The Tectonics of the Double Skin:
Green Building or Just more Hi-Tech Hi-Jinx?

NORTH AMERICAN CASE STUDIES:
Occidental Chemical Center (Hooker Building), Niagara Falls, NY, USA, Cannon Design Inc.
The Telus Headquarters (William Farrell Building), Vancouver, British Columbia by Peter Busby and Associates

Terri Meyer Boake, Associate Professor
School of Architecture, University of Waterloo

B.Arch. and M.Arch. Co-authors/Research Assistants:
Kate Harrison[1]
Andrew Chatham[2]

North American Double Façade Buildings: 1980 to 2001

Where over the past ten years, Europe and the Pacific Rim have seen the construction of a number of vanguard double skin façade buildings, very few have been either proposed or constructed in North America. The first to be constructed was the Occidental Chemical Center (also known as the Hooker Building) in Niagara Falls, New York. It was designed by Cannon Design Inc. and completed in 1980. Occidental Chemical has achieved historic status in texts on building systems as the first of its kind to be constructed in North America. In spite of much press and notoriety, its skin system was not widely adopted in commercial building types to follow. SOM designed a double skin envelope for the Prudential Life Insurance Company in Princeton, N.J. in the late 1980's.[3]

Following few built examples in the 1980's, it would appear that the double skin façade system continued without influence in North America during the 1990's. The next building of note is the double skin façade for the Seattle Justice Center designed by Arup Associates in 2000/ 2001.[4] The European offices of Arup Associates have been responsible for many of the double façade buildings constructed to date in Europe and Asia.

A double skin, referred to in this case as "une façade intelligente", is being used on the "Caisse de Depots et de Placements du Quebec" in Montreal. Façade erection commenced during Winter 2002. They chose to use the system for its thermal, visual and acoustical properties. The double skin used, is a Twin-Face type and integrates an operable window. In designing for the severity of the Quebec climate they used double glazing on the outside and single glazing on the inside skin. Standard recommendations for Twin-Face systems would provide single glazing on the outside buffering skin and double glazing on the interior layer. This approach might work in more temperate climates, but is not suitable to a cold climate installation. Ongoing construction information on the CDP may be found at
http://www2.destinationcdp.com/index.asp?version=3

The Telus Building in Vancouver, British Columbia, designed by Busby and Associates has been recently completed. This building varies from most other examples in that it uses the second skin to encapsulate an existing concrete masonry building, to prevent its destruction, extend its life and create an improved interior work environment.

Occidental Chemical Center (Hooker Building), Niagara Falls, NY, USA., Cannon Design, Inc., 1980[5]

Design Intentions:

View of Occidental in December from Customs Buildings

The construction of the Occidental Chemical Center dates back to the early 1980's. It is important as it is the first North American example of a double skin façade building.[6] It represented a development in the recent history of glass in architecture that is cited to be of fundamental importance.[7] The building is situated immediately on the American side of the Rainbow Bridge that connects Niagara Falls, Canada to Niagara Falls, New York. Its appearance has been likened to a conventional glass curtain wall box. It was constructed with a straightforward square plan with a central core and suspended ceilings. At all four sides a 4-foot (1.2m) cavity allows for maintenance of the movable daylight controlling louvers and window washing, as well as ventilation of the cavity by stack effect. In modern terms, this type of double façade is known as the Buffer Façade.

The architects of the Occidental Chemical building were trying to design a building that was at once both highly energy efficient and also highly transparent. They were trying to capitalize on the location of the building and the wonderful views of Niagara Falls that were afforded by the site.

> *"The result, after comparative analysis of various buildings skins, was (for its time) perhaps the largest passive solar collector in the world, and possibly the most energy efficient office building in its climate zone (a latitude of about 43 degrees, the same as Marseilles in Europe, but with the climatic characteristics of the American continental land mass and very cold in winter."*[8]

The skin system used by Occidental is sometimes termed "dynamic" owing to its ability to change as a function of the time of year and time of day. A full scale mock-up of one module was erected in Tempe Arizona at the College of Architecture at Arizona State University. The design was tested and apparently validated.[9] The louver system was designed to automatically rotate to control daylight entering the building. There were solar cells at the back of each bank of the aerofoil louvers. If sunlight fell on the cell the louver would rotate, tilting the bank and blocking out the sun. In this way direct sunlight would be intercepted and directed to the ceiling. The louver itself would pick up the solar heat gain, which could be exhausted by the stack effect of the cavity if desired (summer conditions). For insulation purposes the louvers would rotate to a closed position and provide additional R-value at night.

