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UNGLAZED SOLAR WALL AIR HEATERS

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ABSTRACT

The new unglazed wall mounted solar air heating panels have become the preferred method of heating air using solar energy in cold climates. Since 1989 numerous systems have been installed on a wide range of applications and in several countries. Monitoring work under IEA Task 14 on a few of the solar wall heating systems has revealed interesting results and that the unglazed panels outperform the traditional glazed solar panels and at lower capital costs. The panels which have the trade name SOLARWALL® are built from conventional building cladding material, look like a typical metal wall and can be any dark colour. This paper will summarize some of the work to date, examples of applications, monitoring results, new developments and provide insight as to why this technology has the potential to revolutionize building construction in the future.

INTRODUCTION

When a heating load calculation is done on a building, as much as 50% of the demand will be to heat infiltration or ventilation air. In many commercial and industrial buildings the inside air is replaced twice each hour and the air exchange can be much higher in applications such as hospitals and plants producing fumes or chemicals. Solar panels which provide space heating by recirculating building air into collectors can only operate when the solar heated air temperature is above room temperature. This means that useful solar heat is generally only available on sunny days. If a solar panel is used to heat or preheat outside air, then any temperature rise of the air over ambient is useful energy. By heating outside air, heat can be produced even on cloudy days.

It is important to understand the history of the concept of using walls as solar collectors and how the low temperature air can be utilized. The unglazed solar air panels developed from a glazed design which heated outside air needed in industrial buildings. Buildings with high ceilings will have heat stratification since hot air rises and cold air falls. Heaters hung from the ceiling blow down hot air but its tendency is to rise. When exhaust fans are located in the ceiling, they will pull out the warmest air, creating a negative pressure condition and increase the problem of cold drafts near doors and windows. Since the late 1970's Conserval has been marketing a fan and duct system to distribute cold outside air along the ceiling which uses the stratified heat to heat the incoming air.

The original glazed solar wall collector had black or brown metal cladding typically found on walls of industrial buildings. The wall would be covered with plastic glazing and then the Conserval fans were used to draw outside air up the wall between the glazing and metal and into the building. It was a low cost design and the system worked very well. Over 20,000 m^2 of these panels were installed. More could

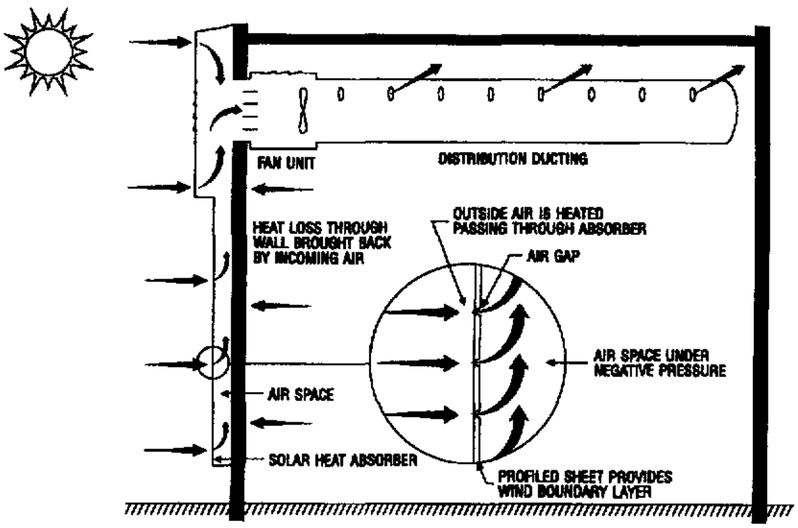

Fig. 1. Daytime Winter Operation

have been installed except for concerns over flammability of the glazing and objections to the appearance of plastic on the walls. A frequent comment made was "can you get rid of the glazing?" Architects were unwilling to specify glazed solar wall heaters. It became apparent that any wide scale use of a glazed solar wall would be difficult.

Conserval had been testing various types of unglazed solar collectors and eventually John Hollick of Conserval and Dr. Rolf Peter of Switzerland came up with the perforated wall idea which when tested gave higher efficiencies than the glazed panels at high air flow rates.

