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MAKING THE GLASS HOUSE HABITABLE

The Debate on Transparency and A. William Hajjar's Contribution in the Mid-Twentieth Century

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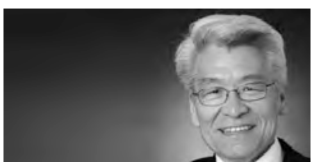

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ABSTRACT

When Philip Johnson completed the Glass House in New Canaan in 1949 and Ludwig Mies van der Rohe the Farnsworth House in Plano in 1951, the debate on how much transparency can be afforded in residential facades was at its peak. While for some enthusiasts the glass envelope renewed the Americans' ideal of living closely with nature, a majority of critics concluded that facades of residences should not consist entirely of glass for reasons of thermal comfort and privacy. One and a half decades later, two seminal writings on the topic of transparency were published: Colin Rowe and Robert Slutzky's "Transparency, Literal and Phenomenal" in *Perspecta* 1963 and Reyner Banham and Francois Dallegret's "A Home is not a House" in *Art in America* 1965. It is within this timeframe that the architect Abraham William Hajjar (1917–2000) presented design proposals to include double skin facades in residential buildings. The designs ranged from Miesian-minimalist approaches to more technical investigations comparable to Keck & Keck's and Buckminster Fuller's works. Hajjar also experimented with a double skin, modest in size, in his own house in State College, PA. The designs and built structures can

be read as responses to the questions raised in the debate of transparency in residential buildings. Hajjar proposed dark and light drapes, plants, and heating systems situated within the double skin, to increase, in combination with natural or forced air movement, comfort inside. In summary, this paper intends to reflect on the transparency discourse in the mid-twentieth century's residential glass house and position Bill Hajjar's unique contribution to it.

KEYWORDS

history of facades, glass house, transparency, comfort, energy efficiency, double-skin, A. William Hajjar

INTRODUCTION

In Roman baths, Gothic cathedrals, nineteenth century arcades, and modernist factories and sanatoria, the adoption of large glass facades was appreciated for reasons of comfort and health, technical progress, and artistic expression. With respect to residences, however, the discussion was much more controversial and thus pushed the concept of glass facades to its limits. The Villa Tugendhat, built by Ludwig Mies van der Rohe in Brno 1929-30, is an early example of a residence with an open plan and large transparent facades provoking admiration and disaffirmation alike. Walter Riezler praised in 1931 how the living room directed attention "toward the open nature" and how thus the rhythm of inner spaces "finds its end only outside, by becoming one with the total room of nature" (Riezler 1931: 328). Justus Bier, by contrast, in his famous 1931 article "Can One Live in the Tugendhat House," identified, "aside from the need of the modern man for wide rooms, open to the outdoors, [...] a similarly strong need for rooms which allow complete closure, in which nature can not flood in, but instead clearly detach from her thus allowing intellectual concentration never possible in such an open room." Bier argued that the Tugendhat House "forces the inhabitants to an exhibit-living that suppresses personal life" (Bier 1931: 393). The house made it on the cover of Henry-Russell Hitchcock and Philip Johnson's publication *The International Style* in 1932 and thus became a starting point of what Wayne Charney called the decade of "The Age of Glass" in the United States (Charney 1985: 62). Some milestones in this decade were George Fred Keck's two residences for the 1933-34 Chicago World's Fair, residences by Richard Neutra, and the "House of Glass" sponsored by the Pittsburgh Plate Glass Company for the 1939 New York World's Fair. After this decade the critique increased, for example with John Gloag quite hesitantly stating in 1944 that the "transparent wall of glass has dangers and disadvantages when introduced in domestic architecture. Large expanses of glass in a room increase the cost of heating in winter, and demand a heavy outlay on fabrics for covering the transparent wall at night. The need for privacy, the site of the house, or flat, and the character of the climate [...] should determine the area of transparency in any room." Gloag concluded that only few "families would really enjoy living in a house that was virtually a conservatory" (Gloag 1944: 9, 16).

The discussion reached its peak when Philip Johnson built his Glass House (1949) and Ludwig Mies van der Rohe the Farnsworth House (1946-51). Both buildings' facades consisted entirely of large glass panes framed in steel mullions, with only few operable glass doors and windows. Both buildings pushed the ideas of shelter within nature, the open floor plan in housing, and the tectonics of transparent facades to their radical limits. Both buildings allow, via their large glass panes, for the closest possible relationship to nature while still providing shelter from weather, flora, and fauna. In Mies van der Rohe's words: "When one looks at Nature through the glass walls of the Farnsworth House [...] it takes on a deeper significance than when one stands outside. More of Nature is thus expressed—it becomes part of a greater whole." A visitor enthused: "You are in nature and not in it, engulfed by it but separate from it. It is altogether unforgettable" (Schulze 1997: 5, 24). The counter positions were radical, too. Elizabeth Gordon's widely read 1953 article "The Threat to the Next America" was the boldest rebuttal, stating that the "all-glass cube of International Style architecture is perhaps the most unlivable type of home for man since he descended from the tree and entered the cave. You burn up in the summer and freeze in the winter, because nothing must interfere with the 'pure' form of their rectangles—no overhanging roofs to shade you from the sun; the bare minimum of gadgets and possessions so as not to spoil the 'clean' look; [...] no children, no dogs, extremely meager kitchen facilities—nothing human that might disturb the architect's composition. [...] They say, 'You must sacrifice comfort in order to achieve serenity.' And what is their serenity? Sitting in the middle of an empty room surrounded by glass walls" (Gordon 1953: 250-51).

This brief introduction shows that arguments against the residential glass house were multi-faceted. They can be summarized as follows:

1) Insufficient boundary with nature: The glass house might work for an exciting weekend vacation—more comfortable than a tent—but living in it for a longer period of time needs additional separation from nature. In "the drama that constantly

plays between shelter and setting” (Schulze 1997: 24) some people questioned if the glass house was shelter at all (for example Biemiller 1950).

2) Lack of privacy: Enjoying the view of weather, landscape, animals, and nature’s rhythms is one side; being gazed at by people from outside is another. How much closure is needed for relaxation, informality, intimacy, and security? As early as 1925 an article stated that “the glass house has always been looked upon as one of the impractical luxuries. It has carried with it, too, the idea that everything within its walls was open to public inspection and that occupants must go to bed with their clothes on to avoid embarrassment.” (*Literary Digest* 1925).

3) Lack of privacy within the house: In addition to the discomfort of being felt observed from outside, there might also be a lack of privacy among the occupants within the house. The glass facade required that, in best case, no partition walls touched it. The resulting open plan decreased the possibilities for individuals to retreat.

4) Lack of thermal comfort: Thermal comfort in residences started as a heating problem in winter. Single-pane glazing with its insufficient surface temperature made the occupant, being too close to the facade, feel cold in winter. The glass house had severe problems of thermal comfort also in summer. In both Johnson’s and Mies van der Rohe’s houses overhangs for shading or additional operable windows for natural ventilation were repudiated as disturbing the minimalist appearance. Ignoring solar orientation by having glass facades on all sides of a house increased these problems, with northern sides being even colder in winter and southern and western sides even hotter in summer.

5) Lack of visual and acoustic comfort: Glare, little protection from outside noise, and hard acoustics inside were discussed problems.

6) Lack of energy efficiency: The large glass walls resulted in higher heating and air-conditioning needs. High energy consumption was widely ignored after Second World War when oil became abundant. Heating parking spaces or outdoor paths—as Johnson did from the Glass House to his guesthouse—was not unusual in the 1950s.

7) Condensation: Increased condensation on single-pane glazing and resulting damage of construction became additional concerns (Barry 1953).

8) Dominance of aesthetics: Elizabeth Gordon called the glass house aesthetics a “cultural dictatorship” (Gordon 1953: 127), incessantly drawing attention to its own formal qualities thus undermining its purpose of providing space for inhabitation. In Edith Farnsworth’s words: “I can’t even put a clothes hanger in my house without considering how it affects everything from the outside” (Schulze 1997: 18; see also Friedman 2007: 141).

ABRAHAM WILLIAM HAJJAR

When A. William Hajjar (1917 Lawrence, MA – 2000 La Jolla, CA) became a practicing architect in the 1940s, the debate on glass facades in residential architecture was in full swing. He was undoubtedly influenced by that, noting "that glass is to the architect what a candy bar is to a child" (Faust 1960: 6). In the 1950s and ‘60s Hajjar developed his concept of the “Air Wall”—an early example of a double skin—that “dismisses all ideas of what buildings have been like in the past” (*CDT* 1960) and that had the potential to solve the problems discussed in relationship to the glass house.

Bill Hajjar finished his Bachelor of Architecture at Carnegie Institute of Technology (today Carnegie Mellon University) in 1940 and his Master of Architecture at Massachusetts Institute of Technology in 1941. After the Second World War, in 1946, he became a faculty member at the Pennsylvania State University where he taught until about 1964. After working for a short period in Philadelphia he resettled in California in 1965. Many of Hajjar’s designs, now archived at the Pennsylvania State University, document his sincere interest in glass facades. Hajjar developed two general strategies to achieve the perfected glass house: (1) a core in the building center locating service spaces such as bathrooms and kitchen, staircase, shafts for plumbing, electric, heating or cooling, mechanical room, and, in some designs, an air-raid shelter; and (2) the Air Wall surrounding the building on all four sides. In 1959, with the support of a research grant by the Pittsburgh Plate Glass company (today PPG), a test building with a core and double skins on all four sides was erected, which quickly received the nickname “the glass house” and “glass shell house” (*CDT* 1960, *Popular Mechanics* 1961, *Patriot News* 1959) (fig. 1). Hajjar hoped, as the archived materials show, that the concepts of core and Air Wall would become feasible for offices and residences alike.