The ceiling acted as a diffuse reflector. The louvers are shaped much like an airplane wing rather than flat. This will permit diffuse reflectance of incoming sunlight as it hits either the top or bottom side of the louver. The louvers were originally coated with a bright reflective surface. As a result of blinding glare into the eyes of motorists crossing the Rainbow Bridge, these were refinished with a white colored coating soon after the building was completed. Initial sketches of the louver system indicated that a specular reflective coating was desired on the louvers to maximize the depth of sunlight penetration into the building.

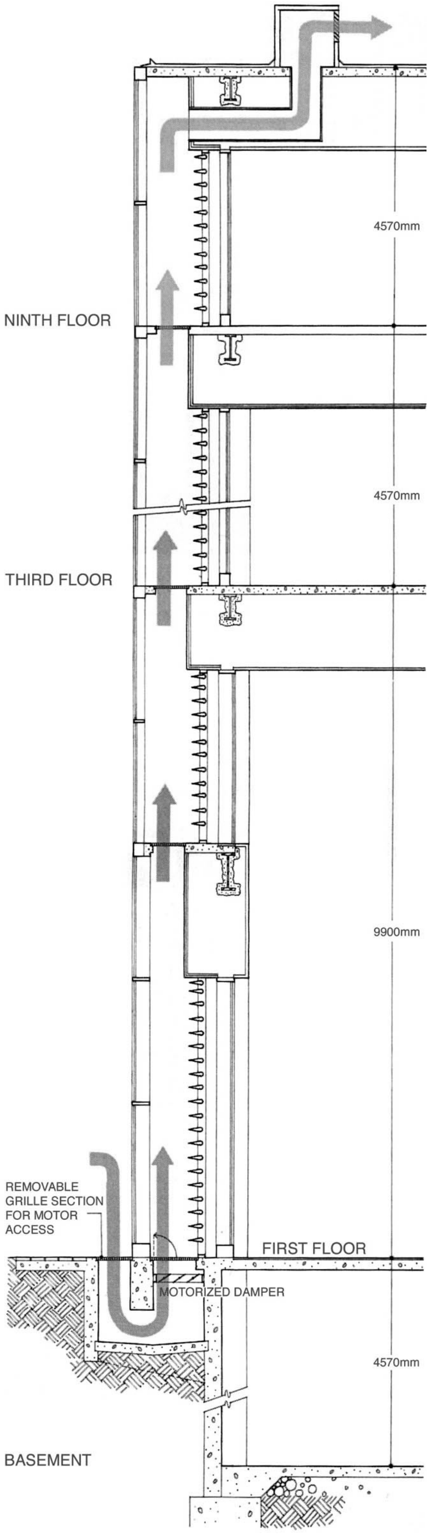
The outer skin was double glazed. The outer pane was a blue-green glass and the inner pane was clear. For the time the choice of a simple iron oxide glass was the result of a selection to use glass chemistry that would maximize light penetration while simultaneously limiting solar gain. Mullions are at 1.5 m on center and transoms at 1.8 m. The inner skin is floor to ceiling single glazing.

The cavity was fitted with motorized dampers at the base and top to assist in controlling the flow of air through the cavity. Reports vary as to the use of the hot air generated in the cavity. Most sources indicate that the air is entirely vented and never reused, although cite the possibility of reuse of this heated air.[10] Other sources agree that this air is vented during the summer/cooling months but indicate that it is directed to the north side of the building to supply heat during the winter months.[11]

Detail of corner of building

A view inside the cavity showing its clear width to allow for maintenance; the plywood sheets that close off the grille at the base preventing air intake.

A view of the front of the building at the excavation where the Aquarium addition is proposed.



Performance as of 2001:

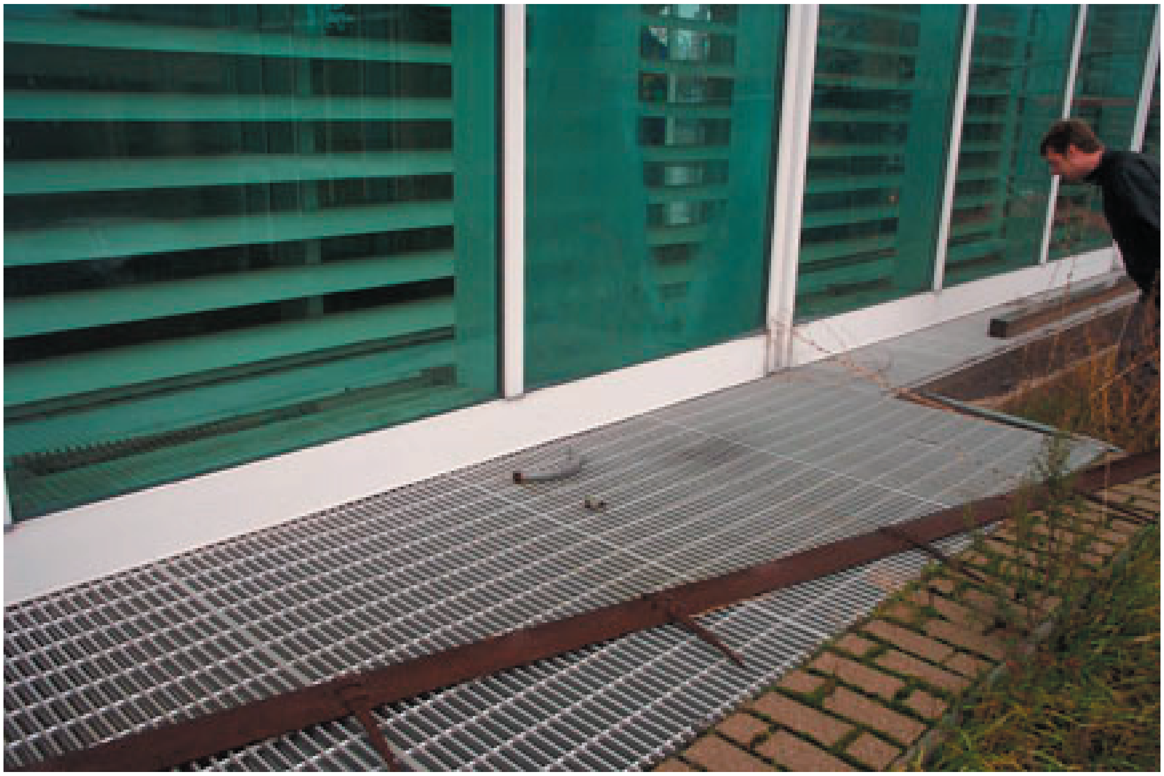
Part of the research group working on double skin façade buildings had the opportunity to visit the Occidental Chemical Building in December 2001. As part of our investigation, an interview was conducted with security and maintenance people who now work at the building.

The building is presently only 30% occupied – the balance of the floor space is looking for tenants. The large plaza that used to exist at the front entrance of the building has been replaced by a large construction site/excavation. A large attraction – "Aquarium" – is being constructed in the space at the front of the building and will connect to the lower floor of the building only, being largely held underground. The Aquarium is advertised to open later in 2002.

Approaching the building, it looks to be in pristine condition. Closer examination would reveal otherwise. Many of the original design intentions and systems of the buffer façade system are no longer functioning – either in whole or in part. A significant percentage of the glazing appeared to be clouded. We initially assumed these panels to be the result of a broken seal on a double glazed unit. This proved incorrect. The coating on the interior surface of the exterior glazed skin was disintegrating or delaminating. Proper maintenance and cleaning of the louvers has not taken place. The air space and associated louvers were "filthy". This could be credited to lack of cleaning, or, site conditions as a result of the recent excavation. The grilles at the base of the cavity are presently closed off with large plywood planks. Although the cavity was originally outfitted with motorized dampers, the presence of the plywood would indicate that these are no longer functioning.

According to security and maintenance, the brightly finished louvers were painted white early on in the life of the building due to the glare issue. This would have had an appreciable change on the diffusion of sunlight into the building. The computer controls for the louvers ceased to function approximately 4 years ago. They have not been repaired. They are now fixed in a horizontal position – inferring that they will provide only partial shading (particularly on the east and west elevations). It was apparent that tenants had decided to supplement the building shading with their own "personally controllable" louvers in the form of vertical blinds.

The interview revealed that the tenants are NOT comfortable, complaining that the building is either too hot or too cold. If the louvers and dampers are not functioning the heat accumulated in the summer months will build up rather than be expelled. Proper shading will also not take place. During the winter, although heat may be generated in the air space, the louvers that were intended to rotate into a closed, insulating position, will fail to provide heat retention at night.



View of air intake grille at base of building. Note clouding on center glazed unit.

It can be seen that the louvers are fixed in a horizontal position, painted white and are very dirty.

It would be hoped that as a result of the capital investment into the attached Aquarium, that the building and location may become attractive enough to prospective tenants to spur on the renovation and repair of the original facility. According to most architectural sources, this building is considered to be “historic”, in a modern sense of the word!

