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ABSTRACT

Natural convection is one of the major modes of energy transport in passive solar buildings. There are two primary mechanisms for natural convection heat transport through an aperture between building zones:

1. bulk density differences created by temperature differences between zones and,
2. thermosyphon pumping created by natural convection boundary layers

The primary objective of the present study is to compare the characteristics of bulk density driven and boundary layer driven flow, and discuss some of the advantages associated with the use of natural convection boundary layers to transport energy in solar building applications.

1. BACKGROUND

Flows driven by bulk density differences have been studied by Brown and Solvasan (1962), Balcomb, Jones and Yamaguchi (1984), and Kirkpatrick, Hill, and Burns (1986). The convective heat transfer per unit solar aperture area for bulk density driven flow as reported by Brown and Solvasan is:

$$q'' = C_1 \left(\frac{w}{W}\right) \left(\frac{\ell}{H}\right)^{3/2} \overline{\Delta T}^{3/2} \qquad (1)$$

Flow driven by natural convection boundary layers have been studied by Nansteel & Grief (1984) and Scott, Anderson, and Figliola (1985). The convective heat transfer for boundary layer driven flow as reported by Nansteel and Greif is:

$$q'' = C_2 \left(\frac{\ell}{H}\right)^{0.401} \Delta T^{1.207} \qquad (2)$$

The length scales w, W, l, and H and temperature scales T_1, T_2, T_H, T_C are defined in Figure 1. The temperature difference $\overline{\Delta T} = T_1 - T_2$ is the temperature difference between the hot and cold zones for the case of the bulk density driven flow. The temperature difference $\Delta T = T_H - T_C$ is the temperature difference between the hot and cold walls for the case of boundary layer driven flow.

As can be seen from comparison of equations (1) and (2), there are fundamental differences between the heat transport for boundary layer and bulk density driven flow. Design guidelines based upon bulk density driven flow recommend that the flow aperture area should not be smaller than 15% of the solar aperture area. The blockage that results from the use of smaller flow apertures can lead to the production of large zone to zone temperature differences, thermal discomfort, and increased thermal losses. Scott, Anderson and Figliola (1986) recently compared the zone-to-zone temperature difference required by boundary layer and bulk density difference driven flows. The result of their comparison is shown in Fig. 2. The boundary layer flow requires a smaller zone-to-zone temperature difference than the flow driven by bulk density differences. Scott, Anderson & Figliola found that the zone to zone temperature difference for the boundary layer flow increased rapidly when the door area was decreased below 2% of the

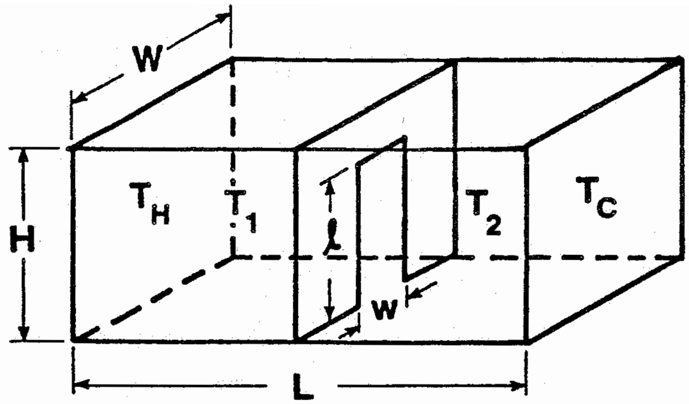

Fig. 1 Schematic Diagram Defining Lengthscales and Temperature Scales for Multizone Airflow.

