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PASSIVE SOLAR CONTRIBUTIONS TO RESIDENTIAL VENTILATION

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ABSTRACT

This paper discusses the use of solar energy to provide make-up heat to the fresh air ventilating a building. Several design strategies are suggested.

Engineering analysis is used to provide an estimate of the performance of an alternate energy ventilation system on a superinsulated residence in Great Falls, Montana. This analysis is compared to the performance of residences currently being monitored within the NCAT/DNR&C Superinsulated Monitoring Program.

For a residence, the energy used for heating air for ventilation totals around 5,000 kWh/year; an amount equal to the energy used to heat domestic service water. The calculations in this paper indicate that solar ventilation could save more energy than solar hot water.

1. INTRODUCTION

We have been shown that careful construction can produce a building which has a natural infiltration rate less that 0.1 air change per hour (ACH). To provide a healthy environment within the building we believe that a ventilation rate of 0.3 to 0.5 ACH is required. Air to air heat exchangers having electric fans have been developed which attempt to provide fresh air while recovering thermal energy from the stale exhaust air. These devices are powered by fossil based energy and inefficiencies increase the building energy requirement which is primarily fossil based energy.

From a utility's point of view, a well insulated, electrically heated house with electric fans that run continuously has some definite benefits. Such a building presents a more uniform load to the utility system. From resource conservation point of view, converting 4 Btus of fossil energy to 1 Btu of electric energy for low temperature heat in a building is a waste. Conscientious building design should be concerned with reducing the use of non-renewable resources.

Solar collectors operate more efficiently at lower temperatures due to a reduction in losses. The notion of using solar radiation to pre-heat ambient air for building ventilation seems attractive. This paper addresses the feasibility of this application.

2. VENTILATION LOADS

For a reference point we will look at data from three, very similar, superinsulated homes in Great Falls, Montana which use air-to-air heat exchangers. These buildings are being monitored under a program sponsored by the Montana Dept. of Natural Resources and Conservation. These are all tight buildings having a floor area of around 2,400 sq. ft. and a volume of about 17,000 cu. ft. Blower door tests showed about 1 ACH at 50 pascals. The average natural infiltration should be less than 0.1 ACH depending on ambient conditions.

Data from this monitoring effort is used to establish thermal performance of these buildings and to break out the role of forced ventilation. Continuous monitoring data is available for ventilation supply and exhaust temperatures. The status of the fan motors is known and a one-time measurement of supply and return air flow was made during January. [2]

These data allow a calculation of the make-up energy that the building heating system must supply to the ventilation air. This load is the ~~sum of~~ heat added to incoming air to bring it up to house temperature plus heat rejected to the atmosphere in the exhaust air. We will call this the VENT LOAD. Data for the three buildings are shown in Table 1.

TABLE 1: AVERAGE DAY IN JANUARY

SITE	TOTAL HEAT kWh	SOLAR INPUT kWh	VENT LOAD kWh	FAN PWR kWh	ACHf
1	90	8	19	7	0.3
2	76	11	22	6	0.3
3	97	14	16	5	0.2

In Table 1, TOTAL HEAT represents the total energy dissipated within each envelope; differences are mostly due to differing thermostat settings. The SOLAR INPUT portion of the TOTAL HEAT was calculated from glazing area, properties, and measured solar radiation. VENT LOAD is the portion of the TOTAL HEAT load associated with heating the ventilation air. If the air-to-air heat exchanger were 100% efficient VENT LOAD would be zero.

The fans ran over 95% of the time on sites 1 and 2 and about 74% of the time on site 3. The energy used to run the fans is shown in the FAN PWR column. Much of this energy is recovered as heat inside the envelope. The varying operating times plus differing flow rates lead to the differing forced ventilation rates, ACHf, shown in the last column of Table 1.

The point of Table 1 is to establish energy cost, VENT LOAD, for producing the existing forced ventilation rate, ACHf, in these buildings. This will be used as a reference for comparing alternate ventilation schemes.

We also assume that 0.3 ACH of forced ventilation is adequate. This amounts to 122,400 cu. ft. each day. There is probably another 0.1 ACH of uncontrolled or natural infiltration in these buildings which is assumed to be the same for all cases.

3. SPECIFIC VENTILATION COMPONENT

Odors and moisture for the kitchen and the bathroom are specific, short term sources that need to be vented. Lets assume that we vent these areas directly to the outside air, without a heat exchanger, similar to most current construction practice. We pay a specific thermal price for doing this but we get rid of a lot of moisture and odors before they are distributed and adsorbed into the living space. Using January data for average ambient conditions we compute the specific ventilation loads shown in Table 2.

