.6

The average efficiencies observed in the active charge/passive discharge system at its Vermont location are 43% greater than those observed in the active heating system at its Colorado location (49.3% versus 34.4%). It is significant that Colorado receives more than twice as much solar insolation as the Vermont location. Low solar collector temperatures were the primary reason for the favorable efficiencies which were observed. Collector temperatures were seen to be coupled quite closely to average mass storage temperatures {within 10°F (5.6°C)} verifying the effectiveness of the polyethylene heat exchanger.

System Performance

Figure 3 shows the response of the building to large fluctuations in ambient temperature and solar inputs for 6 days in January. It can be seen that interior temperatures remained within a reasonable comfort range while these variables fluctuated widely.

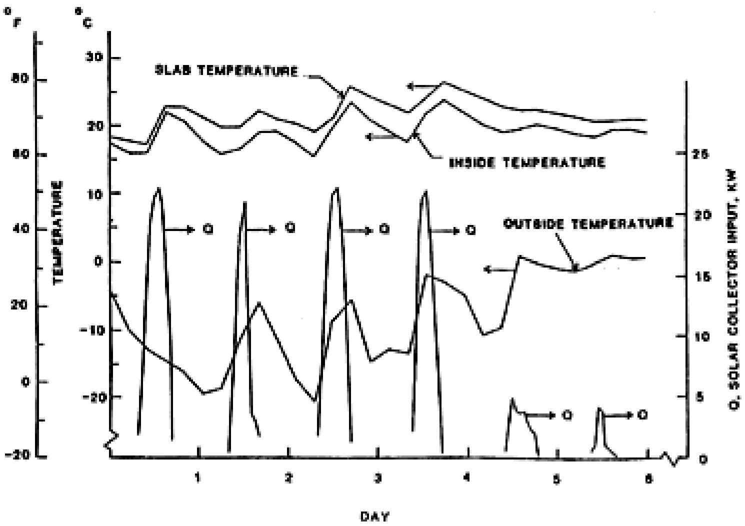

Figure 3: Building temperatures, ambient temperatures and solar insulation for 6 days in January

The mean interior temperature was 65°F (18.3°C) and very few observations were found to be less than 60°F (15.6°C) or greater than 80°F (26.7°C). Auxiliary heating energy was only 1.8 million BTUS (528 KWH during the period from October through April. These observations indicate that the passive radiant storage mass is large enough and effective enough to enable high solar heating fractions in a cold and cloudy climate.

Conclusions

The research has demonstrated that this simple, low-cost hybrid solar heating system offers significant advantages in system efficiency, overall performance, comfort and architectural flexibility.

Acknowledgement

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References

Starr, R. J., and McGowan, J., and others (1984). Technical Evaluation of a Solar Heating System having Conventional Hydronic Solar Collectors and a Radiant Panel Slab. United States Department of Energy, DOE/CE15140-T1.

Balcomb, J. D., and others (1983). Passive Solar Handbook, volume 3, 264-292.

Lof, G. (1981). Operations, Performance and Maintenance of Integrated Solar Heating Cooling and DHW Systems. Solar Energy Research Institute.

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