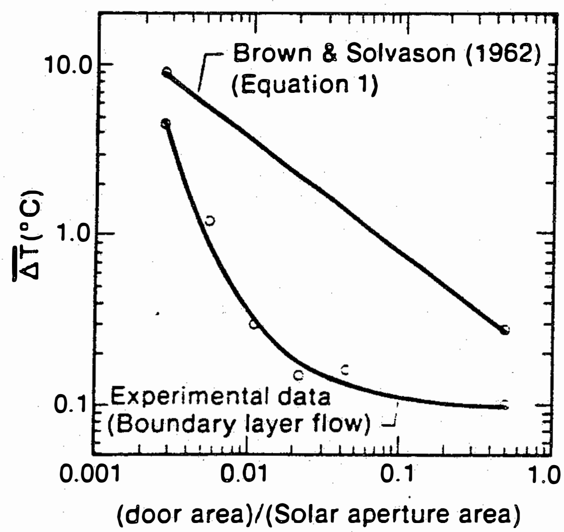

Fig. 2 Comparison Between Zone-To-Zone Temperature Differences Required by Boundary Layer and Bulk Density Flow. (Scott, Anderson & Figliola, 1986)

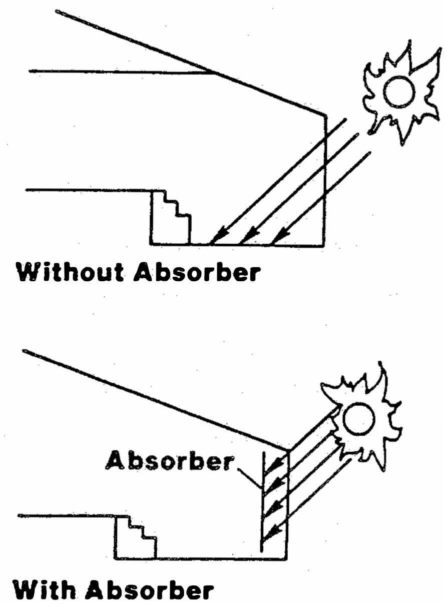

Fig. 3 Bartel House Test Conditions.

2. TEST RESULTS: BARTEL SUNSPACE

Tests were conducted in a private residence to determine the impact of boundary layer flow on the performance of an existing sunspace. Test conditions are shown in Fig. 3. A strong boundary layer flow was created by placing an opaque, selective surface absorber directly inside the sunspace glazing. The thermal performance of the sunspace with the absorber was compared to test results that were taken with the absorber removed. The results of this comparison are shown in Fig. 4. The temperatures of the sunspace was reduced dramatically by the presence of the

3. CONCLUSIONS

There are two major mechanisms for natural convection air flow through an aperture between building zones:

1. bulk density differences created by temperature differences between building zones and,

2. thermosyphon pumping created by natural convection boundary layers.

Preliminary test results indicate that there can be significant benefits associated with the use of boundary layer flows. Boundary layer flows can

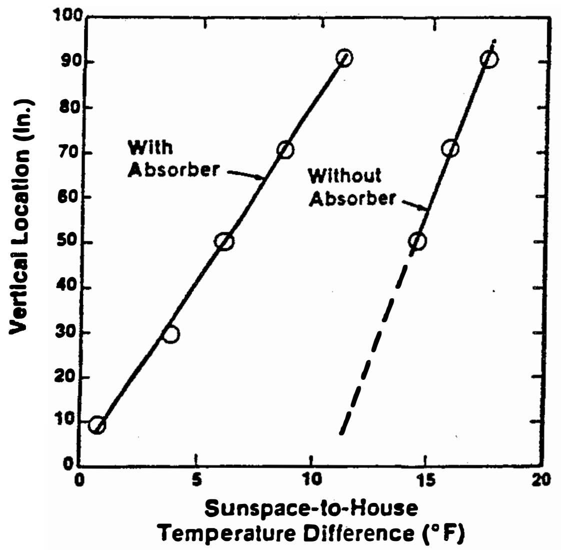

Fig. 4 Sunspace-to-House Temperature Difference in the Presence and Absence of Boundary Layer Flow.

difference and doorway area that is required to transport a given amount of energy between building zones.

4. ACKNOWLEDGEMENT

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5. NOMENCLATURE

$$C_1 = \frac{C_D}{3} \frac{k}{H} \left(\frac{g\beta H^3}{\alpha^2}\right)^{1/2}$$

$$C_2 = 0.915 \frac{k}{H} \left(\frac{g\beta H^3}{\nu\alpha}\right)^{0.207}$$

C_D = coefficient of discharge

g = gravitational acceleration

H = room height

k = thermal conductivity

β = coefficient of thermal expansion

α = thermal diffusivity

ν = kinematic viscosity

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