TABLE 2: SPECIFIC DAILY VENTING

VENTILATION scf/day	VENT LOAD kWh	FAN kWh
12,000	3	0.3

4. GENERAL VENTILATION STRATEGIES

Taking January 1985 in Great Falls for an example we have calculated the thermal performance of several alternate ventilation strategies. These are shown in Table 3. Some of the strategies are supplemented by SPECIFIC ventilation as discussed in the previous section.

The first (reference) case, A-A EXCH, is the air-to-air heat exchanger systems presently installed and operating. The second case assumes we keep the fans but eliminate the heat exchanger. This strategy raises the heat load by 11 kWh/day.

Eliminating the fans and ducting entirely and just "opening the windows" 24 hrs/day saves the fan energy, about 7 kWh/day, as compared to the previous case. The ventilation control is very poor for this strategy but the energy use and economics form a useful and interesting reference.

TABLE 3: AVERAGE JANUARY DAY, 1985

STRATEGY	FANS kWh	VENT LOAD kWh	SPECIFIC kWh
A-A EXCH	7	20	0
NO EXCHANGER	7	31	0
OPEN WINDOW	0	31	0
DAY FLUSH Nat	0	28	0
DAY FLUSH Fan	7	25	3
SOLAR LOW ef	0-7	13	3
SOLAR HIGH ef	0-7	0	3

The DAY FLUSH Nat strategy calls for "opening the windows" only during the day. Using natural ventilation eliminates the fan energy. Also, since the average air temperature is several degrees higher during the day (solar heating) we gain 10% over the previous case. As a percentage, this gain would be greater in all other months.

An enhancement of the DAY FLUSH strategy adds SPECIFIC venting for kitchens and bathrooms and adds a FAN to control the daytime venting. The penalty of this enhancement is additional fan energy but the gain in control would make day flushing more feasible. The incoming fresh air would normally have to be heated to avoid a comfort problem due to the significant air velocities.

5. MORE SOLAR HEATING

The day flushing strategies use the (unavoidable) solar heating effects on the ambient air. We can enhance this effect by using the south side of the building as a low temperature solar collector. There would be a small benefit, perhaps a few degrees F, by taking inlet air from the eves of the south wall. The wall itself functions as a crude solar collector which is extremely sensitive to any wind.

An unglazed, LOW efficiency solar collector panel having air flow between the absorber and the building skin will collect about 20% of the incident solar radiation, Figure 1. If 170 sft of such a collector had been in place during the January test period it would have added about 12 kWh per day to the incoming air. A HIGHer efficiency collector having a wind screen and/or selective surface could supply 25 kWh or all the ventilation pre-heat energy on the average January day.

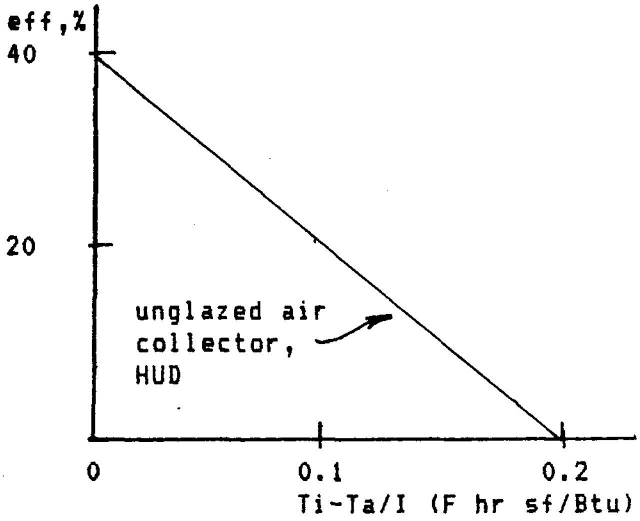

Figure 1. COLLECTOR EFFICIENCY CURVE

The last two SOLAR strategies show significant reductions in ventilation load even when fans are used, Table 3. With sophisticated control of the dampers, the fans might be eliminated. Wind powered venting coupled with natural convection would drive the ventilation air. Figure 2 shows a sketch of the solar powered ventilation strategy.