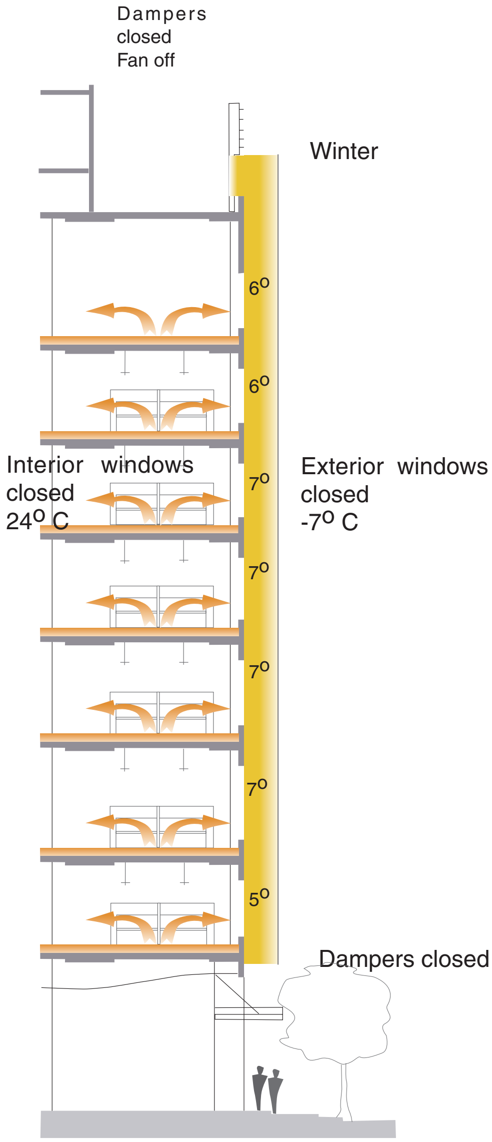
The Telus Headquarters (William Farrell Building), Vancouver, British Columbia by Peter Busby and Associates, 2001[12]

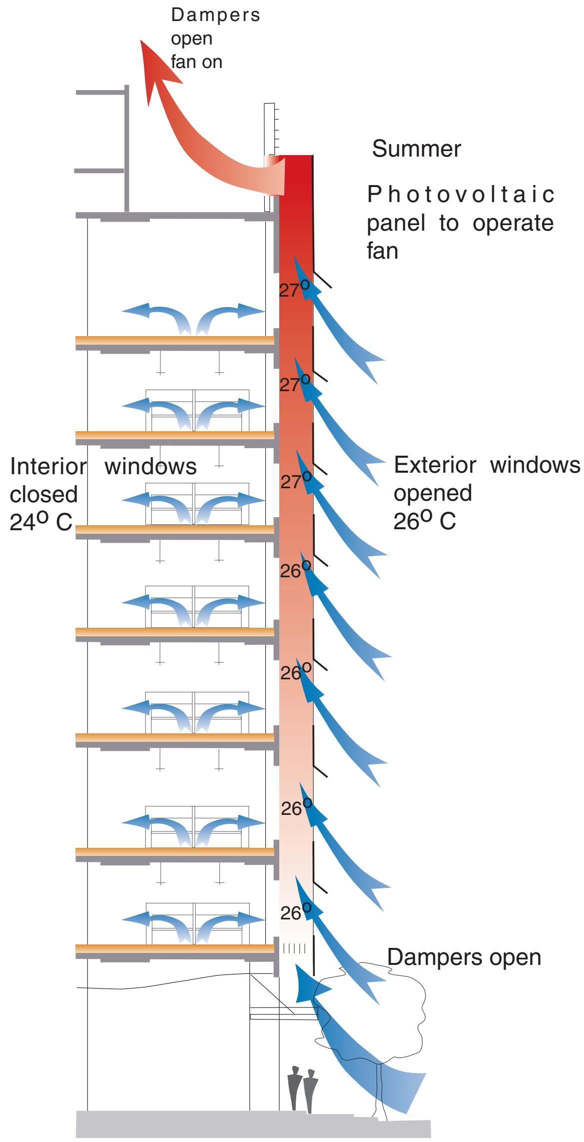
A view of the front facade after the renovation.

The Telus Headquarters was opened for occupancy during the Fall of 2001. It is one of the few double skin façades to be completed in North America, being primarily predated by the Occidental Chemical Building. It employs a double skin façade strategy commonly referred to as Twin-Face. This system provides natural ventilation through operable windows in both the exterior and interior façades. In the Telus Building the cavity extends for the full height of the building, the air space acting as a buffer zone between the busy downtown Vancouver site and the interior office environment. Daylighting seems to have been a motivating factor in the design of the façade.
Differentiating the Telus Building from other current and European double skin projects is its unique position as a renovated concrete and masonry structure. Ordinarily such technologically and environmentally outdated structures would be demolished and replaced by a completely new building. The existing structure and skin of the William Farrell Building was able to be retained, effecting significant environmental savings in accordance with the LEEDS Environmental Assessment system.

The interior of the building was gutted. Existing suspended acoustic ceilings and HVAC runs were removed. This effected as well a cleaning of the interior environment and improved air quality. The exposed concrete ceilings were painted white to assist with daylighting and succeeded in exposing thermal mass. The new outer skin is comprised of a differentially glazed, curtain wall frame, with operable windows, set out from the building to facilitate access to the buffer air space for cleaning.

