Chapter Five
Results and Analyses

In Chapter Four, a series of experimental procedures has been developed for investigating the performance of the double glass façade system. The preliminary results were obtained and analyzed by following approaches.

5.1 Data Analysis

To meet the research objectives and apply the experimental protocol, two analyses were performed:

1. To compare the fraction of transmitted solar radiation removed from the cavity.
2. To determine the temperature difference between the indoor glass surface and the indoor air.

The data were analyzed using statistical techniques including determination of mean values and regression analysis. The data was limited to the sunny, warm weather condition (solar radiation > 0.1 kw/m^2, outdoor air temperature > 60°F). Before the data were statistically analyzed, the cavity heat removal rate had to be calculated.

The heat from the ventilation cavity and fraction of transmitted solar radiation removed were estimated. This was done by first determining the airflow rate through the cavity. The flow rate was multiplied by the cross-sectional area of the ventilation cavity (2.67 ft^2), yielding the volumetric flow (cfm). Additionally the air temperature difference between the ventilation cavity outlet and inlet (t_o-t_i) is calculated. The flow rate and temperature difference are used in Equation 5.1 through 5.6 to estimate the heat removed from the cavity.

$$Q = H / c_p \rho (t_o - t_i) \quad (5.1)$$

where: Q = Air flow rate required to remove heat, cfm
H = Heat to be removed, Btu/min
c_p = Specific heat of air, Btu/lb$_m$°F (about 0.24)
ρ = Air density, lb$_m$/ft^3 (about 0.075)
t_0 = Cavity air outlet temperature
t_i = Cavity air inlet temperature

This equation can be re-write

$$H = Q\, c_p \rho (t_o - t_i)$$
$$H\ (Btu/min) = Q * 0.018 * (t_o - t_i)$$
$$H\ (Btu/hr) = Q * 0.018 * 60\ min/hr * (t_o - t_i) = Q * 1.08 * (t_o - t_i) \quad (5.2)$$
$$H\ (Watt) = Q * 1200 * (t_o - t_i) \quad (5.3)$$

The calculated heat flow is then compared to the transmitted solar radiation. For this, another calculation was performed.

$$q_A = F\,E_t + U\,(t_o - t_i) \qquad (5.4)$$

where: q_A = Total heat admission through glass, Btu/h*ft^2
F = The dimensionless ratio of the solar heat gains to the incident solar raditaion
E_t = Total solar radiation, Btu/h*ft^2
U = U-value, Btu/h*ft^2*°F

The product $F\,E_t$ is the heat gain due to solar radiation, and the product $U\,(t_o - t_i)$ is the heat gain due to conduction. Therefore, the cavity heat gain due to the solar radiation can be simplified as:

$$q_s = F\,E_t \qquad (5.5)$$

For each sample period the geometric relationship between the sun and window was determined, for the given time and day. The sun altitude and azimuth angles relate to the experimental wall were determined. Then the transmittance factor for solar radiation through the exterior lite of glass was estimated for a given angle of incidence. The glass Solar Heat Gain Coefficient (***F***) was adjusted as a function of the angle of incidence based on experimental values for similar glass as determined by Lawrence Berkeley labs and published in the Windows 4.1 User's Manual. The determination of sun incident angle (attitude and azimuth) was calculated using the computer program: Sun Position, by Seattle Energy Works. For each experimental sample period the transmittance factor was multiplied by the incident solar radiation as measured by a Licor pyranometer. Finally the fraction of transmitted solar radiation removed from the cavity was estimated as follow.

$$\text{Fraction } HR = H / q \qquad (5.6)$$

where: ***Fraction HR*** = the fraction of transmitted solar radiation removed
H = the heat removed from the ventilation cavity, Btu/h
q = transmitted solar radiation in cavity, Btu/h

5.2 Determination of Fraction of Transmitted Solar Radiation Removed

Equation 5.6 was applied to determine the cavity heat removal rate. These calculated values were then statistically analyzed. First, descriptive statistics were calculated for the fraction of solar heat removed from cavity for the active system (A-Fhr) and Passive (P-Fhr). The results are shown in Table 5.1 and 5.2.

Table 5.1 The results for fraction of solar heat removed from cavity

	Mean	Std. Dev.	Std. Error	Minimum	Maximum
A- Fhr	0.570	0.143	0.007	0.181	0.999
P- Fhr	0.325	0.099	0.005	0.095	0.785

Table 5.2 The fraction of solar heat removed in different cavity air flow rate

	Active System	Passive System	
Cavity air flow rate (ft/min)	Mean A- Fhr	Mean P- Fhr	Difference (A- P)
10-15	-	0.225	-
15-20	-	0.261	-
20-25	-	0.296	-
25-30	0.438	0.363	0.075
30-35	0.504	0.396	0.108
35-40	0.568	0.412	0.156
40-45	0.616	0.410	0.206
45-50	-	0.477	-

5.3 Determine the Temperature Difference Between Indoor Glass Surface and Indoor Air

The temperature difference between the indoor glass surface and the indoor air (ΔTga) is related to thermal comfort. If the difference is high, the glass may be a radiant heat source resulting in thermal discomfort.

Table 5.3 shows the descriptive statistics for the temperature difference between the indoor glass surface temperature and the air temperature near the indoor glass pane (ΔTga).

Table 5.3 The descriptive statistics for the ΔTga.

	Mean	Std. Dev.	Std. Error	Minimum	Maximum
A-upper- ΔTga	4.318	2.481	.155	1.039	9.924
A-lower- ΔTga	7.099	3.190	.199	2.120	13.943
P-upper- ΔTga	7.172	2.866	.179	.700	14.400
P-lower- ΔTga	3.217	2.155	.134	0.000	9.900

In this chapter, comparisons between the passive and active systems were made using descriptive statistics. More statistical results about the relationship between the environmental factors and the heat removal rate, and the relationship between the environmental factors and the temperature difference between indoor glass and indoor air were shown in the Appendix G and H. Conclusions from these analyses are discussed in Chapter 6.