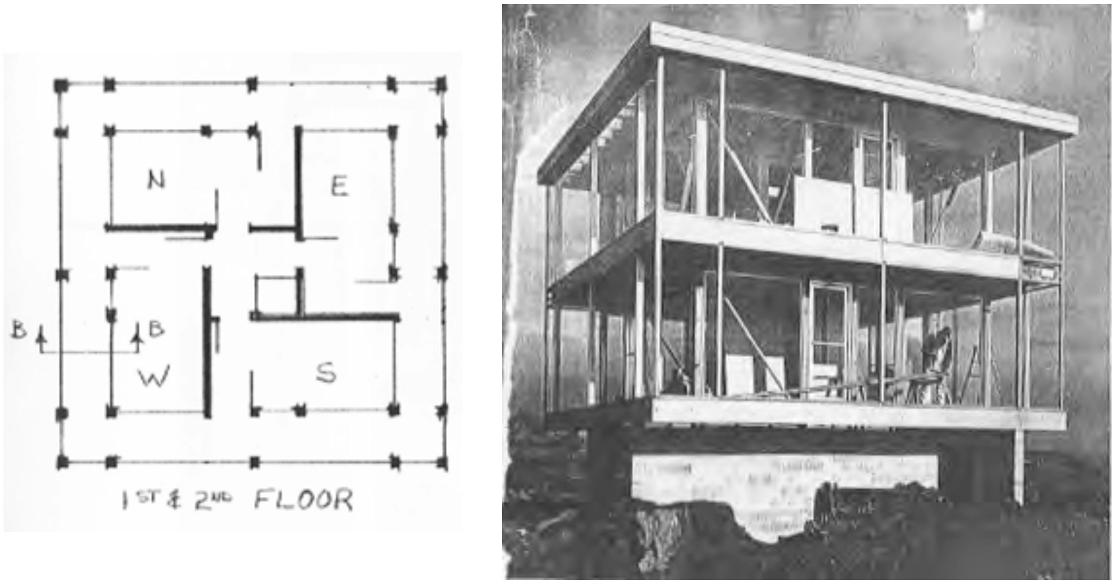


Figure 1. A. William Hajjar, plan of test building and construction photo showing maximum transparency (1959). Source of all images in this contribution if not labeled otherwise: A. William Hajjar Architectural Drawings, PSUA 9399, Special Collections Library, University Libraries, Pennsylvania State University.

THE AIR WALL

Hajjar and his research team described the Air Wall construction as "the addition of a layer of glass around a building to enclose an air space which allows free movement of air around the entire building" (Hajjar et al. 1961: 1). In the test building, the Air Wall was three feet wide, with an outer and inner quarter-inch clear glass plate. Operable openings were installed at the bottom and top, and at each floor plate, so that the air could enter the cavity from below and move horizontally and vertically. The goals of having this construction on all four sides were, first, to create an additional insulation layer for both winter and summer conditions; second, in winter, to allow air to be heated by the sun in the southern wall cavity and to move the warm air horizontally to the colder northern cavity, thus creating a balanced temperature around the entire building; and third, in summer, to initiate vertical ventilation to remove solar heat before it enters the occupied space. The space between the two glass layers was planned to be equipped with additional elements such as heavy drapes for thermal storage. The description shows that the Air Wall was primarily considered a passive system: “The solar heat comes through the outer pane, but heats the curtain instead of the interior. The collected heat fills the three-foot airspace, and the entire wall becomes a radiator. In summer, vents carry off the unwanted heat.” (*Popular Mechanics* 1961: 73). In addition, the idea was to locate electrical lighting and active heating in the cavity. Some archived renderings show an electrical curtain proposed to radiate heat to the inside in winter. Hajjar labeled this curtain as a “permanent solar energy absorbing screen & electrical resistive heating element” or simply a “radiant curtain.” The advantages were first that “[d]uring the cold season you simply add more warm air to the system and warm your entire house without a complex system of ducts and vents” and second that the cavity could be “featured with infinite variations” of additional elements (*CDT* 1960). The overarching idea was therefore to create an ideally tempered layer that surrounds the inner spaces in a way that makes interior heating or cooling (and ducts and vents for that) obsolete.

THE NEW GLASS HOUSE: “AIR WALL CORE HOUSE”

Hajjar’s focus on the two principles of “core” and “Air Wall” in many of his designs suggests that he had his very own solutions for the problems of the glass house as listed above. One design, called by Hajjar the “Heart House,” is, like the Farnsworth House, elevated, hovering in the outdoors (fig. 2). The house embraces a somewhat open plan that avoids interior walls touching the facade. The core includes staircase, kitchen, bathrooms, laundry, mechanical space, and an elevator. The fireplace faces to the living room but is part of the core, as in Mies van der Rohe’s and Johnson’s houses. The core is surrounded by living, dining, and multi-purpose rooms on the first floor, and four bedrooms on the second floor. The rooms are enveloped by a double skin on all four sides, consisting of box frames two feet deep reaching from floor to ceiling. In the frames glass panes or glass louvers can be inserted. The elevated ground floor allows air to enter at the bottom of the double skin. The floor plans reveal that plants were considered to be placed in the boxes.

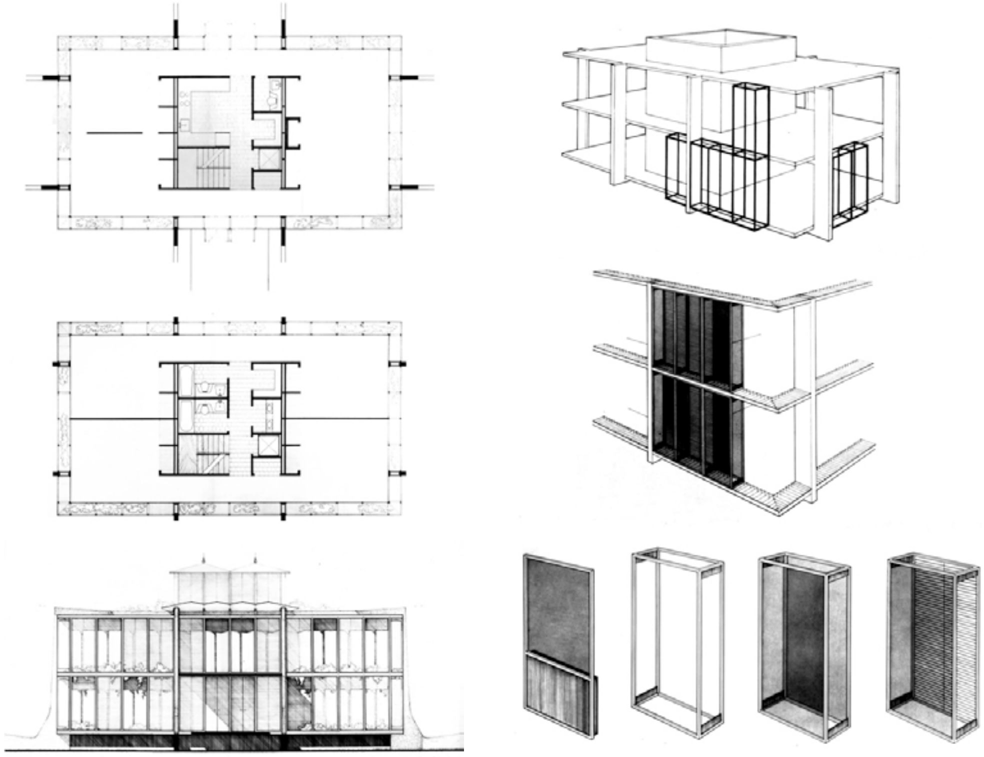


Figure 2. A. William Hajjar and Harlin J. Wall, design of the "Heart House," first and second floor, elevation, and Air Wall system, no date.

Another design has a square plan with a staircase in the center and an Air Wall with beveled corners around the building on the second and third floor where the living and bedrooms were located (fig. 3). The square plan and trimmed facade suggest the intention to facilitate lateral air movement, minimize the surface-area-to-volume ratio, and thus decrease heat loss through the building skin.

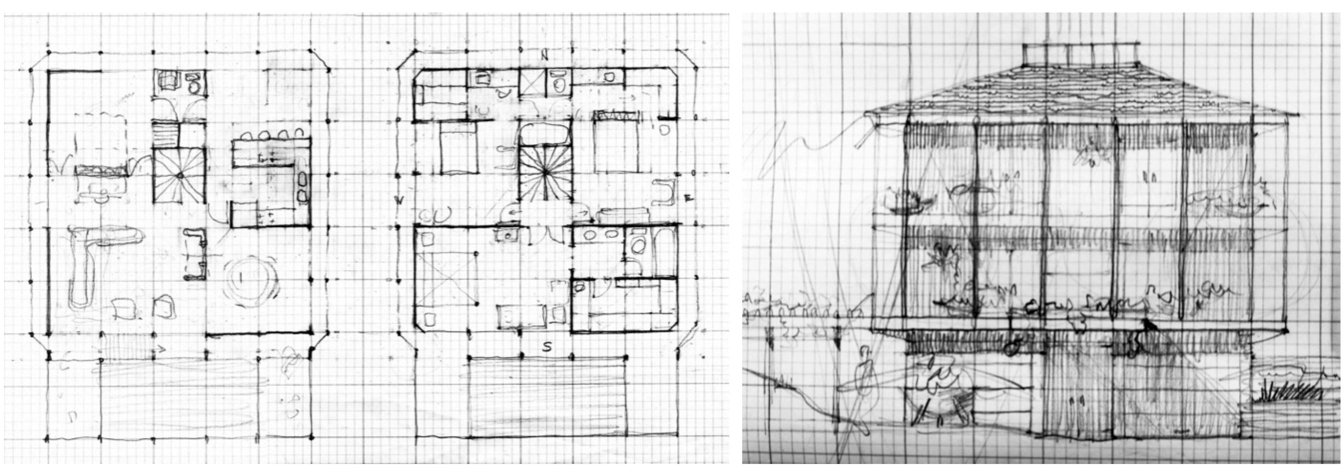


Figure 3. A. William Hajjar, plans and elevation, no date. Note the operable window in the double skin and the airplane on the ground floor.