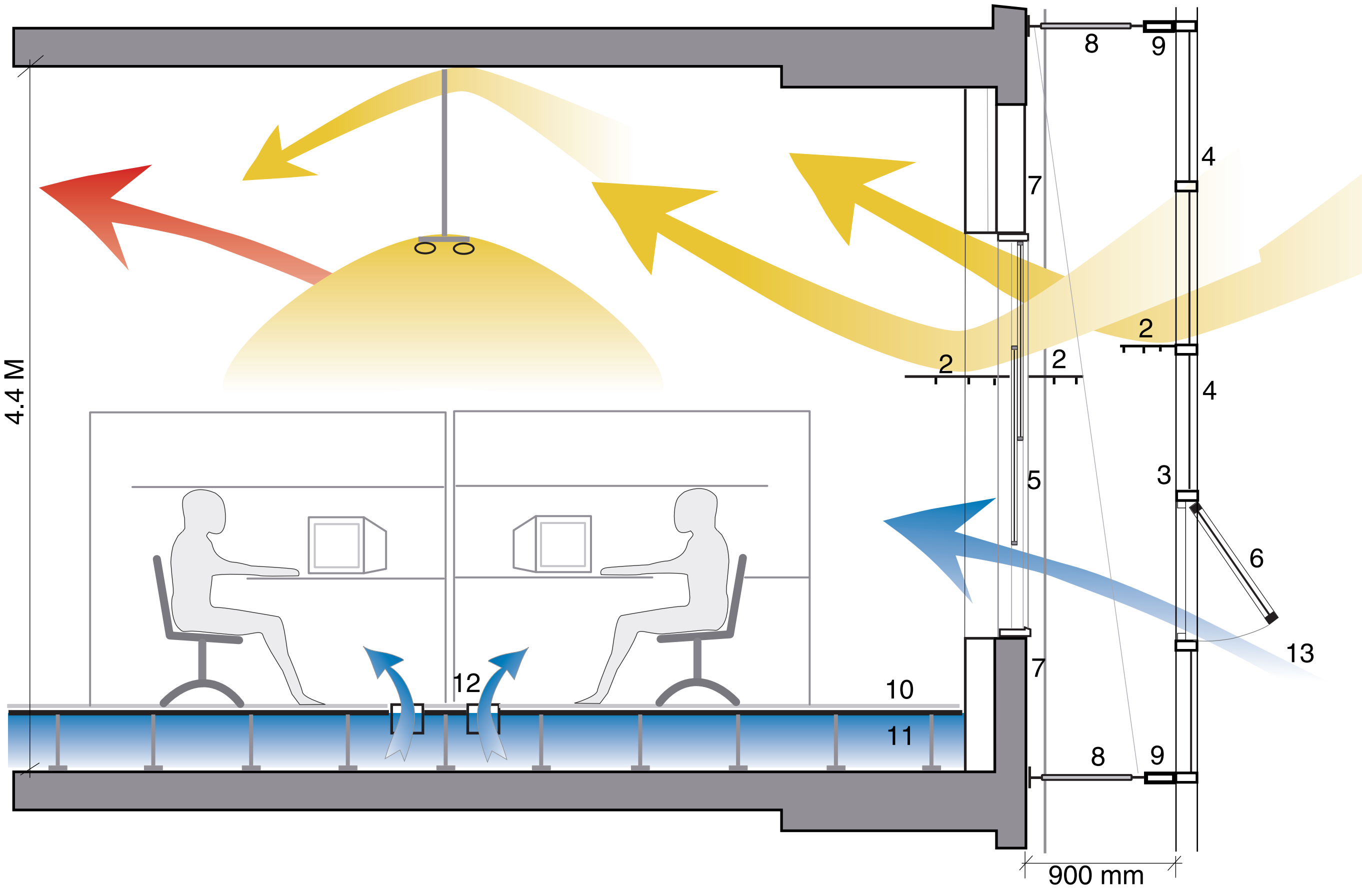
The William Farrell Building is an eight story brick faced concrete structure. It was originally made to house the company’s analog telephone switching gear. With the introduction of digital operating equipment, much of the space in the building became redundant for its intended use. Instead of demolishing the building, Busby and Associates Architects proposed retrofitting the structure. For energy conservation purposes the building was covered with a double glazed aluminum framed curtain wall. This wall acts to reduce ventilation and heating requirements. The cavity between the existing building and the new building is essentially a greenhouse. The interstitial space stores heat in the winter and provides shade and diverts heat from the building in the summer. The cavity is controlled by louvers at the base of the cavity and dampers at the top, to flush the air as required. Photovoltaic cells are linked to the ventilation fans and dampers on the roof.





