Chapter 1
Introduction

1.1 The Double Façade System

Due to recent technological advances and its expressive qualities, glass has become an important feature in modern architecture. Its many desirable qualities, including light transmission, and esthetic appearance, make glass one of the almost indispensable materials in use today. Prior to the energy crisis of the 1970's, the selection and use of glass was focused on aesthetics. At that time the glass wall didn't need to be so ecologically responsive to the environment. Since energy costs were low, the inefficiency of the fully glazed building, with large heat gain and heat loss, resulted in more operation for the heating or the air-conditioning system.

Following the oil crisis of the 1970's, the fully glazed building was criticized due to its energy inefficiency. This led the building industry to develop new products such as photosensitive and photochromic glass, and new coatings such as reflective or selective (Low-E), anti-reflection, ceramic-enamel, and angular selective. Many of these new technologies have helped reduce energy consumption in buildings with large glass area.

Although many of these technologies have the potential to save energy, additional reduction may be possible for the fully glazed building. With this belief, the intelligent glass façade is being used frequently in Europe. The main purpose of the double glass envelope is to balance the desire for daylight and outdoor view with the concerns for heat gain and loss. The air cavity can be heated by the sun to create a warm buffer zone that protects interior zones in winter, or can be configured to function as a thermal chimney in summer utilizing the stack effect to remove excess heat. These systems are reported to be energy efficient although little scientific evidence is available to support this claim.

A typical double glass envelope system comprises a layer of single glass and a layer of double-glazing, separated by an air space. An operable shading device or heat absorbing glass can be installed in the air space to minimize the solar heat gain. The placement of the glass can vary. In the Commerzbank building, a 60-story high rise commercial building, for example, the outer skin is a fixed single glass pane, and the inner skin is an openable double-glazed pane. Between these two glass layers is a 7 inch air cavity with a Venetian blind. The Occidental Chemical Center, a 9-story high office building, on the other hand, has the green-tinted double insulating glass on the outside and clear single glass on the inside, separated by a 4 foot-wide air space with the motorized horizontal blinds.

In addition to the energy savings, the double envelope system has other potential benefits such as acoustic control, water penetration resistance, and improved office atmosphere because of the view and utilization of daylight. The double envelope system also offers a choice for renovation of existing building facades to transform into more energy efficiency buildings (Warson, 1999).

1.2 Natural Ventilation vs. Mechanical Ventilation

The cavity in double glass façades is either naturally or mechanically ventilated. Natural ventilation can provide an environmental friendly atmosphere and reduce the requirement for mechanical ventilation. On the other hand, natural ventilation is not without risk. It may create a door-opening problem due to pressurization. Besides, if the air path is not appropriately designed, the solar heat gain within the façade cavity will not be removed efficiently and will increase the cavity temperature.

For the naturally ventilated double facade system, the air is brought into the cavity and exhausted by two means: wind pressure and/or the stack effect. Wind pressure typically dominates the airflow rate. If properly designed, wind flowing over the façade can create pressure differences between the inlet and outlet inducing air movement. Without wind, the cavity can still be ventilated due to the stack effect. As air flows into the lower inlet, it is heated and becomes less dense and thermally buoyant. As a result, air will flow into the inlet and out the outlet while removing heat. Because there is the potential for stack-driven and wind-driven pressures to be counteractive, the air path and exterior openings need to be correctly sized and configured to insure the stack-effect pressures and wind-driven forces are additive. Otherwise, the preheated airflow in the cavity will tend to radiate to the interior, and opening the inner layer window in summer will introduce a burst of hot air (Figure 1.1).

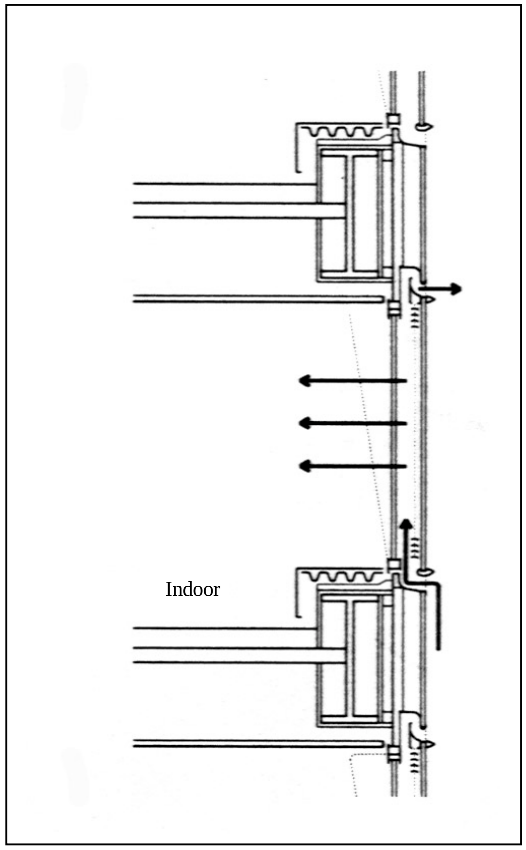

Figure 1.1 The heat flow condition in the natural ventilation system: Commerzbank Headquarters (Detail, 1997)

In urban environments, natural ventilation systems may also experience significant problems of noise transmission and pollution and may result in uncomfortable indoor environments in extreme weather conditions. Therefore, a natural ventilation system is more suitable in suburban areas with temperate weather where the airflow in the cavity will be close to the indoor air condition.