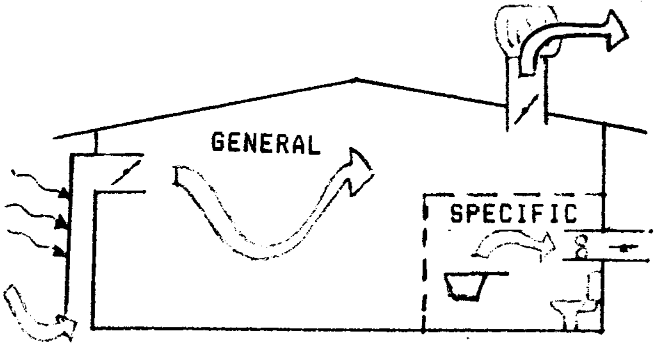

Figure 2. SOLAR POWERED VENTILATION

6. EXTRA PASSIVE WINDOWS

We considered another strategy (not shown) where extra "passive solar" windows were added making the building itself the collector. This strategy is not thermally attractive due to the large night-time losses of this type of collector in the Montana climate.

Venting a superinsulated house which is overheating due to passive solar gains primarily trades potential stored heat for comfort. There is a small thermal benefit to venting "extra" heat due to a lowering of the conduction heat loss component.

7. PERFORMANCE USING AVERAGE CONDITIONS

The previous example used only January data, typically the coldest month, to illustrate the various ventilating strategies. To gain a better view we consider the annual average conditions for ambient temperature and solar radiation in Great Falls, Mt. [1]

Figure 3 shows a graph of average daily, daily maximum, and daily minimum for each month. From this graph we see that controlled ventilation is only an issue for about 8 to 10 months of the year; opening the windows is an adequate (low energy) ventilation strategy for the other 2 to 4 months.

Solar radiation on a vertical, south-facing surface varies between 22,000 and 36,000 Btu/sft-month. During the period between September and June the average solar radiation is 29,400 Btu/sft-month. The average daily temperature is 40.1 deg F with a maximum of 50.4 and a minimum of 29.3 deg F. Due to the consistence of the solar radiation and the daily temperature swing we will simply use these average values to calculate annual estimates of performance. These are shown in Table 4.

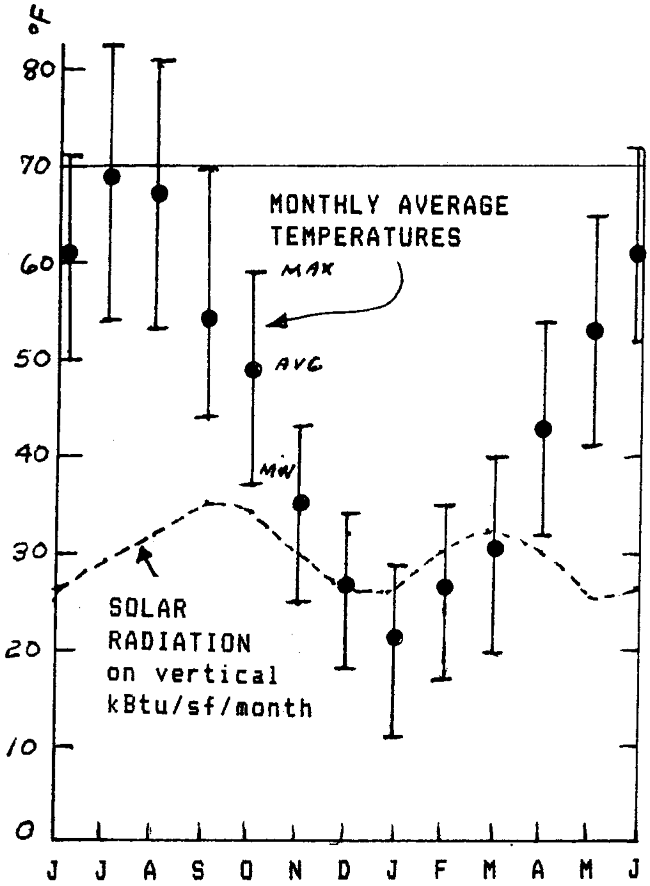

Figure 3. GREAT FALLS CLIMATE DATA

TABLE 4: AVERAGE VENTING DAY, SEPT-JUNE

STRATEGY	FANS Wh	VENT LOAD kWh	SPECIFIC kWh
A-A EXCHANGER	7	9	0
NO EXCHANGER	7	19	0
OPEN WINDOW	0	19	0
DAY FLUSH Nat	0	16	0
DAY FLUSH Fan	7	14	2
SOLAR LOW ef	0-7	5	2
SOLAR HIGH ef	0-7	(-5)	2

The options for Table 4 are exactly the same as discussed for the January data. Based on currently available monitoring data the air-to-air heat exchanger was given an average efficiency or 55%.