The new unglazed panels have been called by many names. The Americans refer to it as a "transpired panel". The automotive industry prefers the name "high performance panel". We call it the "perforated wall" and also refer to it as the SOLARWALL® system.

TECHNICAL DISCUSSION

Extensive testing and field monitoring by Natural Resources Canada has shown that the best performance occurs at high air flow when the air can travel uniformly through each hole in the metal absorber, travel up the wall to a header and then horizontally to the nearest fan. Figure 1 illustrates the typical operation of the perforated solar wall system. Collector efficiency is stated differently from other solar panels. Outside air is always entering the collector so the efficiency of the panel is at the maximum or Y-intercept of a typical solar efficiency curve.

A test wall of 5 m^2 has been used extensively to compare efficiencies of various designs and materials. The test wall is located at the National Solar Test Facility near Toronto Canada and the test results are shown in fig. 2. Three wind conditions were simulated - zero wind, 1.5 m/s and 3.5 m/s velocity and the results are as one would normally expect. The field monitoring of large solar wall heaters, however, differ from the NSTF numbers. A 420 m^2 wall at a General Motors plant in Ontario is being monitored by Natural Resources Canada as part of the IEA Task 14. The GM performance results have been superimposed onto the NSTF results in fig. 2 and are significantly higher.

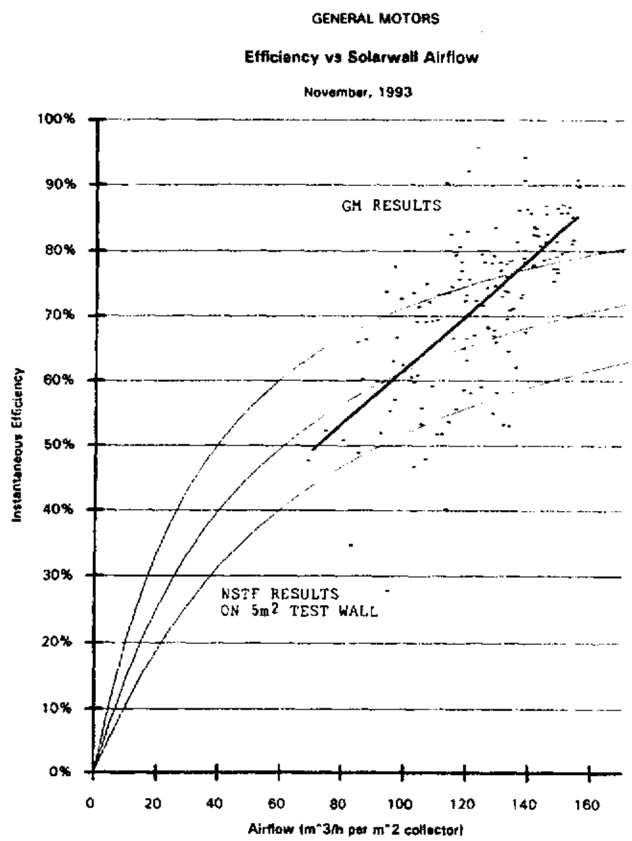

Fig. 2. Solar efficiency curves versus air flow through collector.

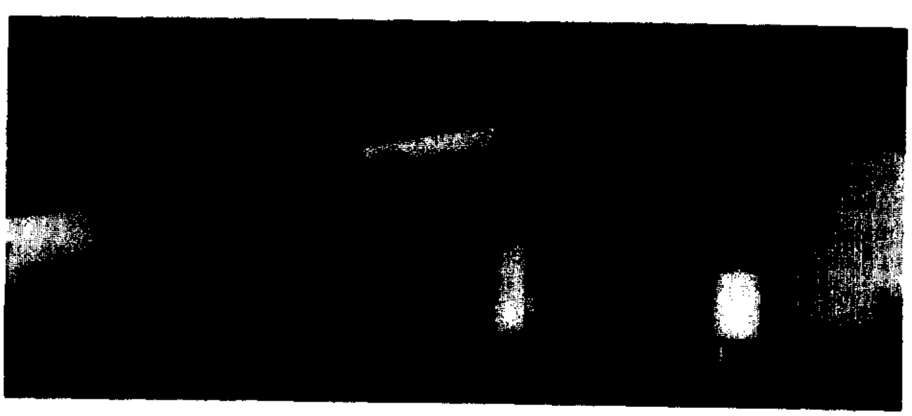

Fig. 3. General Motors 420m² Solarwall® system in Oshawa, Ontario.

