

## **Chapter 2**

### **Literature Review**

The double façade system was first introduced in France in the early 1930s. During this time, Le Corbusier (1887-1965) designed a multiple glass layer wall called “Mur Neutralisant”, which acts as an air duct to neutralize the effect of the cold or sun. Unfortunately, this idea was never implemented due to the high first cost. However, this innovative concept has been employed in many modern buildings. The double façade system was used in the US in the 1980’s and is now common in Europe. Examples of buildings using this system include: the Occidental Chemical Center (1980), New York, USA, by Cannon Design with Hellmuth Obata and Kassabaum; The Lloyd’s Building (1986), London, UK, by Richard Rogers Partnership; Business Promotion Center (1993), Duisburg, Germany; by Sir Norman Forster and Partners; Headquarters for RWE AG (1996), Essen, Germany, by Ingenhoven, Overdiek, Kahlen and Partners; and Commerzbank Headquarters (1996), Frankfurt, Germany, by Sir Norman Forster and Partners. Even renovated buildings, such as the BCT Telus Communications Operation Building in Vancouver, Canada, also transform the original wall into a double glazed system.

#### **2.1 Buildings with Double Façade Systems**

##### **2.1.1 Occidental Chemical Center**

The Occidental Chemical Center is a corporate office located in Niagara Falls, New York. After comparative analysis of various building skins to coordinate with the highly energy efficient and highly transparent building, the architect decided on a double-envelope system.

The wall is designed with a 5-ft (1525 mm) wide space between an outer wall of green-tinted double insulating glass and an inner wall layer of clear single glazing. The venting air comes from the bottom of the wall through a motorized damper to adjust the ventilation rate. This treated air carries warm air up where it is vented at the roof if unwanted, or redistributed to under heated elevations. The most significant device is the adjustable louvers within the cavity. The louver blades are connected in banks and rotate automatically to shield the building and collect the sun’s radiation in the summertime. It also disperses the sunlight indoors during the daytime. During the winter, the louvers can be closed to reduce the heat loss at night during unoccupied periods. In its design state, the analysis shows that the heating load is only about 2 percent and cooling load is about 19 percent if compared with a conventional building with the same volume (Progressive Architecture, 1983).

1. Green tinted double insulating glass
2. Single pane clear glass
3. Aerofoil louver
4. 5 ft (1525mm) air cavity
5. Removable grill
6. Motorized damper

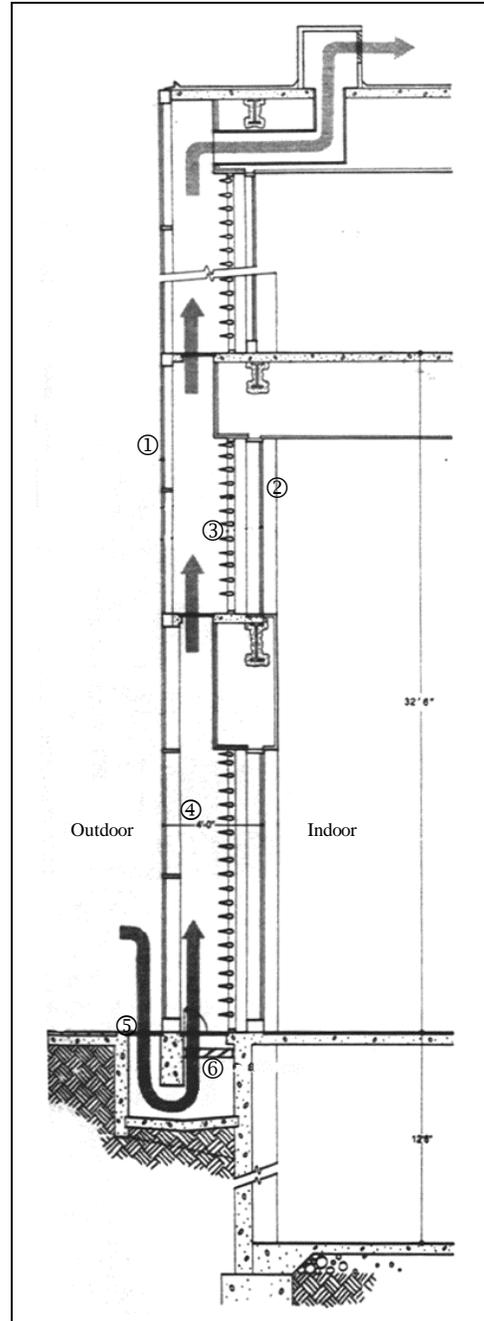


Figure 2.1 The section view of the Occidental Chemical Center (Progressive Architecture, 1983)