Hajjar's designs provide solutions to the above listed problems of the glass house as follows:

1) Insufficient boundary with nature: The room-tall, transparent glass facades allow a close connection between inside and outside but create at the same time a buffer space that is more than the minimum boundary.

2) Lack of privacy: The multiple layers of glass, louvers, vegetation, curtains, etc. promise higher privacy in the house, needed for informal relaxation and the feeling of security. Compared to the test building, the presented residential

designs have smaller glass plates, more mullions, glass louvers, and objects within the Air Wall that reduce the view and increase privacy. Bedrooms are on the upper floor thus more protected from outside observation.

3) Lack of privacy within the house: The floor plans with their centered cores create clear zones that allow for retreat of individuals in the house, on the ground floor as well as in the bedrooms.

4) Lack of thermal comfort: The second layer of glass doubles the insulation value of the facade thus highly improving thermal comfort. In summer the box frames provide an overhang and thus shading. The glass louvers allow for natural ventilation. The research on the test building found that, for the summer condition, the "air wall construction reduces heat gain more effectively than conventional windows" and that "at low solar altitudes the air wall is more effective than conventional fenestrations with an external overhang." In addition, forced and natural ventilation in the cavity were experimentally compared and it was concluded "that the type of ventilation [...] had an insignificant effect" (Schutrum et al.: 182). Since the Air Wall is a continuous space, in which air can be moved from the warm to the cold side, the orientation of the rooms becomes less crucial for comfort. Rooms can be oriented to the best view, for example, without sacrificing thermal comfort.

5) Lack of visual and acoustic comfort: The multi-layered facade also improved visual comfort (reduction of glare) and control of outside noise.

6) Lack of energy efficiency: When used in "passive mode"—particularly for solar heat gain in winter or shading and natural ventilation in comfortable weather conditions—the double skin could reduce energy consumption. Utilization of solar energy was particularly addressed: "The Air Wall Concept uses the available solar radiation to reduce heating loads during the cold months." In addition, the "value of the air wall construction in reducing the cooling load from solar radiation sources has been demonstrated. The use of high absorptance, low transmittance drapery materials has demonstrated what is needed for the minimum cooling load." (McLaughlin 1961: 1, 5) Since Hajjar intended to equip the wall cavity also with electrical heating devices, higher energy consumption at least in winter seemed likely, however.

7) Condensation: The double skin had the potential to decrease the problem of condensation and thus of construction damage. Positioning vegetation in the cavity might have been counterproductive.

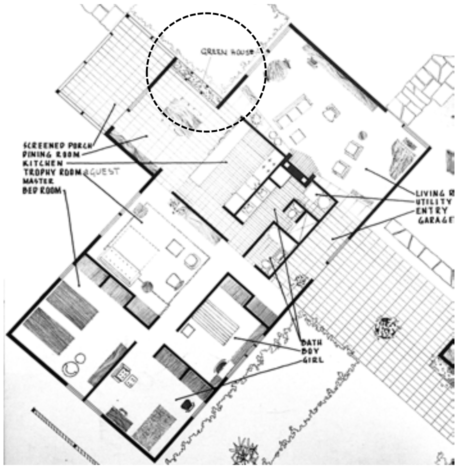
8) Dominance of aesthetics: The Air Wall promised high flexibility and adaptation to individual needs, while, at the same time, in Hajjar's words, did not "destroy the clean line—the very effect you wanted from using all that glass" (*Patriot News* 1959).

BACKGROUND

Equipping residential buildings with facades made of two panes of glass with technical systems between the two was not an entirely new invention by Hajjar. In 1898 glass scientist Jules Henrivaux described his vision of a "house of constant temperature" that was enclosed by a "double wall [...], the interior of which may be made to circulate in winter warm air, and in summer compressed air which expands and cools the building. In these walls are placed the electric wires, water pipes, etc. [...] We ardently hope then that some skillful Maecenas [...] will dare to take the initiative and have a habitation of glass constructed which may be called the house of constant temperature, the hygienic house *par excellence*, [...] the 'House of the Future'" (Henrivaux 1899: 391, 393). It is also known that Le Corbusier experimented with the double-skin facade for residential and office buildings, which he called "mur neutralisant" (neutralizing wall). His idea was to mechanically condition the air in the cavity (Bryan 1991, Fernandez 2011). Built experiments with neutralizing walls were the Villa Schwob in La Chaux-de-Fonds (1912-16) and the Centrosoyus office building in Moscow (1929-35). Le Corbusier also proposed to apply it to the United Nations Headquarters in New York in the late 1940s but was not able to follow through with his idea.

Also in the USA, experiments with two panes of glass and a conditioned cavity in between were not unknown. An early example was a glass "double shell" in the 1937 Alfred Loomis Residence in Tuxedo Park, NY, designed by William Lescaze, which "provides both sonic and thermal insulation [...] by interposing a buffer environment between inside and outside climates." (Architectural Forum, Nov. 1948: 141). The same journal presented in 1944 a "winter window" for a "solar weekend house" by Henry Wright (Nov. 1944: 136-42) and discussed in 1948 facades that include "the mounting of heat intercepting glass at the outer edge of wide sun hoods, with ordinary glass at the building line and vents at the top and bottom of the air space" (Nov. 1948: 140). In a scale similar to Wright's "winter window," Hajjar experimented with multiple glass layers in the

1960s, for example, in an integrated “green house” for the Indianapolis Home Show competition (fig.4) and in a south-facing window in his own house in State College, PA (fig. 5-6). In comparison, however, the Air Wall, being oriented to all four sides of a building, was quite a different, more complex concept.



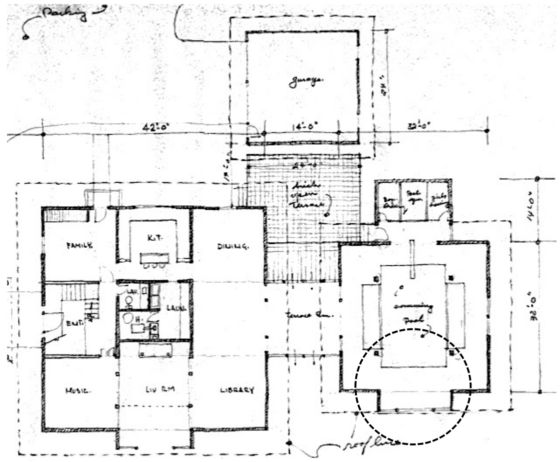


Figure 4. A. William Hajjar, Indianapolis Home Show Competition entry with green house, no date.

Figures 5-6. Hajjar’s own house in State College, PA, built in 1962, including a double window at the south side of the pool building (photo: author).

ARCHITECTURAL VISIONS

In the documents archived at Penn State, Bill Hajjar did not provide any reference to architects or buildings that might have served as models to him. In addition to the glass structures mentioned above, also the works by George Fred Keck and R. Buckminster Fuller can be imagined as having been influential. The parked airplane drawn in one of Hajjar’s designs (fig. 3) suggests inspiration from Keck’s two residences built for the 1933-1934 Chicago World’s Fair that showcased the plane as the private vehicle of the future. One, the “House of Tomorrow,” was a three-story octagonal structure enclosed by large glass walls, with a centered staircase and mechanical shaft working structurally like a tree trunk with supporting branches; the other, the “Crystal House,” was a rectangular structure with a core shaft, a structural facade, and a garage housing Fuller’s Dymaxion car. Fuller, in turn, designed in 1928 his “4D Tower” which also embraced a tree-trunk like core. All of these structures could have served as inspiration for Hajjar, particularly when compared to his most futuristic proposal in which he morphed the cubic building toward a sphere, the core toward a trunk, and the Air Wall to an all-side double skin including roof and underside (fig. 7). Hajjar’s vision of the Air Wall, when compared to the mentioned buildings, is, however, a unique building element.