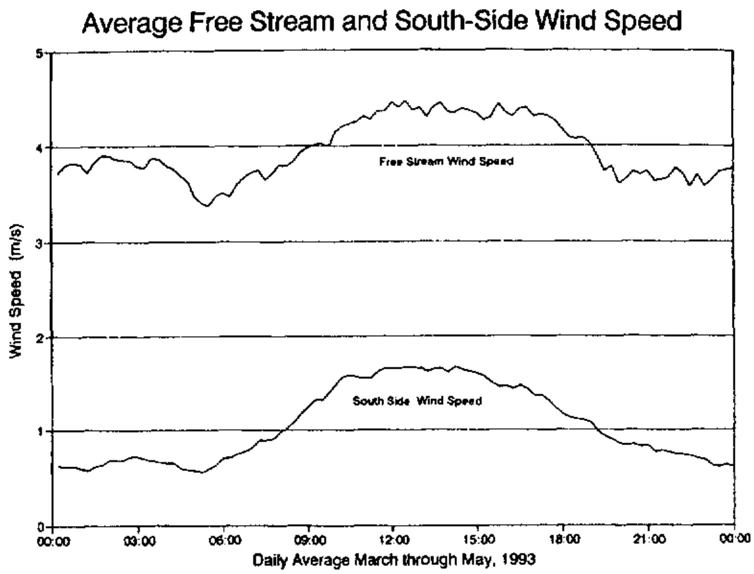

Fig. 4. Roof versus wall wind speeds.

Wind on the wall is lower than wind on the roof and can be as low as one third of the roof wind speed. Wind speeds were measured at solar wall projects at McDonnell Douglas, Ford of Canada and General Motors and all gave similar results. Figure 4 illustrates the wind speeds at the GM installation.

The next major factor is edge losses. A wall which is 100 meters long will have two sides as does the test wall which is only two meters wide but the proportion of edge to wall area is much greater in a small test panel. Attempting to predict solar efficiency from small samples has shown the solar contribution to be significantly underestimated.

Additional Energy Savings

The Ford and GM results detailed two other areas of energy savings with the solar wall design. The solar heating results in fig. 2 can be called active solar gains. There are also passive solar gains as illustrated in fig. 5. Passive gains can be defined as the difference in air temperature between the roof and the south wall. The air at the south wall will be warmer before it enters the wall. The ground in front has been heated and that heat is rising against the wall and the area of air intake is the entire wall instead of a small fan intake on the roof. One may ask why does the roof not heat up the same as the ground. It does but the roof area in front of the fan intake may only be a few square meters compared with hundreds of square meters of ground in front of the entire wall air intake. The passive solar gains can be significant.

An even greater energy savings comes from the building heat loss through the wall which is picked up by the incoming air and returned to the building. Figure 5 illustrates the savings for the 420 m^2 which occur 24 hours a day or as long as the fan is on.

The south wall of the GM plant was a typical insulated metal wall with exterior metal cladding, horizontal girts mounted approximately 2 to 3 meters apart, fastened to an interior metal liner sheet. The space between the two metal sheets was filled with fiberglas insulation 5 cm thick. One would expect the wall