### 2.1.2 The Lloyd's Building

The Lloyd's building is a steel frame with glass curtain wall located in a temperate weather condition in London , England. This building is functionally and aesthetically a

living and breathing machine. The wall system in this building consists of a double-glazed unit on the outside and a single glass unit on the inside with a 3-in (75mm) cavity between them. This triple-glazed external cladding acts as an air duct from ceiling to floor.

The energy saving strategy of the Lloyd's building was to integrate the atrium form, concrete structure and triple-glazed cladding. Treated airflow comes from the bottom of the sub-floor and is drawn out by the luminaries on the ceiling. This extracted air is then taken to the cavity and expelled to the outer duct. This ventilation system demonstrates good performance for thermal control – and no heat loss from the offices during the winter while reducing heat gain in summer.

The sparkle glass used in the triple-glazing is another innovation. The glass strengthens the translucent quality and reduces the heat gain during daytime, and refract artificial light back to the office at night. It replaces the louver devices that are usually utilized in the cavity.

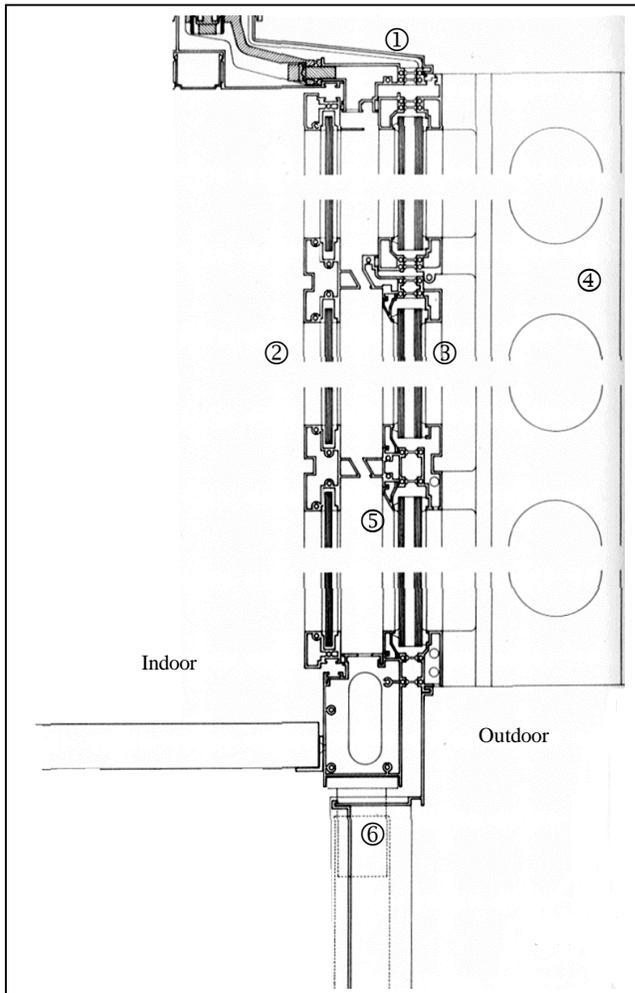


Figure 2.2 The section view of the Lloyd's Building (Wigginton, 1996)

1. Zinc duct for air supply
2. Single sparkle glass layer
3. Open-able low-E double glazed with sparkle glass
4. Aluminum luminaire shield
5. 3 in (75mm) air cavity
6. Supply and extract ductwork

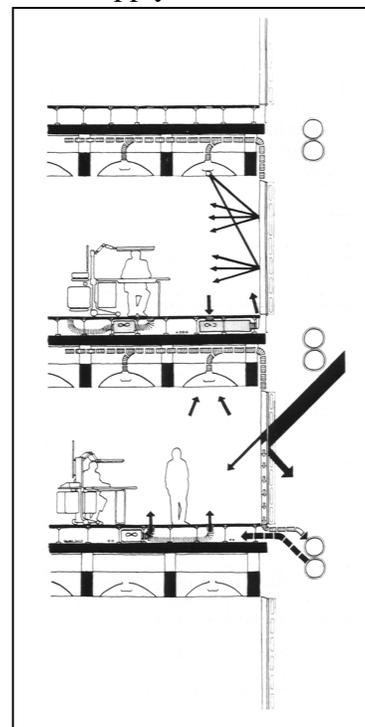


Figure 2.3 The heat flow condition of the Lloyd's building (Pettifer, 1986)

### 2.1.3 Business Promotion Center

The Business Promotion Center is another significant example of the double façade. The building is a response to the “strict German codes that heavily regulate the detailing of exterior cladding” (Barreneche, 1995) and esthetic concerns.