Winter Wall Section:
Dampers Closed

Summer Wall Section:
Dampers Open



Detail of Wall to Room Function:

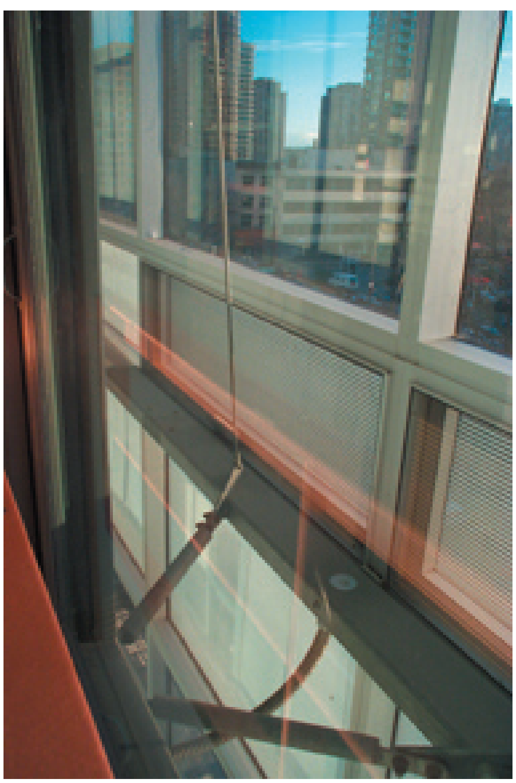
1 Interstitial space - seasonal climate buffer zone
2 Daylight reflector and sunshade
3 Aluminum framed glazing curtain wall
4 Solar shade glass panel - ceramic frit glass panel reduces solar heat gain
5 Operable windows - existing restored
6 Operable windows - new mechanized
7 Existing exterior wall - exposed concrete
8 Curtain wall hangers
9 Steel reinforcing for curtain wall frame
10 Raised office floor
11 Air plenum in raised floor
12 Air diffusers
13 Natural ventilation possible in moderate temperatures

The existing windows were restored to operating condition. This provided both a cost and an environmental savings. To supply fresh air, mechanized operable windows were fitted on the new glazed wall. The existing brick veneer was removed. The exposed concrete acts as a heat sink. The curtain wall is hung off of the existing building with steel brackets and supports. The new glazing wall extends beyond the property line of the site, but as it only starts below the second floor level, does not impinge on the sidewalk space.

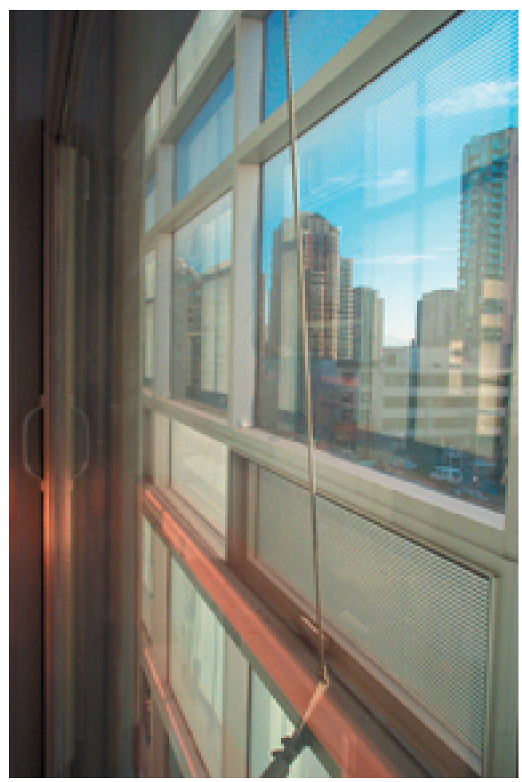
"The double skin acts as a ventilation chimney in warm weather and as an insulation jacket in cool periods. In winter months louvers at the top of the double skin remain closed, trapping a layer of air, allowing the building mass to retain available solar energy, which is then reradiated into the building. The exposed concrete structure acts as a heat sink, helping to reduce temperature fluctuations. In warm weather, with the louvers open, heat building within the double façade causes convection air movement. Assisted by fans, warm air is drawn up and out of the top of the air space, creating negative pressure within the interior, which in turn draws warm air away from the occupied areas." John McMinn, 2001

View of interior, façade faces south-west, 4 p.m., November

This image was taken prior to occupation. The white painted interior was very brightly lit. The low sun angle provided penetration to the back corners of the office space. Much shading is provided by the existing concrete wall. In fact, were it not for the ratio of wall to window area, the glare in the space would make the working condition impossible.