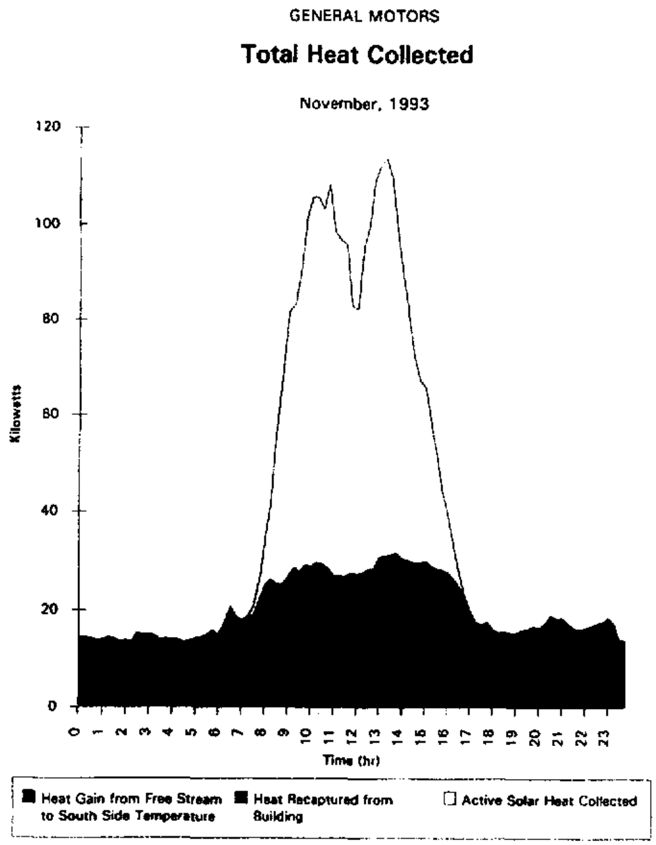

Fig. 5. Breakdown of General Motor Solarwall® energy output.

with insulation to have a thermal resistance of at least 1.2 °Cm²/w. In actual fact, the resistance measured was much less in the order of 0.3 °Cm²/w. This heat loss has been picked up by the incoming air into the SOLARWALL® system and accounts for the temperature rise of the air during nighttime operation. It appears that the interior metal liner is absorbing heat from inside the building, transferring that heat to the horizontal girts, and then to the exterior metal wall which is near ambient temperature.

Temperature Rise

Figure 6 illustrates the temperature rise of the air versus solar radiation for various air flow rates through the solar panels. These results are based on measurements performed on the 5 m² test wall at the NSTF facility. Based on the results from the General Motors field data, one may expect that these numbers are conservative and results would be somewhat higher on larger installations. Most of the industrial air preheat systems have been based on higher flow rates which would be represented by curves C, D, E, and higher. The purpose of preheating ventilation air is to achieve a reasonable temperature rise on the incoming air, but not to be heated much above room temperature. Recent results have shown that higher temperature rises at lower air flow rates are possible. Curves A and B were run on lower porosity walls and show that temperature rises of 30 - 35°C are indeed feasible.