This envelope incorporates an outer glass layer, single-glazed panels fastened to aluminum tension rods, an inner glass, operable low-e double-glazed panels, and an 8-in (200mm) cavity between layers. Within the cavity, venetian blinds with partial perforation provide solar control and radiation collection. Conditioned air rises through this continuous cavity, and is then expelled through the top by the stack effect. The system is similar to the Occidental Chemical Center, but with a reverse of wall configuration. In summer, this airflow traps and removes the heat. In winter, the cavity serves as a thermal buffer to capture and offer warm air for occupants through sliding windows.

This building is a successor to the Occidental Chemical Center, but is an extension not just simply a copy of the cladding system. The architects examined the building's function, and location to develop this appropriate curtain wall system.

1. 0.5 in (12 mm) single pane glass
2. Operable low -E double glazed window
3. Micro- electronically controlled perforated blinds
4. 8 in (200cm) air cavity
5. Conditioned air inlet

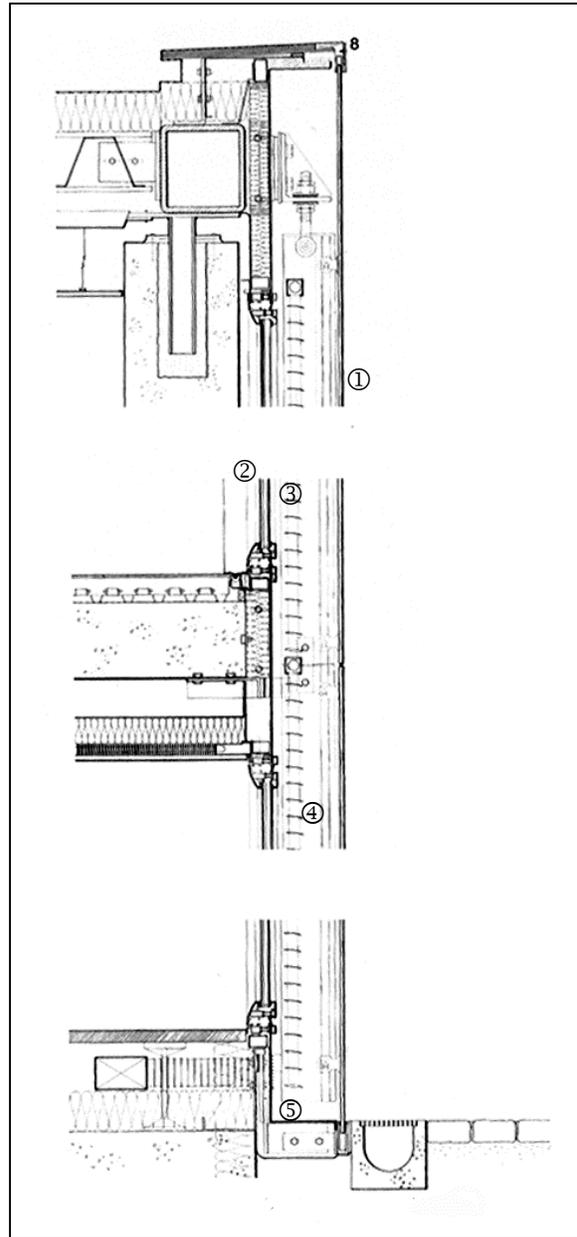


Figure 2.4 The section view of the Business Promotion Center (Wigginton, 1996)

### 2.1.4 RWE Headquarters Tower

Because of the desire for light, the architects, Ingenhoven, Overdiek, Kahlen and Partners, developed this thermal protection wall to balance the thermal conservation and daylight illumination. The “breathing wall” in the RWE Headquarters Tower is composed of single pane clear glass fixed at the outside and the operable double-pane glass inside.