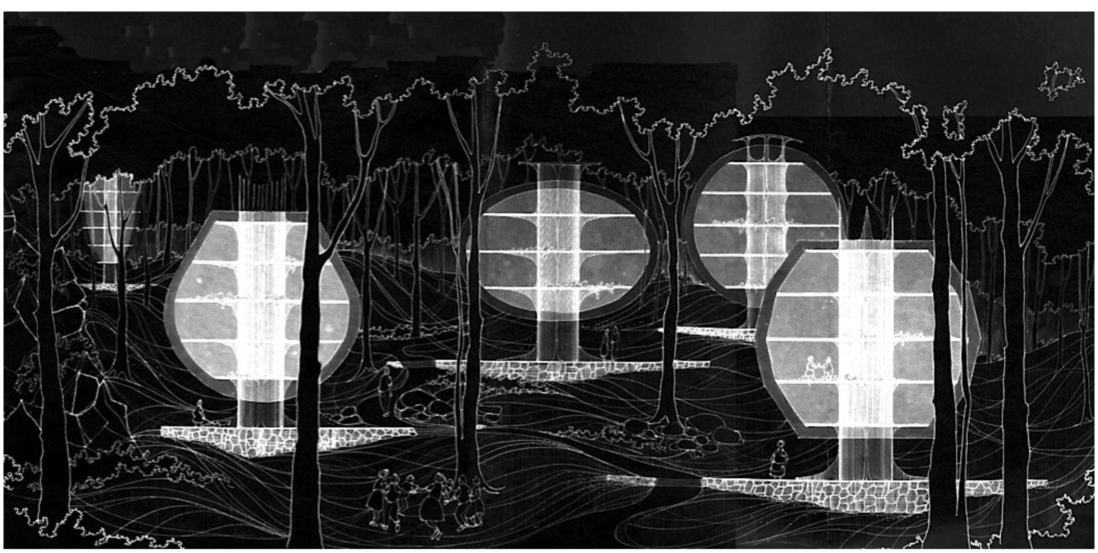


Figure 7. A. William Hajjar, “Future Concept of Airwall Core Buildings,” no date.

Hajjar's son Mark described his father's vision as creating individual ozone layers around houses, similar to the earth's atmosphere that allows flora and fauna their existence on earth: "Since the envelope of atmosphere around the earth contributes to the heating and cooling of the earth, could it, on a smaller scale, do the same for a cube shaped building? The sun heats the air on the surface of the earth that faces the sun, and the air currents circulate the air around the earth thus bringing the cool air from the unheated side of the earth to the sunny side and the heated air to the cooler side of the earth. If this happens naturally, what if a building were built with a blanket of air held in place between two walls of glass. Would the air move around the building in a similar way as it does around the earth thus heating and cooling the building without the need for any man made mechanical systems" (Mark Hajjar 2013). This description might come closest to Reyner Banham and Francois Dallegret's vision of the "transparent Mylar airdome" in their 1965 polemic "A Home is Not a House" in *Art in America*. Their proposal for a building envelope—being even less than Johnson's and Mies van der Rohe's glass walls—consisted of two transparent plastic layers, the air cavity in between being "inflated by air-conditioning output" (Banham and Dallegret 1965: 77). Both Banham/Dallegret and Hajjar came up with double skins, but went into opposite directions with it. While Banham/Dallegret attempted to define the "un-house" in order to relate a minimum shelter with "America's monumental space [...], the great outdoors" (Banham and Dallegret 1965: 76, 73), Hajjar's focus was the habitability of the glass house by designing a filter adjustable to specific environments and user needs.

With Colin Rowe and Robert Slutzky's "Transparency, Literal and Phenomenal," published in *Perspecta* in 1963, the discourse on transparency moved away from technical and societal questions toward the analysis of formal complexity of spaces. Rowe and Slutzky contrasted "literal transparency"—defined as the material quality of glass and unambiguity of building volumes—with "phenomenal transparency"—defined as a sectional stratification of spaces within buildings. Clearly, Bill Hajjar's experiments with core and Air Wall in cubic buildings belonged to the realm of literal transparency and could hardly be employed in the emerging discourse of postmodernism. Hajjar continued believing in his concept. In 1977 he attempted to register a business under the name "Air Wall Research & Development" in California and in 1978 he corresponded with the consulting engineer Charles Duke on improving the Air Wall with respect to thermal storage.

Hajjar was not able to realize in any of his buildings—aside from the test facility—his invention of a double skin that entirely surrounds a building. Therefore, it might be arguable if he deserves a more prominent position in the history of residential glass houses than the one he has today. However, his efforts are significant in two respects: First, Hajjar can be understood as a representative of those mid-century architects, who, rather than either highly praising or deeply vilifying transparency, attempted to reconcile transparency with comfort. Usually, we learn only about the radical voices of this debate, but not about architects, who tried new methods of bringing aesthetic and pragmatic realms together. Until today, we have not stopped discussing how much transparency can be afforded with respect to comfort in single-family houses, and buildings such as Werner Sobek's "R128" (2000), "S3" (2009), and "D10" (2011) have further fueled this debate. Hajjar's proposals are not only unique historical examples of this debate but also provide employable ideas for today. Second, the Air Wall is a significant example not only of the debate of transparency in residential architecture but also of the history of the double skin. While we normally start the history of double skins sometime in the 1980s—with a handful predecessors in the first third of the nineteenth century—Hajjar's prototype of a double skin to surround a building on all sides is an extraordinary attempt of the 1950s and '60s. Until today only few projects have experimented with such a set-up, in particular the Götz Headquarter by architects Martin Webler and Garnet Geissler in 1997, in which the air in the cavity is moved mechanically around the building. In the history of transparency as employed in residential architecture, on the one hand, and in the history of the double skin, on the other hand, Hajjar's Air Wall provides new insights and ideas that have not been fully explored and utilized yet.

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REFERENCES

Architectural Forum. "Solar Weekend House." 80 (Nov. 1944): 136-42.
——. "Enclosure." 88 (Nov. 1948): 135-141.
Barry, Joseph A. "Report on the American Battle Between Good and Bad Modern Houses." House Beautiful. (May 1953): 172-73 and 266-73.
Biemiller, Carl L. "Living under Glass." Holiday 7 (May 1950): 89.

Bier, Justus. “Kann man im Haus Tugendhat wohnen?” Die Form, vol. 6 (1931): 392-93.
Bryan, Harvey J. “Le Corbusier and the ‘Mur Neutralisant:’ An Early Experiment In Double Envelope Construction.” Architecture and Urban Space, Proceedings of the Ninth International PLEA Conference, edited by Servando Alvarez et.al., Dordrecht: Kluwer Academic Publishers, 1991.
CDT. “Test of Air-Wall Construction.” *Centre Daily Times*, August 10, 1960.
Charney, Wayne Michael. *The American Glass House, Its Conception and its Realization, 1850-1950*. Ph.D. dissertation, Northwestern University, 1985.
Faust, William. “The Designing Professor.” The Pittsburgh Press, March 20, 1960: 6-7.
Fernandez, Vanessa. “Preservation of Modern-Era Office Buildings and Environmental Controls.” APT Bulletin: Journal of Preservation Technology vol. 42, no. 2-3 (2011): 21-26.
Friedman, Alice T. *Women and the Making of the Modern House: A Social and Architectural History*. New Haven: Yale University Press, 2007.
Gloag, John. *The Place of Glass in Building*. London: George Allen & Unwin, 1944.
Gordon, Elizabeth. “The Threat to the Next America.” House Beautiful April 1953, 126-130 and 250-251.
Hajjar, A. William. Architectural Drawings, 1952-1961. Special Collections Library, Penn State University Libraries. https://www.libraries.psu.edu/findingaids/9399.htm
Hajjar, A. William, et. al. "A Proposal for Additional Observations on the Air Wall Principle" from February 17, 1961: 1. Special Collections Library, Penn State University Libraries. https://www.libraries.psu.edu/findingaids/9399.htm
Hajjar, Mark. Letter to Tim Pyatt, dated September 20, 2013. Special Collections Library, Penn State University Libraries.
Henrivaux, Jules. "A House of Glass." Chautauquan vol. 28 (January 1899): 389-93.
Literary Digest. “Shall we live in Glass Houses?” (May 9, 1925): 23.
McHale, John: R. Buckminster Fuller. New York: Braziller, 1962.
McLaughlin, E.R., College of Engineering and Architecture, Thermal Performance of Air Wall Construction for Pittsburgh Plate Glass Company. October 5, 1961. Archive.
Menocal, Narciso. Keck and Keck, Architects. Madison: Elvehjem Museum of Art, University of Wisconsin-Madison, 1980.
Neumann, Dietrich “’Can One Live in the Tugendhat House?’ A Sketch” Wolkenkuckucksheim | Cloud-Cuckoo-Land 32 (2012): 87-99.
Patriot News. “Penn State Architect Wants to ‘Bottle’ Us In Glass Shell House. 9/27/1959, no page.
Peter, John. Design With Glass. New York: Reinhold, 1964.
Popular Mechanics. “Glass ‘House’ Tames Solar Heat.” 116, no.1 (July 1961): 73.
PPG. Pittsburgh Plate Glass Company. A.I.A. File No. 17-A-1962.
Riezler, Walter. “Das Haus Tugendhat.” Die Form (1931): 321-332.
Rowe, Colin, and Robert Slutzky. “Transparency: Literal and Phenomenal.” Perspecta vol. 8 (1963): 45-54.
Schutrum, L.F., J.L. Stewart, R.D. Borges, and V.L. Pass, “Air Wall Construction—A Means of Reducing Air-Conditioning Loads.” ASHRAE Transactions 74 (1968): 176-184.
Sobek, Werner. http://www.wernersobek.de.

THE “AIR-WALL”:

A Mid-Twentieth-Century Double-Skin Facade by A. William Hajjar

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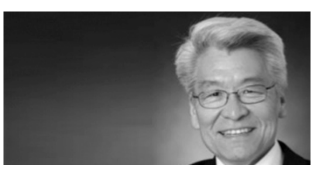

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ABSTRACT

Passive design strategies and eco-friendly approaches to architectural design in general have taken on a new importance in architectural discussions in the past few decades. Largely because of its potential for transparent aesthetics, the double-skin façade has attracted considerable attention from architects and architectural engineers. This paper focuses on Abraham William Hajjar’s “Air-Wall” project with the purpose of showing that far from being a new innovation of the last twenty-five years the double-skin façade is an architectural element that traces its development to the early twentieth century. A. William Hajjar was a faculty member and researcher in architecture at the Pennsylvania State University in the mid-twentieth century and a practitioner in the local town of State College, PA. In this paper, early examples of double-skin façades from 1903 to 1960 (including the Steiff factory in Germany and Le Corbusier’s architecture showing his concepts of *mur neutralisant* and *respiration exacte*) are explored and the impact of Hajjar’s Air-Wall on the development of this technology in the twentieth century is investigated. Aesthetics, materiality (assembly), and performance are the key elements considered.

