SOLAR AIR HEATING ON PINE RIDGE INDIAN RESERVATION: PROMISING APPLICATION OF A TRIED AND TRUE SOLAR TECHNOLOGY

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ABSTRACT

Active solar heating of air, as opposed to water, is an appropriate solar technology for certain applications. Its advantage is in its simplicity and low cost. Freeze protection is inherently provided, controls are simple, maintenance is limited, and initial investment is minimal. Because air is not a good heat storage medium, direct solar heating is most beneficial for day use spaces or as a supplement to other heating sources. Retail areas, small offices, workshops, and homes that are occupied during the day are examples of appropriate day use spaces.

The Lakota people of Pine Ridge Reservation in South Dakota have a strong desire to take advantage of renewable energy sources. Homes on the reservation are occupied during the day, since much of the economic activity on the home. Solar air heating is an appropriate renewable energy technology for introduction on the reservation due to its simplicity.

Fig. 1: Installation of solar air heater at the Yellow Bull residence (photo courtesy of Donald Alvarez, © 2003)

1. INTRODUCTION

With the exception of the development of transpired solar collectors in the 1990s, direct heating of air with active solar collectors has received little attention in the U.S. since 1985. This simple thermal technology was largely perfected in the U.S. between 1945 and 1985 in response to concerns about energy supply (1). Use of solar air heaters has not gained broad commercial acceptance because it has not been considered cost effective.

2. BACKGROUND

2.1. Solar Air Heating

Direct heating of air, as opposed to solar heating of water and transferring the heat to air, has some key advantages. All the issues related to freeze protection in a water heating are resolved with an air heating system. Controls are simpler, maintenance is limited, and initial investment is reduced since the non-collector costs are fewer and the systems are easier to install. The decision to use any technology must reflect a match between the capabilities of the system and the requirements of the application. While efforts continue to store the heat collected by air in thermal mass (2), such as a rock storage bin, these methods are difficult to employ reliably. However, there exist many applications where solar air heating is useful as an instantaneous heat source (3).

2.2. Solar Air Heating on Pine Ridge Indian Reservation

One example of where air collectors make sense is in colder climates where energy is expensive and where people spend a lot of time at home during the day. We will describe the use of retrofit solar air heaters to offset expensive imported energy (electricity, wood, or propane) on the Pine Ridge Indian Reservation in South Dakota.

The winters in South Dakota are bitterly cold, with 4164 heating degree days per year (4). The economic and cultural structures of Pine Ridge are such that people are often at home during the day. Homes are typically poorly constructed and, according to a Colorado State University study, heating them can consume 50-70% of a household's cash income in the winter (5). Furthermore, the local forest resources are being depleted for fuelwood, making it increasingly difficult for people to find the wood they need to heat their homes. Weatherization is equally important to offset energy requirements and is comparable to solar heating in cost and benefit. Weatherization and solar heating together can save between 20% and 50% of the cost of heating a home (6).

2.3. The Oglala Oyate Alternative Energy Program

The Oglala Oyate Alternative Energy Program (OOAEP) represents a cooperative effort to provide environmentally sound, economically beneficial and culturally appropriate energy solutions to the Oglala Lakota people living on the Pine Ridge Reservation. The partnership grew out of a shared concern that current energy solutions on Pine Ridge are reducing quality of life and threatening the health of the people and the ecosystem. The OOAEP is comprised of the Pine Ridge Area Chamber of Commerce, the Oglala Lakota College, Youth Opportunity, and the non-profit environmental organization Trees, Water, and People.

The OOAEP has two primary objectives: to increase the awareness of alternative energy among Lakota peoples and to help Lakota families reduce energy spending. Therefore, each installation is conducted as a workshop, teaching Lakota youth the principles of solar energy. In the course of the workshop, the participants learn basic carpentry and electrical skills, and the mechanics of installing a solar air heater. Once an individual has participated in two solar installations, they are eligible for the paid position of directing an installation. In the long term, the OOAEP plans to explore the feasibility of creating one or more Lakota-owned businesses to manufacture, market, install, and maintain solar air collectors on the Reservation.

3. SOLAR AIR HEATING

Heating of air using solar energy requires four basic elements: an absorber plate that gets hot when the sun strikes it; a glazing material to allow sunshine in but not let heat escape; a path for air to flow over the absorber plate and pick up heat; and insulation to keep heat from escaping off the back of the collector (2).

3.1 History of Solar Air Heating

The first patented solar air heater was marketed in the U.S. in 1890. Several other solar air heaters were tried out before 1973 when the energy crisis stimulated extensive development of all kinds of solar heating technologies. Between 1975 and 1985, the federal tax subsidies for solar heating created a surge in the solar air collector market, with 85 companies offering commercial products in 1980. During the 1990s, unglazed solar air heaters (also known as transpired collectors), generally used for preheat of ventilation air in large spaces, were developed in Canada and the U.S. In Europe, solar air heating enjoyed a revival during the 1990s thanks to their widespread use by architects. The success of this technology motivated the International Energy Agency (IEA) to conduct a series of workshops to exchange information and experience about these solar air heating systems. This work was performed under IEA 'Task 19' and resulted in the publication of a Solar Air System Design Handbook (7).