The mechanically assisted ventilation systems usually use an underfloor or overhead ventilation system to supply or exhaust the cavity air to ensure good distribution of the fresh air. Air is forced into the cavity by mechanical devices. This air rises and removes heat from the cavity and continues upwards to be expelled or re-circulated. Because air is not pumped in directly from the outdoors, there is potentially less risk of condensation and pollution in the cavity (Barreneche, 1995). Also because the mechanically assisted ventilation systems allow the building to be sealed, they provide more protection from traffic noise than naturally ventilated systems. In areas with severe weather conditions or poor air quality, the mechanically assisted ventilation system can keep conditions in the buffer zone nearly constant to reduce the influence of the outdoor air to the indoor environment (Figure 1.2).

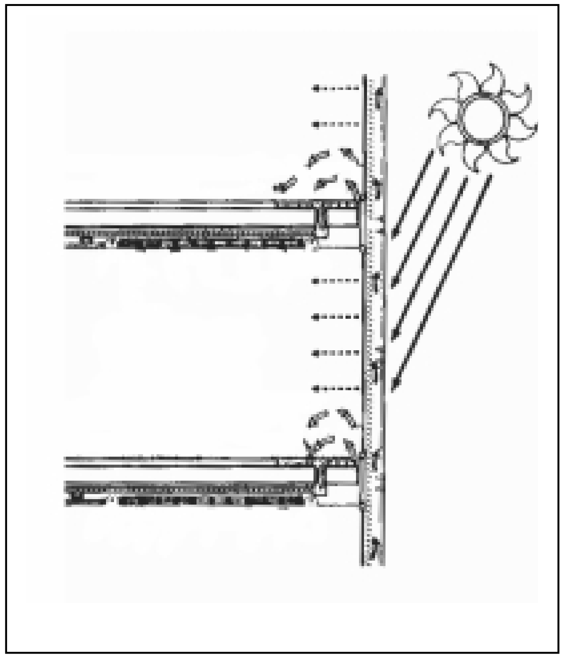

Figure 1.2 The heat flow condition of the Business Promotion Center (Compagno, 1995)

In addition to the environmental factors mentioned above, the thermal performance also is a primary consideration of selecting a double envelope system. Because of the different ventilation source, the thermal performance, like cavity heat removal rate and glass surface temperature, of these two systems may vary as well. To fairly investigate and compare the thermal performance of the active and passive systems, a proper test protocol needs to be established.

1.3 Objectives and Hypotheses

The thermal performance of double façade systems depends on many factors. Because the interactions among these variables are complex, current computer simulations approaches may be inaccurate. Therefore the energy savings and cost/benefit of these systems are not well established. For this, an experimental test protocol is needed to analyzed these systems. This test protocol must consider the various design parameters and environmental variables that influence the performance of the system. The protocol should then be applied as a proof-of-concept.

The performance of the double glass façade is uncertain as is the desired configuration. Therefore, this study has the following objectives.

1. To develop an experimental test protocol for determining the performance of double glass envelope system.

2. To apply the protocol and increase our understanding of the thermal performance of the glass double façade.
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3. To use the protocol to compare the heat removal rate for the double façade with active and passive ventilation.

4. To use the protocol compare the temperature difference between the indoor glass surface and indoor air.

While applying the proposed protocol, the following hypotheses were preliminarily tested.

1. During overheated periods, the average cavity heat removed rate will be higher for the active system.

$$\mu_1 - \mu_2 > 0$$

where: μ_1 = average heat removal rate for the active system
μ_2 = average heat removal rate for the passive system

2. During overheated periods, the average temperature difference between indoor air and indoor glass surface will be lower for the active system.

$$\Delta T_2 - \Delta T_1 > 0$$

where: ΔT_1 = average temperature difference between indoor glass surface and indoor air for the active system
ΔT_2 = average temperature difference between indoor glass surface and indoor air for the passive system

The proposed protocol can then be used for subsequent studies that should begin to answer questions concerning the energy efficiency, cost/benefit, and thermal comfort conditions that result from the use of double glass façade.