KEYWORDS

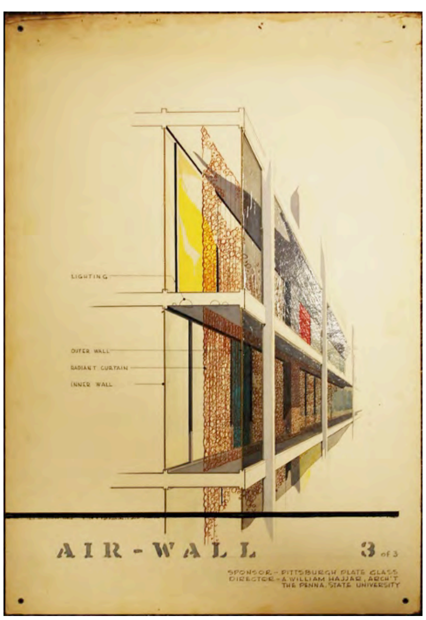
Air-Wall, Façade, Double-Skin, Architectural Glass, Sustainability, William Hajjar

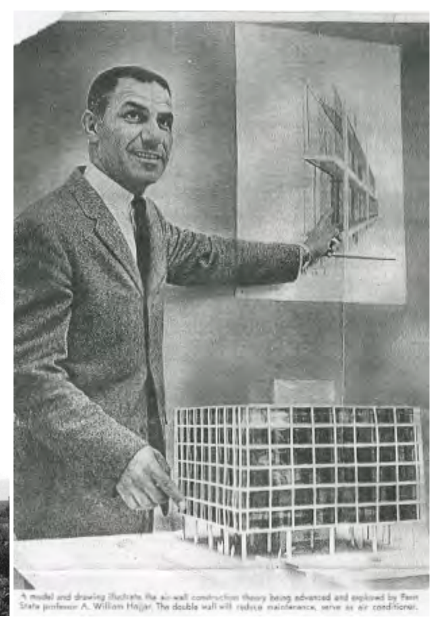
INTRODUCTION

Over several years, A. William Hajjar (1917–2000) was a member of the architecture faculty at the Pennsylvania State University from the late 1940s to the early 1960s and a practitioner in the local town of State College. After his death in 2000, the Hajjar family donated his professional archives to the university. In January 2013, a display of some of the items from Hajjar's archives at the Special Collections Library at Penn State attracted considerable attention. Created in 1959/1960, the color rendering "Air-Wall" (fig. 1) proved to be of particular interest: the drawing shows a double-skin façade designed by Hajjar to improve the energy efficiency of his work. This drawing, essentially rediscovered at the display, provided the impetus for the formation of a research group to study Hajjar's Air-Wall system. The purpose of present article, which is based on the data produced by this research group at Penn State, is to highlight Hajjar's Air-Wall as part of the history of double-skin façades in the early-to-mid-twentieth century.

Abraham William Hajjar, known as "Bill" to his friends, was born on February 11, 1917, in Lawrence, MA, and was the youngest of a large immigrant Lebanese family. He received his bachelor's degree in architecture from the Carnegie Institute of Technology (now Carnegie Mellon) in 1940, and his master's from the Massachusetts Institute of Technology in 1941. While in Boston, he worked with his friends, Vincent Kling and I.M. Pei, before joining the Department of Architecture at the State College of Washington in 1942. Later, in 1946, Hajjar moved to State College, PA, to join the architecture faculty at Penn State.

An architect in the town of State College and a professor of architecture at Penn State, Hajjar was also a researcher at the university. He was involved in several research and design projects, including his Air-Wall system, which he conceived in the 1950s and tested in his State College projects. Air-Wall construction, based on Hajjar's proposal document, provided an additional layer of glass around a building in order to create an insulating air chamber. To test the potential of his façade technology, Hajjar persuaded the Pittsburgh Plate Glass Company (today PPG) to fund the building of a four-story test house with a two-story double-skin transparent façade on all four sides at the University Park campus (figs. 1-3).



Figures 1-3. From left to right Hajjar's Air-Wall drawing, the test building at Penn State's University Park campus, and William Hajjar presenting the project to the Pittsburgh Press (March 1960). All images are from A. William Hajjar Architectural Drawings, PSUA 9399, Special Collections Library, University Libraries, Pennsylvania State University, unless otherwise stated.

BACKGROUND

In general, the double-skin façade (DSF) is a façade system with an internal and an external layer of glazing between which there is a ventilated cavity. The external and internal screens can each consist of a single piece of glass or double-glazed units, the depth of the cavity and the type of ventilation depend on the environmental conditions and the level of performance the envelope is required to achieve (Kragh, 2000). There are a number of different DSF approaches. Based on the *Architectural Record* Continuing Education article entitled "Using Multiple Glass Skins to Clad Buildings," there are three basic system types. These systems—the Buffer System, the Extract Air System, and the Twin Face System—vary significantly in respect to ventilation method and their ability to reduce overall energy consumption (Lang and Herzog, 2000). However, according to the Belgian Building Research Institute's *Source Book* (2002), a DSF, in general, consists of multiple layers described as follows:

- Exterior glazing: Usually hardened single glazing is used for the exterior.
- Interior glazing: An insulating double-glazing unit is used for the interior glazing. For this glazing, a clear, low E coating and/or solar control glazing can be used.
- Air cavity: Situated between the two panes, the air cavity can be entirely natural, fan-supported, or mechanically ventilated. The width of the cavity can vary as a function of the applied concept from 200 mm to more than 2 m. The extent of the width influences the way in which the façade is maintained.
- Interior window: To allow rooms to benefit from natural ventilation, the interior window can be opened by the user.
- Solar shading: Automatically controlled, the solar shading is integrated inside the air cavity.
- Heating radiator: This unit can be installed next to the façade as a function of the façade concept and of the glazing type.

On the other hand, Hajjar described his "Air-Wall Principles" in "A Proposal for Additional Observations on the Air-Wall Principles" (February 17, 1961) in the following terms:

> The addition of a layer of glass around a building to enclose an air space which allows free movement of air around the entire building. During the winter months devices within the Air-Wall space intercept solar radiation and heat air which can be circulated laterally through the Air-Wall space to improve comfort conditions on the shaded sides of the building. During the summer months the devices within the Air-Wall reflect a portion of the solar radiation, and the heat resulting from the portion of the radiation which is absorbed is exhausted to the weather by air circulation vertically through the Air-Wall.

While William Hajjar and his research team continued experimenting with the Air-Wall system after constructing the test building on Penn State's University Park campus (1959–1960), the structural set-up of the Air-Wall was described as follows:

> An Air-Wall is the addition of a wall of glass out from the exterior wall of a building providing an insulating air chamber. The Air-Wall may include a solar inceptor, such as a fiber glass drape, in the Air-Wall chamber. Solar radiation entering the outer wall of the chamber is either absorbed, transmitted or reflected by the interceptor, depending on the properties of the material. (ASHRAE, 1968: 176)

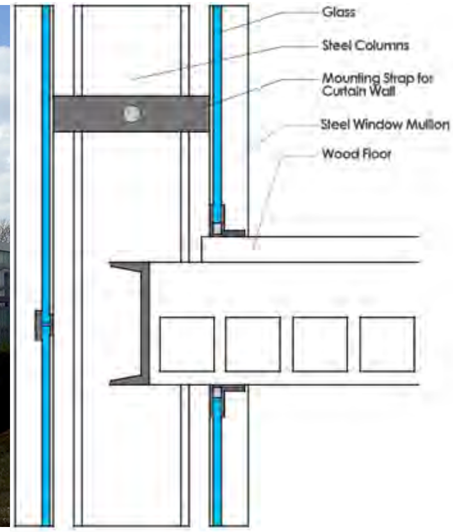
A question that arose during our study of Hajjar's Air-Wall pertained to whether the Air-Wall system constitutes a DSF. Definitions of DSF are complicated and vary quite a lot. However, DSF is generally defined as a façade system that has both an internal and an external layer of glazing with a ventilated gap, as described above. Although the glass properties of the two layers of glazing and the ways in which the gap can be ventilated vary, in line with this basic definition, Hajjar's Air-Wall can certainly be seen as a DSF.

CONTEXTUALIZING HAJJAR'S AIR-WALL

The purpose of this section is to provide a brief history of the DSF in order to contextualize Hajjar's Air-Wall system as part of that history.

While Otto Wagner designed a double skin skylight in the main hall of the Post Office Saving Bank in Vienna, Austria (1911), in 1903, the first known DSF was built for the Steiff Factory Building in the little town of Giengen in southern Germany (figs 4-

5). By the time the Steiff toy factory was built, some industrial buildings in Germany had already been built with predominantly glass walls and roofs that were uninterrupted by structural members. However, the Steiff factory has lightweight double-glass walls. While the factory is famous as the home and birthplace of the Teddy bear, the three story eastern wing of the 1903 factory is known for its double skinned curtain wall. The structure uses rolled iron frames to hold and support continuous glass walls, clipped to vertical steel columns. A frame containing the second sheet of glass is set about half a meter inside. The exterior glass encloses the structural steel completely (Fortmeyer, 2014).