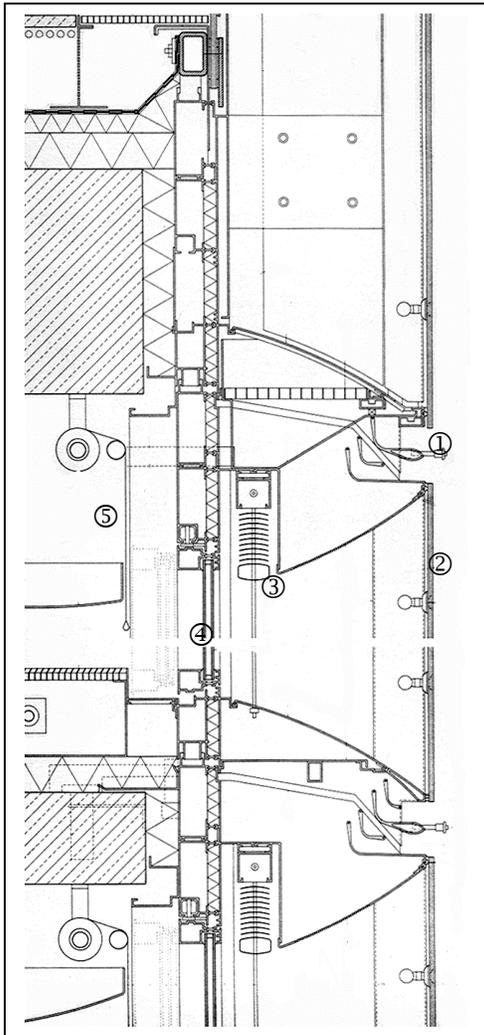


Figure 2.5 The section view of the RWE Headquarters Tower (Detail. 1997)

A louvered blind is utilized in the 20-in (500mm) buffer zone. A “fish mouth” mullion (①) allows fresh air into the buffer zone at the bottom of each floor. An exhaust outlet is located at the top. The cavity working individually at every floor offers an insulating layer in all seasons.

The sophisticated design of the “fish mouth” creates a wind pressure difference between cavity air inlet and outlet and makes the wind driven and thermal buoyancy driven air flow pressurization additive.

In order to offer the opportunity for the occupants to control the sliding window, the thermal balance problem becomes a challenge for this building. On extreme weather days, opening windows may cause the unwanted heat gain or indoor heat loss by natural ventilation in the cavity. This accessibility raises the risk of unforeseen problems.

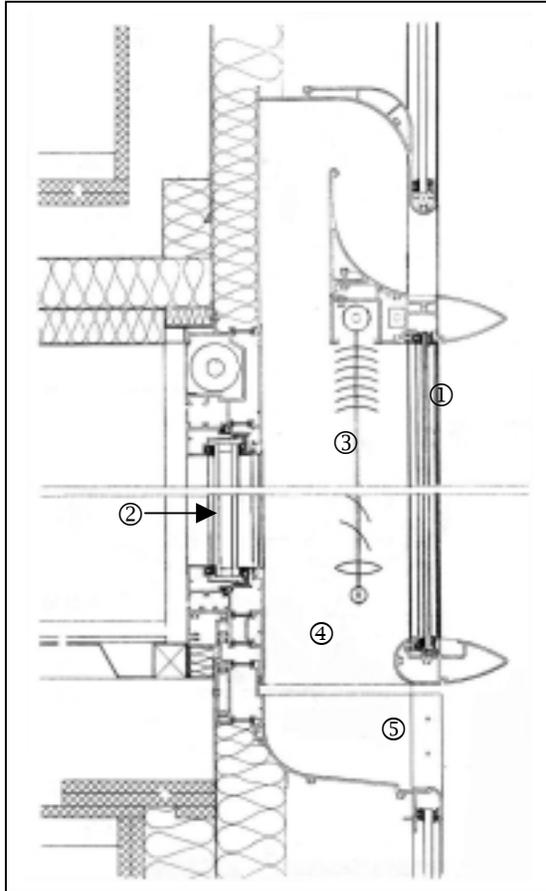
1. Cavity air inlet/outlet
2. Single pane clear glass
3. Louvered blind
4. Operable insulating double pane glass
5. Internal fabric blind

### 2.1.5 Commerzbank Headquarters

The 56-story (980 ft) Commerzbank Headquarters is the tallest office building in Europe. To meet the requirements of reducing energy consumption and increase the opportunity for occupants to come in contact with plants, the Commerzbank Headquarters integrates internal gardens, atrium spaces, the double-envelope and an electronic building

management system. This result is reported to be one of the most energy efficient buildings in Europe (total energy cost 185 kw/h/m<sup>2</sup>/y) (Jones, 1998).