3.2. Types of Solar Air Collectors

There are three basic kinds of active solar air collectors: flat plate, building-integrated, and transpired.

3.2.1. Flat Plate

A flat plate air collector looks a lot like a flat plate liquid collector and operates much the same. The glazing material may be either glass or fiberglass. Commercially available collectors today use low iron tempered glass for its superior transmissive qualities. Fiberglass may be preferred for use on the Pine Ridge reservation for its lightness and resistance to breakage. Fiberglass will need to be replaced after 10 to 15 years due to discoloration and reduced transmission. Collectors can be designed so the fiberglass is easy to replace.

We have used salvaged, reconditioned back pass flat plate collectors in our work on Pine Ridge, some single-glazed with glass, some double-glazed with glass, and some double-glazed with fiberglass.

3.2.1.1. Full Flow Air Collector

In a full flow collector, the absorber is perforated and the air flows around it. Since the air contacts the glazing, it is necessary to use two sheets of glazing to form an insulating dead air space. Full flow collectors are simpler to design because the air is in direct contact with both sides of the absorber plate, increasing heat transfer. They are more expensive and heavier, if the glazing material is glass (3).

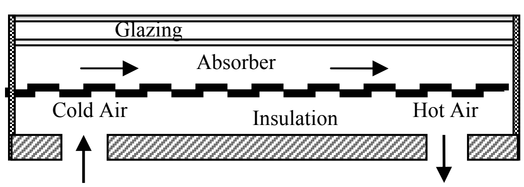

Fig. 2: Full flow flat plate solar air heater

3.2.1.2. Back Pass Air Collector

In a back pass collector, the air flows between the absorber plate and the insulated panel that forms the back of the collector. Only one sheet of glazing is required because there is a dead air space between the absorber plate and the glass. The absorber plate is either corrugated or has baffles attached to increase turbulence and surface area for better heat transfer (3).

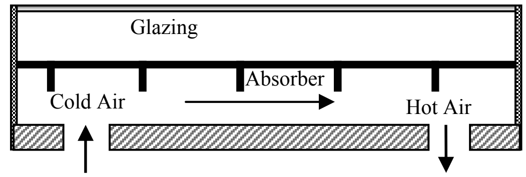

Fig. 3: Back pass flat plate solar air heater

3.2.2. Building Integrated Air Collector

Solar air heaters may be built on site as part of the wall or roof. They may be glazed or unglazed. Unglazed collectors are only suitable for preheat or low temperature applications such as crop drying. The dimensions and materials can be modified to fit in with the building design.

3.2.3. Transpired Air Collector

Transpired collectors consist of a dark perforated absorber with a fan pulling air through it so it is heated. The perforations are a specific size and spacing according to research done at the U.S. National Renewable Energy Lab. If the collector is being used to preheat ventilation air, then it is installed on the south face of the building and forms an air space from which the heated air is pulled by the fan into the conditioned space. In this case it generally covers most of the south side of the building like a second skin.

Transpired collectors have mostly been used to preheat ventilation air in large buildings and for crop drying. Since they are unglazed, they only produce an average temperature rise of 20ºF (8).

4. PILOT STUDIES ON PINE RIDGE RESERVATION

4.1. System Operation

The Lakota systems consist of one or more reconditioned flat plate collectors, a 382 cfm squirrel cage blower, a differential controller, a backdraft damper, and 6 inch ducting. All of our collectors are mounted on the ground against the South wall of the home or house trailer. If possible, the return duct is run through the crawl space or basement. If no such space is available, the duct is run along the interior wall of the house.

The collectors are oriented due south and tilted about 60º up from horizontal (the latitude in Pine Ridge is about 43º).
Other important considerations in the design of a solar air heating system are the length of duct runs, size of ducting, control of the system, location of the supply and return vents, and size of the fan. The hot air supply duct should be

kept as short as possible to minimize heat loss in transit (10-15 feet maximum). Any outside runs should be insulated. We use insulated flex duct for ease of installation. The cold air return duct can be up to 50 feet (9).

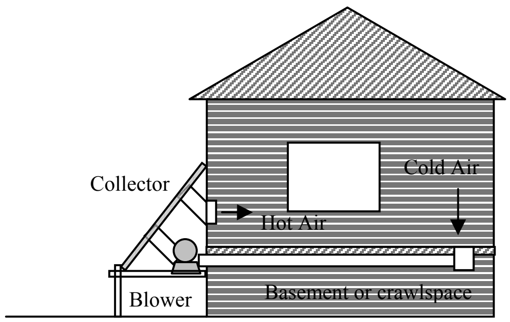

Fig. 4: Typical solar air heater

These systems are intended to heat only the day use space in the home and occupants are advised to keep the doors to other rooms closed. The supply of hot air from the collector is located as close as possible to the collector, generally on the wall adjacent to the collector. The return vent must be placed such that hot air is distributed throughout the space to be heated. This is best accomplished with the return on or near the floor to draw the coldest air back to the collector. This also increases the efficiency of the collector since it creates a larger temperature difference from inlet to outlet. It is best to locate the return on the far side of the room to be heated, for maximum circulation and mixing of the room air.