Figures 4-5. Steiff factory building (1903) (left), image by author, and a detailed section of Steiff factory's DSF (right), adapted from *Fortmeyer, 2014.*

The "neutralizing wall," a DSF with an air cavity that could be heated or cooled and was intended to prevent any exchange of radiation between the interior and exterior, was defined by Le Corbusier in the late 1920s. During this period, Le Corbusier focused on the use of reinforced concrete frame construction, manifested via his Domino concept, whereby the wall is freed from its traditional structural role so that it can function in another way. However, earlier in 1916, in Villa Schwob Corbusier incorporated a thermal distribution function into the opaque exterior walls, something that he later called "*mur neutralisant*," i.e., a neutralizing wall (Bryan, 1991). *Mur neutralisant,* as Harvey Bryan describes it, is a "double wall construction with conditioned air being circulated in the cavity between the two walls" (1991: 257). In Villa Schwob, Le Corbusier used heating pipes laid at the bottom of the cavity between the double wall. It is important to note that Le Corbusier also used other thermal phenomena in the project, for example the orientation of the villa and its two-story living room 5m-by-6m window facing south.

Other European architects were also trying to maximize the glass façade with the goal of maximizing sunlight. In the interwar period, coal was expensive and heating buildings sufficiently and cost-effectively in winter was a critical issue. For example, the Bauhaus School (1926) in Dessau, Germany, designed by Walter Gropius, and the Van Nelle Factory (1930) in Rotterdam, the Netherlands, designed by J. A. Brinkman and L. C. van der Vlugt were two buildings with large glass façades oriented toward the south or the west.

After a decade of designing Villa Schwob, in 1927, Le Corbusier used the *mur neutralisant* in his design for the League of Nations building. This time, he elevated the idea into an elaborate affair, with large mechanical ventilators bellowing heated air into the cavity space between the eight-story-high double-glazed walls of the assembly hall. Corbusier designed the technical aspects of this project in consultation with physicist Gustave Lyon. Historically, this was the first use of the hermetic or airtight glass curtain wall (Bryan, 1991). However, this project was never built.

Trying again in 1928, Le Corbusier designed the Centrosoyus building in Moscow. This time, he introduced Lyon's scheme for mechanical ventilation for the interior and the *mur neutralisant* for the perimeter of the building. Le Corbusier asked for additional information on the practicality of the system from the American Blower Corporation. However, they could not prove the practicality of *mur neutralisant*, writing back to him that "your proposal will demand approximately four times more steam and more than twice the fan energy to heat and ventilate the building than that which would be necessary with current methods employed in our country to heat and ventilate a building exposed to the same atmospheric conditions" (American Blower Corporation letter to Le Corbusier, 1930). Therefore, the client only agreed to employ a double glazed wall with no ventilated spaces in between.

Le Corbusier continued working with his idea and proposed the concept of "*respiration exacte*," which means exact breathing. This system consisted of a closed fan-driven heating, ventilating, and air-conditioning system that was largely based on Gustave Lyon's ventilation scheme (Le Corbusier, 1991: 64). Corbusier's exact breathing system was the forerunner of today's hermetically sealed, air-conditioned buildings.

Le Corbusier applied both of these concepts to his projects, including the Cité de Refuge in Paris (1930) and the Palace of the Soviets in Moscow (1931). The Cité de Refuge, a multi-story hostel for the Salvation Army, is a more known and interesting project because it was actually built. Here, also the client was concerned about Le Corbusier's system. However, this time Le Corbusier approached Saint Gobain, the French glass company to see if representatives would test the *mur neutralisant* and so that a body of technical information pertaining to it could be developed. After making a test chamber to house a 1.5- by 2.5-meter window (one regular and one double-glazed with hot and cool air circulating in between), the French company confirmed the American Blower Corporation's result and also acknowledged that the warmer glass surface would improve comfort. Therefore, the client agreed to install only a 1,100 square meter sealed single pane curtain wall (south façade), heating, and ventilation but not the air-conditioning component of the *respiration exacte*. However, two years after the building had been completed, operable windows were installed, and after two decades (1952) Le Corbusier suggested significant improvements, including the addition of sunscreens, opaque panels, and traditional operable windows to the south façade, some of which he executed.

In 1947, Le Corbusier proposed his *mur neutralisant* to the 10-member board of design for the United Nations Building. In fact, Le Corbusier actually proposed a combination of his naturalizing wall and the exact breathing system with a *brise-soleil*, "a system comprised of solar glass filters separate from the building and intended to block unwanted sun-light, a reduced version of the contemporary ventilated double-skin façade" for this project in New York (Fernandez, 2011: 23). Although Le Corbusier's ideas for the design of the building were well received by the board members, his technical suggestions received little attention. He even wrote a letter to Senator Warren Austin, President of the U.N. Building Commission, to little effect. Soon after, Le Corbusier distanced himself from the project. This was the last time Le Corbusier offered his *mur neutralisant*. In subsequent designs, he relied more on passive strategies such as *brise-soleil* and natural ventilation through operable windows (Bryan 1991, and Fernandez, 2011).

Historians such as Reyer Banham viewed *mur neutralisant* as an "unreal and unworkable" concept. However, writing in 1991 Harvey Bryan argued that Le Corbusier neglected to consider the contributions of solar, even though he had used it to good effect in the Villa Schwob (Banham, 1969, and Bryan 1991). According to Bryan, the issue was not how to blow hot air into a double-glazed cavity, but "how to use the solar energy that became trapped within the cavity" (Bryan, 1991: 261). Bryan's suggestion was a double glazed wall with "operable louvers at the top and bottom and a horizontal grate at each floor which also works as a sun shading device as well as allow air to move vertically" (Bryan, 1991: 261). In the winter, both vents can be closed to reduce heat loss from the building, whereas in the summer, both can be opened and a shading device can be used to prevent solar radiation from striking the inner pane. Many of these features were indeed incorporated, thirty years earlier, into Hajjar's Air-Wall test building (fig. 6).

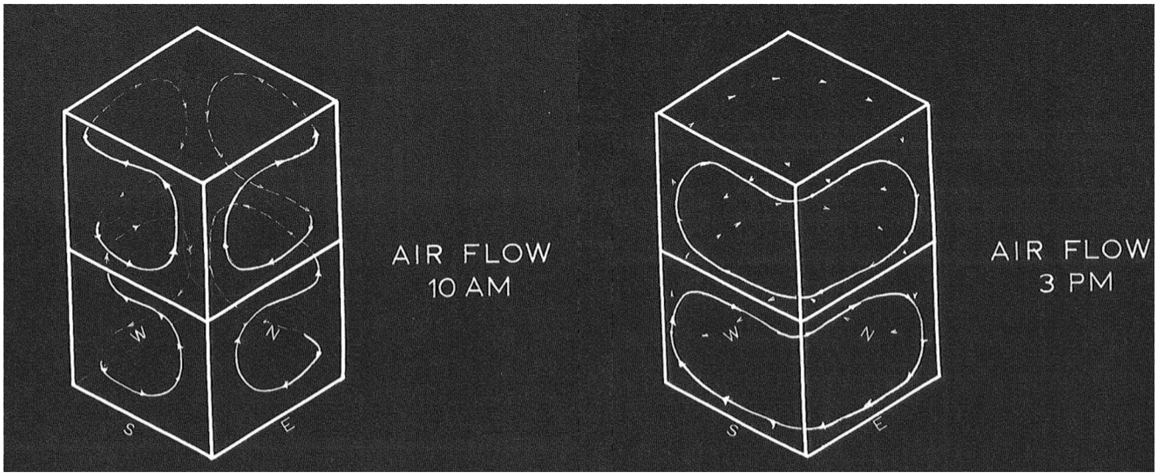


Figure 6. A diagram by William Hajjar showing air flow of Air-Wall test building in 3/12/1960, with a note stating "All Air-Wall Vents closed. No Shading Devices."

Le Corbusier's *mur neutralisant* was not successful (other than in his Villa Schwob) perhaps because his grasp of the physical principles was weak, but his work did pick up a thread that links the early twentieth century experiments in Germany and Austria, with examples that appear in the second half of the twentieth century. Further efforts, such as Hajjar's Air-Wall, the Equitable Life Assurance Society Building in Charlotte, NC (1977), the Occidental Chemical Building in Niagara Falls, NY (1981), and many other examples, suggest that the questions concerning the double-envelope wall, which Le Corbusier started to raise, had not been completely answered at the end of the twentieth century and perhaps remain to be answered to some extent even today.

HAJJAR'S AIR-WALL SYSTEM

Hajjar's first built project in State College, PA, was a house he designed and built for his own family in the early 1950s. By the time he started working as an associate in the office of Vincent Kling in Philadelphia, PA, in July 1963, he had designed more than 50 projects in the State College area.

The Journal of Architectural Education published an article in 1947 detailing the results of a survey sent to 60 schools of architecture on the mailing list of the Association of Collegiate Schools of Architecture. The questions were centered around the nature of architectural research, the aims of a general program of architectural research, the focal areas and specific projects that schools consider, the role of the American Institute of Architects (AIA) in future research conducted at the schools, and so forth ("The Schools and Architectural Research"). Thirty three percent of the member schools responded, which shows both the importance of architectural research in the AIA and the vision of the schools that responded. The schools reported that most of their research related to technical deficiencies, materials, and methods of construction. They stated that the AIA should not set up a testing laboratory, but encourage institutions to conduct their own tests and report the results. Air-Wall research can also be understood within this move toward increased research at schools of architecture. Hajjar was not the only researcher and designer involved in the Air-Wall project. Based on research proposals and publications that came out of the research reports, it is evident that a team of engineers was assembled which included members of the Department of Architectural Engineering at Penn State and the research lab at PPG. A 1968 ASRAE paper lists L.F. Schutrum and J.L. Stewart as research engineers at PPG; R.D. Borges as a technical service engineer at PPG; and V.L. Pass, associate professor of architectural engineering at Penn State. However, Hajjar was the main designer of the system and, judging from the many surviving photos and press clippings, was the spokesperson for the project. Based on the popularity of Le Corbusier's designs (and those of other European architects working on the same idea), it is likely that Hajjar became interested in the idea of the DSF in concert with other kinds of environmentally controlled designs. However, he adapted the idea for the central Pennsylvania environment (fig. 7). He tested his idea of Air-Wall system in other projects on a smaller scale, "green houses" and "winter gardens," for example.