The strategy for this building is to use natural ventilation, similar to the RWE Headquarters Towers. The outer layer of the facade is a fixed single glass; the inner is an operable low-e double-glazed unit. The outdoor air enters and leaves the 7-in (165mm)



cavity, thus removing the hot and stale air from the offices when the inner panes are open. Within this cavity, Venetian blinds controlled by the building management system can adjust the blade angle to accommodate the weather condition. They can be inclined to resist excessive heat and can be adjusted to reflect sunlight into the building. This energy-saving system, including the sky-garden and other strategies, is expected to reduce between half and two thirds of energy cost when compared to conventional buildings. (Bailey, 1997)

Because of the flow of outdoor air in the cavity and the operable window at the inner layer, the Commerzbank building has the same problem with the pressure balance as the RWE Headquarters Tower. When the cavity air temperature is warmer than indoors, the performance of this system is uncertain.

Figure 2.6 The section view of the Commerzbank Headquarters (Davies and Lambot, 1997)

1. Laminated radar absorbent outer glass
2. Low-E coated double glazed movable unit
3. 2 in (50mm) Venetian blind
4. 7 in (165mm) air cavity
5. Bird wire

## 2.2 The Performance of Double Façade System

Several studies have shown that the double façade system has better thermal performance than traditional façade systems. In Soontorn Boonyatikarn's paper titled "Performance of an air-flow envelope", the double envelope system is shown to have improved mean radiant temperature and thermal comfort when compared to conventional windows (Boonyatikarn, 1987). Also, in the paper titled "Thermal performance of a supply-air window" by S.A Barakat, the air flow through the window cavity recovered a large fraction of the heat loss. This represented about 50% of the energy required to heat

ventilation air. If compared to a conventional window, the effective steady state U-value of the air flow window was found to be in the order of  $0.5 \text{ W/m}^2 \text{ K}$ . The overall reduction in purchased energy of the supply-air window unit relative to a similar double-glazed window unit or to a triple glazed window unit is about 25% and 20%, respectively. (Barakat, 1987)

The performance of the double façade can vary because of configuration differences. Generally, the options for configuring the system include:

- Natural vs. mechanically assisted ventilation
- Single story vs. multiple story module
- Glass layer properties and sequence
- Cavity size and depth
- Shading device location and properties

In his paper titled “A parametric study of Trombe walls for passive cooling of buildings”, Guohui Gan reports the effects of different wall configurations. The cavity ventilation rate induced by the thermal buoyancy increases with the wall temperature, solar heat gain, wall height and thickness. Provided that the dimension of the inlet and outlet openings increases with channel width, the ventilation rate also increases with the distance between the outside and inside glazing layers. The use of double glazing instead of single glazing for a Trombe wall system not only reduces heat losses in winter but also enhances passive cooling (Gan, 1997).

In the book “The Technology of Ecological Building” by Klaus Daniels, it is reported that when outdoor air temperature is  $77^\circ\text{F}$  ( $25^\circ\text{C}$ ), the highest cavity temperature can vary from  $113^\circ\text{F}$  ( $45^\circ\text{C}$ ) to  $158^\circ\text{F}$  ( $70^\circ\text{C}$ ) in a typical naturally ventilated double façade system with different properties of shading devices. Daniels also indicates that during direct solar radiation and calm days, natural ventilation caused by thermal buoyancy is clearly measurable, since the temperature increases per story by approximate  $1.5\text{-}3^\circ\text{C}$  (for direct solar radiation) or by  $1^\circ\text{C}$  per floor on overcast days. Natural ventilation due to thermal buoyancy on calm days proves ineffective only when external temperatures are significantly higher than internal temperatures (Daniels. 1997).

Although many existing examples suggest that the double envelope system can save energy, the rate of heat removal has not been well documented. For the active ventilation system, a poor seal of the inner glass pane can cause a short-circuit of the air circulation in the cavity and consequently the heat will not be removed efficiently (Saelens, 2000). For the passive ventilation system, the wind driven pressures can counteract the thermal buoyancy driven pressures which results in a negative relationship between wind speed and the cavity heat removal rate (Jones, 2000). These results suggest that further research is needed.