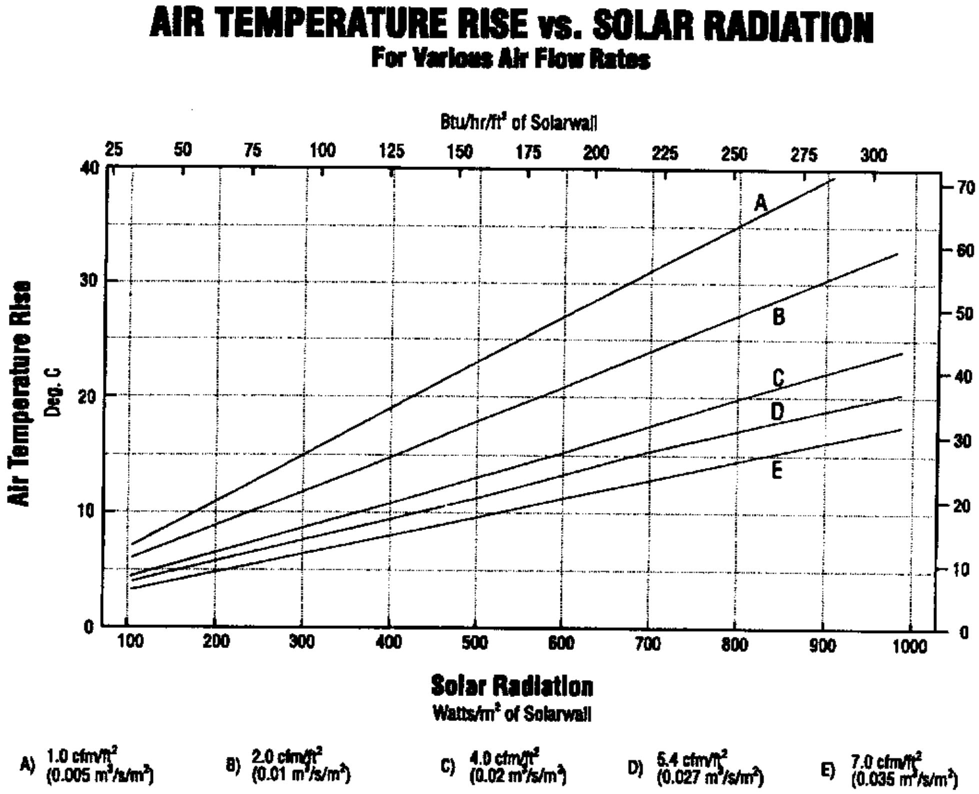

Fig. 6. Temperature rise of solar heated air at various air flow rates and solar radiation levels.

With the lower air flow rates, the SOLARWALL® system can be considered for use in space heating applications where the ambient temperature does not normally drop below the freezing point.

Another major use for the higher temperature application is in crop drying. Two recent projects, one for drying tea and another for drying cocoa beans in southeast Asia are being installed. Other solar crop drying systems are being considered in Mexico and California for various produce such as fruit, seeds, coffee beans, onions, and garlic. The solar cladding sheets used for crop drying applications are being roof mounted to take advantage of the high summer sun.

A few photos of SOLARWALL® installations on various applications are presented. These include the General Motors building in Canada, a power station in Germany where the solar heated air is used to preheat combustion air, and one of a few apartment buildings in Canada.

SUMMARY

The SOLARWALL® cladding system is the first truly integrated building material which is also a solar collector. The metal cladding has the appearance of conventional metal facades and offering the panel in a choice of dark colours allows the building owner and designer to maintain an aesthetically pleasing appearance and still utilize solar heating. Home owners have begun to install SOLARWALL® cladding to provide heated ventilation air to their homes, including one which was built air tight and suffering from indoor air pollution. A potential application in Scotland is to add heat and also remove dampness from traditional Scottish homes.

Fig. 7. East wall with $262m^2$ Solarwall®, Sarnia, Canada.

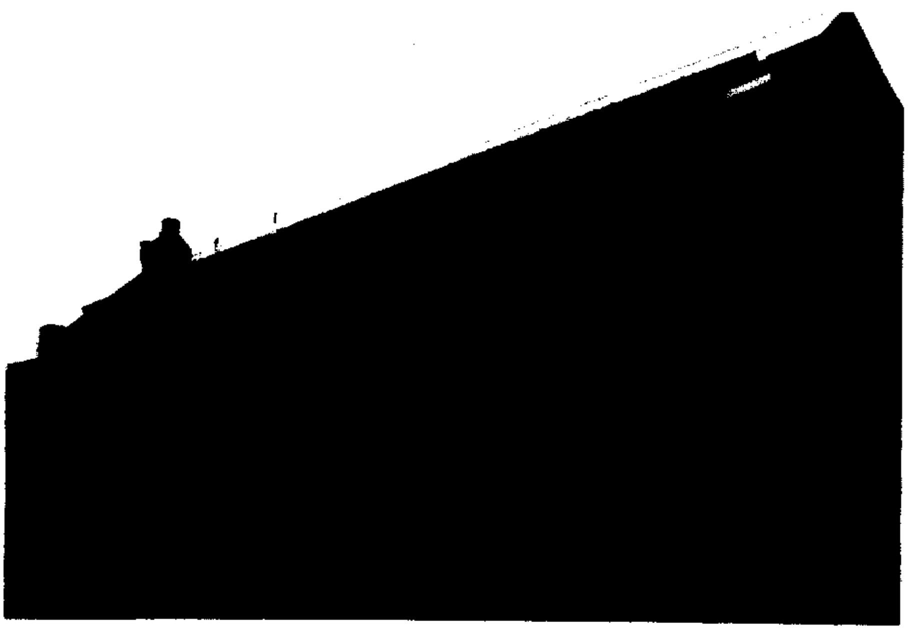

Fig. 8. $370m^2$ for cogeneration plant, Göttingen, Germany.

Fig. 7. East wall with 262m² Solarwall®, Sarnia, Canada.

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