4.2. Performance

A 4'X8' collector may be expected to provide 25-50% of the heat needed for 400 to 800 square feet of building space (10). This corresponds well to the living space of a typical Lakota home. Of the six installations, 5 had electric resistance heaters. Four of the homes used wood as their primary heating source. One system was installed in a trailer that had no source of heat and was used during the day for quilt making.

We have made a preliminary analysis of the performance of our installations using fchart software (12) to determine the solar heating contribution and the money saved from displaced electric heat. A rate of $0.09/kWh was used for electricity, which was the rate on the reservation in 2003. The heating load used to calculate solar fraction (the fraction of the heating load that can be served by solar energy) is based on an assumed UA value of 200 Btu/hr·ft^2·°F. The slope and intercept values used were obtained from the Solar Rating and Certification Corporation (13).

Since we are looking at the possibility of designing collectors for manufacture on the reservation, we were also interested in how different collector designs would perform. We ran the analysis for three collector configurations: double-glazed with fiberglass, double-glazed with glass, and single-glazed with glass. These results are presented in Table 1.

The average cost of the equipment needed for the installation, using reconditioned collectors, is $1060. A solar air heating system consisting of one 4'X8' collector and associated blower and ducting saves about $112 compared to electric heating. This system would therefore pay for itself in 10 years if replacing electric heat. Using new collectors would raise the system cost to about $1500. It should be noted that simple payback has less significance in the current application because these installations are a form of energy assistance rather than being an investment of the owner. In the case of the quilt-maker, she was unable to work on very cold days and the solar heater will increase the number of days she can quilt. For a sustainable business to be created around this idea however, owners might be required to make the investment and would certainly be interested in payback. It will be necessary to collect more actual data on energy use and savings for these installations to draw firm conclusions on their benefits.

TABLE 1: PERFORMANCE OF AIR COLLECTORS ON PINE RIDGE RESERVATION

Collector Configuration	Intercept ($F_R\tau\alpha$) (Btu/hr·ft^2·°F)	Slope (F_RU_L)	Solar Fraction	Solar Heat (10^6Btu)	Savings/year ($/year)	Life Cycle Savings ($)	Simple Payback (yrs)
2-filon	0.574	-1.195	0.19	3.8	$107	$4,239	10
2-glass	0.490	-0.500	0.20	4.0	$111	$4,518	10
1-glass	0.625	-1.184	0.22	4.3	$118	$4,960	9

5. RESULTS

The Lakota people who are using the solar heating systems are very pleased with them. It has been difficult to quantify the fuel and cost savings because record keeping is a challenge, especially for those heating with wood. The Yellow Bulls, who have operated their system consisting of three 3'X6' panels for one winter, say that on a sunny day they don't need to put wood in their stove until 7 pm, three hours after the solar heating system generally shuts down. This means that from about 10 a.m. to 7 p.m. they are no longer burning wood.

The Oglala Lakota College and Youth Build Trades students have been enthusiastic about the solar heating workshops. A total of about 50 youth have participated in at least a portion of a solar lecture and workshop/installation. There are six solar air heating systems currently operating on the reservation and at least four more will be installed in 2004.

5.1. Business Model

One of the goals of the OOAEP is to develop employment opportunities for Lakota since the rate of unemployment is estimated between 50% and 80%. Solar air heaters can be manufactured in a locally owned machine shop with minimal investment, creating much-needed jobs. The synergy of cutting dependence on expensive, imported energy; creating employment in a clean renewable energy industry; and establishing a nationally marketable product for the tribe is profound.

A team has been assembled to design an efficient, low cost, solar air heater that can be manufactured with locally available labor and materials, recycled when possible. A group of Lakota interested in forming a solar business has been meeting to discuss their interests and capabilities. The next step is to build some prototype collectors; test their performance; and write a business plan to manufacture them on the reservation.

Such an enterprise would not only provide a sustainable source of income and employment in the community, but it would also help to promote a clean rural environment by providing more environmentally friendly, economically sound and culturally appropriate energy solutions to the Lakota people.

6. SUMMARY

Solar air heating can be an appropriate energy solution in the right application. Spaces that are occupied during the day, such as homes on the Pine Ridge Indian Reservation, are good candidates for cost effective solar air heating.

Although the benefits of solar air heating need to be quantified more thoroughly by collecting actual energy use data for each installation, there is sufficient evidence that the pilot solar air heating installations on Pine Ridge are saving resources and money. In addition, they are providing the Lakota people with energy alternatives and first hand knowledge of solar energy.

7. ACKNOWLEDGEMENTS

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