While Hajjar was thinking about the idea of a double-glazed wall, PPG was an established and well-known glass company researching and working on glass projects. PPG's commercial and residential building products were reduced during the war period because of their production of glass and acrylic for military products. However, in 1951, the company's Glass Division began to produce its heat-absorbing *Solex* plate glass. Later, in 1953, they introduced Twindow units, which were double layered insulated glass windows.

The first grant proposal was submitted to PPG in 1958 for $10,000 and was accepted. With the second grant of $17,072 from PPG in 1959, the construction of the test building began on the University Park campus at Penn State (figs. 8-10). Follow-up grants during the 1960's focused on detailed tests of the Air-Wall's performance. The tests featured detailed data on the function of a series of fiberglass draperies inserted into the Air-Wall cavity to absorb or deflect heat. Hajjar's Air-Wall proposal probably appealed to PPG because it corresponded with their efforts to expand their product line to take full advantage of the post-war building boom. In 1947 PPG and their rival glass company Libbey Owens Ford published the results of their separate competitions for house designs, many described as "solar" and featuring sealed double-gazing units such as PPG's Twindow. In 1952 PPG's heat-absorbing Solex coating was featured in the well-publicized Lever House all-glass office building, and in that same year PPG opened its first fiberglass plant. Soon afterward new float-glass methods were speeding plate production and PPG opened a new research center in Harmarville Pennsylvania "to ensure a continuing flow of glass products." The first full report on the heat transmission of the Air-Wall project was submitted to PPG by the research team at Penn State in May 26, 1961, and another report on thermal performance was submitted that October.

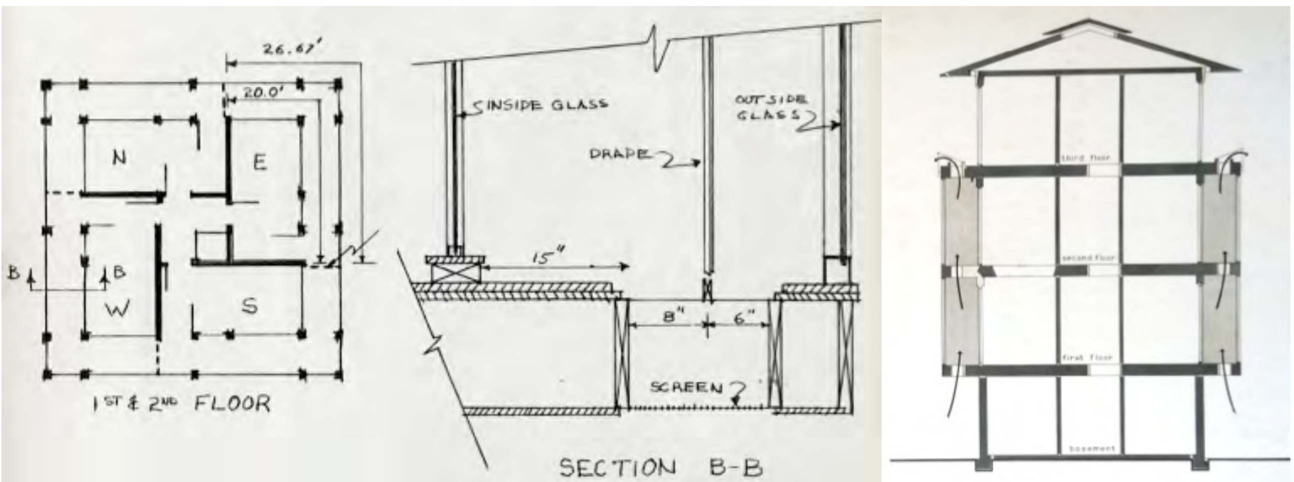
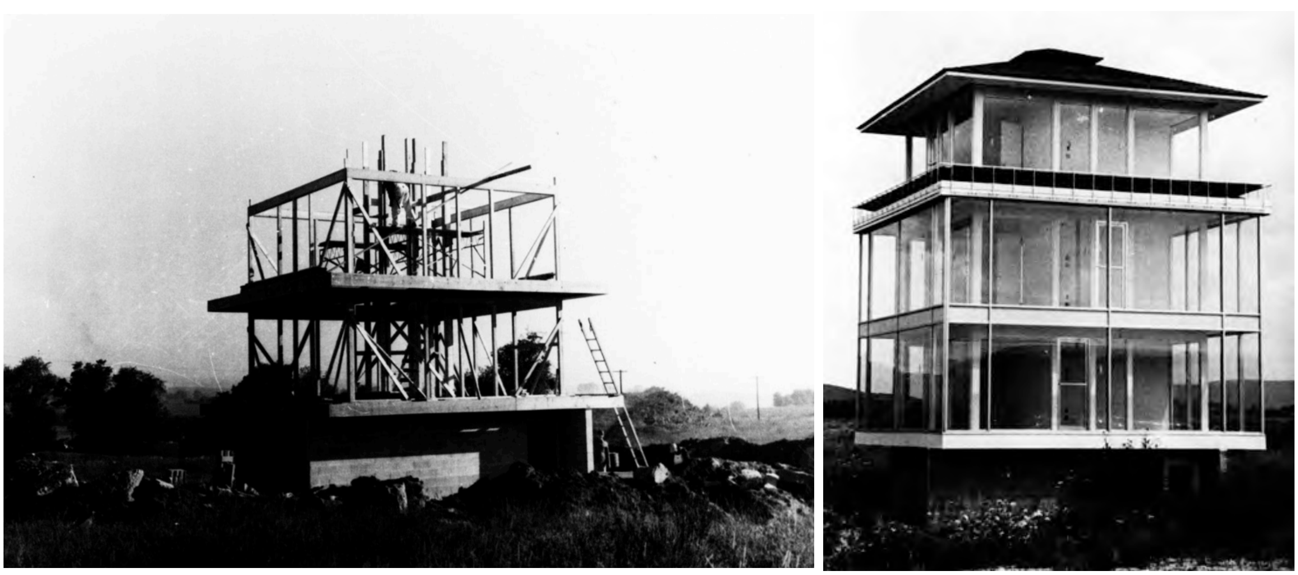


Figure 7. Plan and sections of the test building drawn by Hajjar.

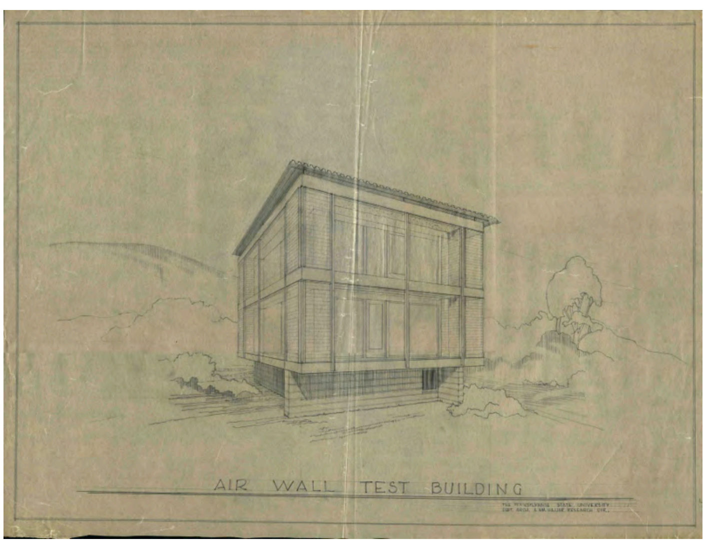


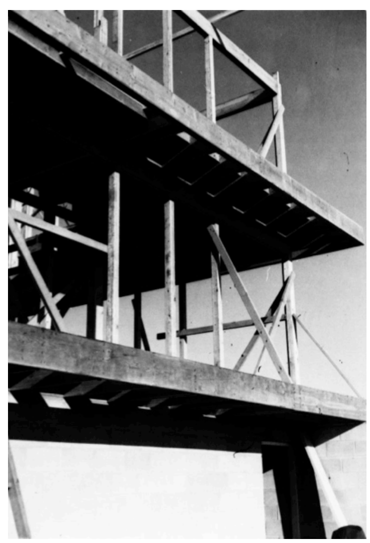
Figures 8–9. Air-Wall Test Building under construction in 1959.

Unlike Le Corbusier's double-skin façade, a closed system designed so that hot air would blow into the double-glazed cavity, Hajjar's Air-Wall used solar energy that became trapped within that cavity. Given the operable vents (figs. 7 and 11) at the top and bottom of the Air-Wall, the system was useable both in winter and summer and in sunny and shady conditions (table 1).