Note that the daytime flushing strategies are not far behind the air-to-air heat exchanger depending on how you choose to account for fan energy. Don't forget that we are assuming that we actually have appropriate hardware and controls practical daytime flushing.

For the solar collector strategies, we used the same collector area, 170 sft, as for the January example. The LOW efficiency collector meets 74% of the ventilation load.

We note that the HIGH technology collector produces and extra 5 kWh per day above the energy required for preheating the ventilation air. This could easily be stored in the structure on the average day with about 2 deg F overheating.

On a clear day we would have about 5 deg F overheating due to the collector. When added the passive solar gain and there may be a comfort problem. Solutions to this problem would be to reduce the collector area to around 100 sft or to ventilate more on overheating.

8. CONTROLS AND OTHER PROBLEMS

The key practical problems that I see with any of the natural ventilation systems are;

(a) control of the ventilation rate, and
(b) good dampers.

Any system that makes use of solar heating during the daytime will have to have higher flow rates in order to achieve the required daily-average infiltration rates. If we bring cool air into the building at high velocities we create a comfort problem that is potentially much worse than the "draft problem" that exists with some existing heat exchanger systems. The technology for doing this is not exotic but the cost and reliability requirements are not known at present.

The engineering feasibility of using wind powered venting in a place like Great Falls with an average wind speed of 18 mph is good. Interfacing both wind and solar to the practical requirements of ventilation through low-cost and reliable controls would be a significant engineering task. In terms of energy savings, the motivation for doing this is clear.

9. NOTES ON UNEVEN VENTILATION RATES

Buildings that most people currently live in have very uneven infiltration rates. The driving forces for natural infiltration are temperature difference between interior air and ambient air and wind. These driving forces vary by an order of magnitude throughout time.

The amount of ventilation needed depends on the building itself and what the occupants do in the building. In a given building, the required ventilation also varies with time. Neither data or hardware is currently available to optimize ventilation strategies. Appendix 1 illustrates one design approach to a ventilation demand sensor and control system. More work is needed in this area.

The alternate energy assisted

ventilation strategies investigated in this paper will produce ventilation rates that vary hour-to-hour and day-to-day. The average amount of fresh air introduced can be controlled to some extent and these systems do offer an improvement in control over completely natural infiltration.

10. CONCLUSIONS

(1) Low technology solar collectors could contribute significant heat to fresh air for ventilating buildings.

(2) The same collector system could be controlled so as to produce net solar heating gains.

(3) Solar ventilation could save more energy than solar water heating.

(4) The most difficult engineering problems with these systems seems to be effecting adequate, low-cost controls.

11. ACKNOWLEDGEMENTS

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REFERENCES

[1] Fowlkes, C.W.; MONTANA SOLAR DATA MANUAL, Montana Department of Natural Resources and Conservation, 32 S. Ewing, Helena, MT.

[2] Palmiter, L.; Montana Super-insulation Project, Monthly and Daily Summaries, NCAT Contractor Report, 1985

APPENDIX 1: CANARY CONTROL SYSTEM

Preliminary development on a ventilation demand sensor by the co-author of this paper (age 7) is shown in Figure A1. This is called the "Canary Control" and is based on the proven performance of this approach for mine ventilation problems.

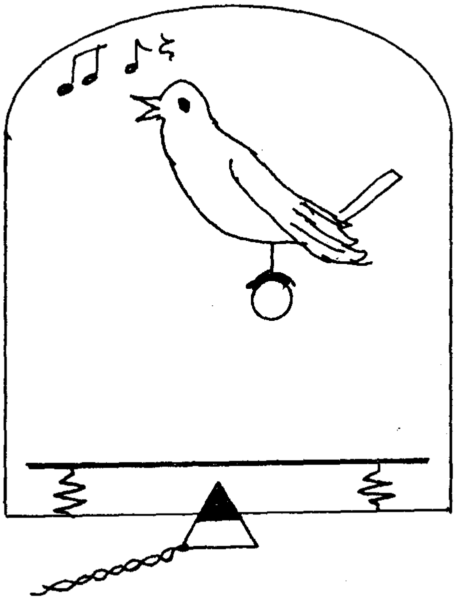

Figure A1. MANUAL RESET, CANARY CONTROL

A large ventilation fan and damper are controlled by a microswitch in the floor of the cage. Unhealthy air will cause the canary to lose consciousness and fall off his perch actuating the fan motor. The fan continues to run until the canary revives and hops back up to his perch. If the canary does not revive, the system must eventually be manually reset (with a new canary), an inherent safety feature.

(The co-author is prepared to negotiate a manufacturing license for this device.)