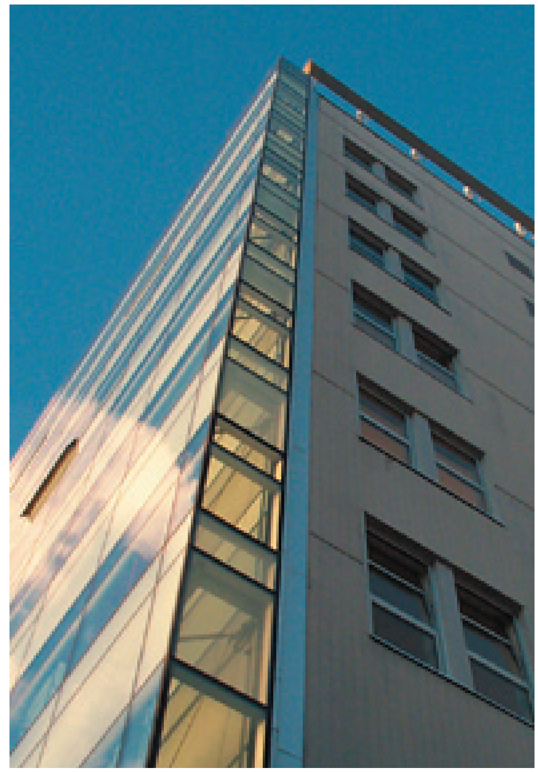


Views looking into the cavity. Note the differentiated glazing materials: clear and fritted, as well as the operable window.



The envelope helps to modulate internal temperatures. Motorized windows on the new curtain wall, as well as operable existing units, enable the occupant to obtain natural ventilation when possible. The window glass on the curtain wall is fritted at different densities for temperature modulation. Photovoltaic panels are fitted in the new curtain wall and are linked to ventilation fans and dampers on the roof that ventilate the interstitial space. Each workstation is equipped with individually controlled diffusers to allow the flow of fresh air through a forced air plenum under the raised floor. The daylight reflectors allow light to penetrate deep into the building.

A view of the shading device attached to the interior of the windows. It also serves as a daylight reflector/light shelf to bounce light up to the white painted concrete ceilings.



A view of the north east end of the double skin addition clearly showing the depth of the new system.

Here we can see the differentiated glazing: clear versus fritted glass, and two of the operable windows in an open position.

The Telus Building will only be fully occupied during the Winter of 2002. It will be interesting to follow the performance of this building to see whether or not the design intentions of Busby and Associates are realized in the function of the double skin of the building and whether the occupants find the work environment invigorating.

Comparing the Occidental Chemical and Telus Buildings:

The Occidental Chemical Building, constructed in 1980, and the Telus Building, constructed in 2001 may exhibit similarities in the aesthetics of their façades, but they employ two quite different strategies in their selection and detailing of the double façade skin systems for each. Whereas Occidental Chemical uses a Buffer System (no natural ventilation), Telus has adopted the Twin-Face system and has made significant use of natural ventilation and its occupant control. Trends in the construction of double façades on an international scale would indicate that Twin-Face is the current preferred method of construction, in part due to its ability to provide access to natural ventilation.

Occidental Chemical was a new building and Telus is a renovation. Both, however have adopted the double skin system to achieve environmental goals. In the case of Occidental Chemical, the buffer system was adopted to reduce cooling loads in the summer and reduce heat loss in the winter. Telus has employed the second skin for similar heating and cooling purposes and to allow the retention of the existing concrete masonry structure and single glazed windows. This scored the designers points in their LEED Environmental Assessment. The exterior concrete wall provides significant thermal mass in the cavity that will enhance the thermal properties in the winter and slow heat transfer in the summer by making the wall work in a fashion similar to the adobe walls common in hot-arid climates. Occidental does not provide thermal mass in the cavity.

Both Occidental Chemical and the Telus Building are of similar height, 9 stories versus 8 stories. This makes their full height cavities quite similar in proportion – particularly when considering the free space dimension from the face of the louver to glass in Occidental to the free interior space in Telus. The buildings as well have similar face dimensions, although Occidental is completely wrapped with its second skin and Telus only uses this on its two street facing façades (south and west) – the east side is on an urban lot line and is basically a blank wall and its north face is buried against an adjacent building. Both air spaces run the full height of the building and are not compartmentalized, and are able to be closed at the bottom and top by control dampers as well as fan assisted to exhaust the warm air more quickly when the stack effect is insufficient. The full height cavity in the Twin-Face system is somewhat unusual. Most of the European examples of Twin Face buildings use highly compartmentalized systems with input and output louvers at each floor level (RWE, Debis and Helicon).

A chief difference in the function of the Buffer Façade of Occidental and the Twin-Face Façade of Telus lies in the exclusion or inclusion of natural ventilation and user operable windows. It must be said, that the general building style that was prevalent in the 1980's when Occidental was designed was the sealed glass box. Natural ventilation was not a part of mid to high-rise office design. Telus is responding, with its ventilated skin, to current pressures towards natural ventilation and user control as a means to improve air quality, worker comfort and worker performance.