Weather Conditions	Operations
High outdoor temperature with sun	Solar energy enters through outer glass wall to be absorbed by a permanent hanging screen and transmitted to air by conduction in Air-Wall chamber. Fresh air is drawn from a dampered louvre arrangement at each corner of building and moved horizontally through Air-Wall chamber to be exhausted at adjacent corner of building, thereby reducing heat load for air conditioning of building.
High outdoor temperature – no sun	All exhausts and intakes are closed. Outer skin forms an insulating air chamber for building, thus reducing air conditioning load of building.
Low outdoor temperature with sun	Solar energy enters through outer glass wall to be absorbed by permanent hanging screen and transmitted to air by conduction in Air-Wall chamber. Exhaust and intake louvres to outside are closed. Louvres which normally isolate Air-Wall chambers one from the other on each side of building are opened, and a gentle movement of solar-heated air is moved to shade side of building, thereby, reducing heat loss from shade side of building and offering adequate cooling for sun side of building.
Low outdoor temperature – no sun	All exhaust and intake louvres to the outside are closed. A printed electrical circuit on the permanent hanging screen is employed as a radiant heating panel and is directed toward the building. This can be accomplished through several schemes as follows: a. Use of reflective outer screen located inside of outer glass wall. b. Use of a special glass as outer wall with inner surface possessing reflective qualities. c. Employing Twindow as outer glass wall which will aid in the loss by indirect radiation. The purpose of the radiant panel being to obtain an intermediate air temperature in Air-Wall, and thereby, covering the building with a warm blanket of air to improve interior comfort and reduce actual building heat loss.

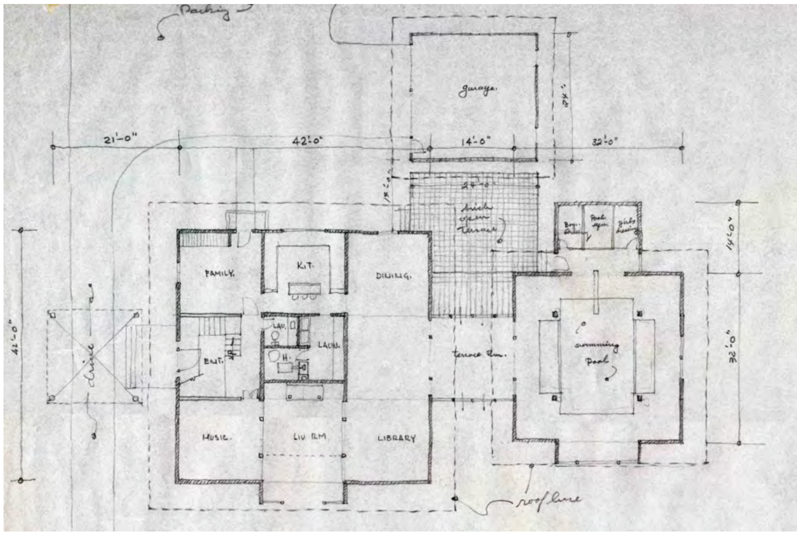
Table 1. Hajjar's Proposed System Operation for Given Weather Conditions, February 20, 1959, Hajjar's collection.





Figures 10-11. Hajjar's drawing for Air-Wall test building (left) and the test building under construction in 1959. Please note the Air-Wall vents under construction.

The Air-Wall system was not the only architectural aspect that Hajjar tested in this building. He was simultaneously working on his idea of constructing a "core" of services (e.g., utilities, elevator, kitchen, bathroom) in some buildings, especially in residential projects. Both of these concepts, the Air-Wall (on a small scale) and a core of services, were incorporated in the second house that Hajjar designed for his own family in the State College area. The construction of Hajjar's second house was finished in 1961 (figs. 12–13). In a letter to the editor of *Architectural Forum* dated September 30, 1960, James Coogan, director of public information at Penn State, stated that Hajjar was preparing to bring the two concepts of the Air-Wall system and the central core idea together for "an 'open house' at which he will seek to interest Pittsburgh Plate Glass Company and other industries in building an Air-Wall House at the 1964 World's Fair in New York." In a document entitled "Heart House, Proposed Air-Wall Core House," Hajjar and his associate, Harlin Wall, proposed a combination of the Air-Wall system and the core house concept in a residential project.



Figures 12–13. Hajjar's second house in State College, PA, 1961, plan of the house showing multiple service spaces and a double window on the south side of the interior pool. Image by author.

Although Hajjar left Penn State in July 1963, first on a two-year leave of absence to work in Philadelphia, and then permanently, to move to La Jolla, CA, around 1967, where he continued researching his idea. In a letter to William Hajjar, Dr. Charles Duke, consulting engineer, wrote on October 25, 1978 that "The Airwall experiments confirmed that it is possible to capture significant amounts of solar energy with a passive system." However, the equilibrium temperatures, as he stated, were too high in the afternoon and too low at night (110 F and 40 F). Based on the "average" temperature of 75, Duke suggested using thermal storage, which "might [make it] possible to 'heat' comfortably an Airwall building even during central PA winters." For storage media, Duke proposed "Eutectic Salt Trays," plastic trays or similar containers, designed to "assist the transfer of heat to and from the air." Duke's letter confirmed that the major weakness of Hajjar's Air-Wall, which stored heat during the day for use at night, was something that could be solved by the engineer's proposal for thermal storage.

CONCLUSION AND FUTURE WORK

Although the history of the DSF is commonly associated with European architects and engineers, William Hajjar and his Air-Wall research team developed an adaptation of European DSF in central Pennsylvania probably in response to high energy costs. Double skin façades were generally designed to foster user comfort via better heating, better cooling, better insulation, noise reduction, and of course, aesthetical aspects. In the Air-Wall test building, however, the principal goal was to show that the system was able "to control the solar radiation load" (Air-Wall Proposal, 1961). Accordingly, Hajjar's idea of designing a utility core, here in the test building allowed him to have four rooms on each floor of the two-story double-skin glass box such that each room had a glass wall facing one of the cardinal directions.

In terms of architectural aspects, the test building that once stood on Penn State's University Park campus can be analyzed as a step in the development of the mid-twentieth century modern glass box, championed by Mies van der Rohe, Philip Johnson, and SOM, etc. Although the purpose of this paper was to highlight Hajjar's Air-Wall as part of the history of the DSF, the Air-Wall can be studied in multiple ways: for example, in terms of glass as its traditional rigid form and its newer textile application as fiberglass, in terms of building types (office buildings and dwellings), or in terms of its nexus between air-conditioning and passive solar design and between transparency and comfort. Hajjar's archive in the Special Collections Library of Penn State consists of several documents related to various projects design and developed by A. William Hajjar, many of which related to the Air-Wall concept. This provides opportunities for further research on the part of our research group and other researchers interested in the development of the double-skin glass façade in the mid-twentieth century.

ACKNOWLEDGMENTS

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REFERENCES

"Air Wall Construction—A Means of Reducing Air-Conditioning Loads," *ASHRAE Transactions* Vol.74 (1968).

American Blower Corporation, (1930) Letter to Le Corbusier dated January 24. Foundation Le Corbusier, Paris.

"A Proposal for Additional Observations on the Air Wall Principles" from February 17, 1961. A. William Hajjar Architectural Drawings, PSUA 9399, Special Collections Library, University Libraries, Pennsylvania State University.

Banham, Reyner. *The Architecture of the Well-Tempered Environment.* Chicago: The University of Chicago Press, 1969.

Bryan, Harvey J. "Le Corbusier and the 'Mur Neutralisant:' An Early Experiment In Double Envelope Construction." *Architecture and Urban Space*, Proceedings of the Ninth International PLEA Conference, Seville, Spain, September 24-27, 1991, edited by Servando Alvarez et.al. Dordrecht, Boston, London: Kluwer Academic Publishers, 1991.

Coogan, James H. (1960). Letter to *Architectural Forum* dated September 30. A. William Hajjar Collection, Special Collections Library, University Libraries, Pennsylvania State University.

Duke, Charles E. (1978). Letter to Mr. A. William Hajjar dated October 25. A. William Hajjar Architectural Drawings, PSUA 9399, Special Collections Library, University Libraries, Pennsylvania State University.

Fernandez, Vanessa. "Preservation of Modern-Era Office Buildings and Environmental Controls." *APT Bulletin: Journal of Preservation Technology* Vol.42, Nos. 2-3 (2011): 21-26.

Fortmeyer, Russell, and Charles D. Linn. *Kinetic Architecture, Designs for Active Envelopes.* Austria: Image Publishing, 2014.

Hajjar, A. William. Architectural Drawings, PSUA 9399, Special Collections Library, University Libraries, Pennsylvania State University. https://www.libraries.psu.edu/findingaids/9399.htm

Kragh, M. "Building Envelopes and Environmental Systems." Paper presented at *Modern Façades of Office Buildings* Delft Technical University, the Netherlands (2000).

Lang, Werner, and Thomas Herzog. "Using Multiple Glass Skins to Clad Buildings." *Architectural Record*, July 2000. http://www.archrecord.com/CONTEDUC/ARTICLES/7_00_2.asp.

Le Corbusier, *Precisions on the Present State of Architecture and City Planning,* translated by Edith Schreiber Aujame. Cambridge, Massachusetts, London: The MIT Press, 1991.

Poirazis, Harris. *Double Skin Facades for Office Buildings*. Lund, Sweden: Department of Construction and Architecture, Lund University. 2004.

"The Schools and Architectural Research." *Journal of Architectural Education*. Vol. 1, Architectural Research (Spring, 1947): 25-39+42.

Southall, L.M. Diaz, R. "Le Corbusier's Cite de Refuge: Historical & Technological Performance of the *Air Exacte*." Paper presented in *Le Corbusier, 50 Years Later*, International Congress, Universitat Politecnica de Valencia, 2015.