Whereas the glass on Occidental Chemical is uniform over the entire building envelope, the Telus Building has used differentiated glazing: clear vision glass in a band on the exterior skin that aligns with the interior windows, and fritted glass in the "spandrel" sections to cut out unnecessary heat transfer.

The overall width of the double skin including cavity is 1200 mm in the Occidental Chemical Building and 900 mm in the Telus Building. It must be recognized that North American architecture, particularly with the office building type, is commercially driven. The 300 mm savings around the perimeter of the building may result in an increase in net leasable area that will assist in offsetting some of the initial capital cost required to construct this type of wall system .

Name Location Date Completed Architect	**Occidental Chemical** Niagara Falls, New York 1980 Cannon Design Inc .	**Telus Head quarters** Vancouver, B.C. September 2001 Busby & Associates Architects
Climate	Cold	Temperate
Facade construction	Buffer system – no natural ventilation. Full building height cavity. Air cavity -buffer zone.	Twin-face - natural ventilation through operable windows in both faces. Full building height cavity. Air cavity -buffer zone.
Daylighting	Yes -maximum exposure, floor to ceiling glazing, but dropped acoustic ceilings.	Yes-Tall windows and light shelves.
Shading	Yes-Operable louvers in air space with photocell control and manual override.	Yes-Sun shades / light shelves. Glazing of different densities.
Adaptability to various orientations	Undifferentiated façade, but louvers have ability to alter position according to orientation and sun angle.	No
User control	Only on supplementary interior vertical blinds.	Yes-operable windows, interior and exterior . individual air diffusers w/control
Ventilation	HVAC – cavity air is not used by central system but expelled.	Natural- operable windows. High ceilings HVAC -Forced air plenum in floor
Aesthetics	Square plan office tower with central core, 1.2m double skin around entire exterior	Curtain wall frame applied to existing brick faced building, renovation
Cavity Dimension	1.2 m	900 mm

What has the Telus Building achieved that the Occidental Chemical Building may not have? I believe that the environmental success of the double façade system as constructed for the Telus Building is far more believable than the Occidental Chemical Building. Key differences must include the "points" scored for the retention of the William Farrell Building Structure and the added benefit of this existing exterior mass structure in assisting with normalizing the temperatures in the building. Whereas the complete failure of the computer control systems over the function of the louvers in the Occidental Chemical Building has rendered the interior environment extremely uncomfortable, the ventilation strategies employed in the Telus Building would appear to be less likely to fail, and the primary means of shading (fritted glass and solid wall) are not building elements that are subject to failure by mechanical aging. Each building does rely on computer assisted mechanical systems to control cavity ventilation, dampers, fans, windows and louvers. Standard curtain wall construction does not. Such systems are subject to failure over time – as Occidental Chemical illustrates. Hopefully a visit to the Telus Building in 20 years will prove increased longevity in these all important control systems.

The Twin-Face system used by Telus, with its continuous versus segmented cavity, has created a second skin system that from indications is less capital intensive than the segmented systems used in many of the European examples. This type of skin may perhaps tip the economic scales in favor of double skin buildings in the competitive, commercially driven, North American market.

Looking to the Future:

The depth of this initial investigation was limited by timeframe, access to proprietary information, availability of actual dollar costs for both the capital and maintenance aspects of the systems, and actual performance data for the systems in use. There is little published data to be found on the Occidental Chemical Building. Most text references speak distantly/historically of the building and do not include current occupancy information. The Telus Building has just been completed, and although early reviews are favorable, it remains to be seen how the building will in fact perform. We anticipate undertaking additional research to both substantiate the more subjective means of comparison used in the current case studies, as well as in creating a larger database of both North American and off shore examples.

Endnotes:

1 Kate Harrison was responsible for significant contributions to the case study on Occidental Chemical Center (Hooker Building), Niagara Falls, NY, USA, Cannon Design Inc.
2 Andrew Chatham was responsible for case study research on: The Telus Headquarters (William Farrell Building), Vancouver, British Columbia by Peter Busby and Associates.
3 Rick Diamond. Progressive Architecture. March 1989. p. 117
4 Maurya McLintock. Arup Associates. ACSA Technology Conference 2001. Proceedings (in press).
5 Research conducted by Kate Harrison, line drawings by Kate Harrison, photography, Terri Boake
6 Lechner, Norbert. Heating, Cooling, Lighting. Wiley. p. 382
7 Michael Wiggonton. Glass in Architecture. Phaidon. p. 156
8 Michael Wiggonton. p. 156
9 Michael Wiggonton. p. 156
10 John S. Reynolds and Benjamin Stein. Mechanical and Electrical Equipment for Buildings. Wiley. p. 350
11 Nobert Lechner. p. 382
12 Research conducted by Andrew Chatham, line drawings by Andrew Chatham, photography, Terri Boake