From *l'Air Exact* to *l'Aérateur*: Ventilation and its Evolution in the Architectural Work of Le Corbusier

HARRIS SOBIN
University of Arizona

Le Corbusier's mature modernist architecture evolved through three distinct periods: a Purist or "High Tech" phase of the 1920s; a Transitional or Reassessment phase of the 1930s; and a Primitivist or "Low Tech phase from 1945 to 1965. From an environmental control standpoint, each of these periods was characterized by a focus on innovative and prototypical design solutions for a single, primary environmental "topic", "theme" or problem. For each period, the primary "theme" or "topic" changed from light (Purist period) to heat (Transitional period) to air and ventilation (Primitivist period). It can be shown that for each of these periods, Le Corbusier developed both a building envelope system and an iconic element that "solved the particular "theme" (or range of environmental problems) which characterized the preoccupations of that period. These solutions were generally additive, that is, the acquisitions of a prior period would persist into the next, at times leading to direct conflict with one another.

Throughout his career, it was characteristic of Le Corbusier to break an overall architectural problem into its constituent parts, then develop designs in which each element represented the solution to that particular part of the overall problem. Thus, for each of these primary environmental "themes" or "topics", Le Corbusier would typically develop an environmental symbol or iconic/totemic element, a sort of architectural "objet-type." These elements include the fenêtre en longueur (ribbon window) of the Purist period, the brise-soleil (sun breaker) of the Transitional period, and the aerateur (pivoting air-vent) of the Primitivist period. Each of these symbolic elements, while originally intended to be functional in character, also powerfully exemplifies, at a scale smaller than that of the building in which it was used, the environmental "theme" which marks each distinct period of Le Corbusier's modernist architectural work. The way in which each of these elements was developed and implemented provide evidence, at that smaller scale, of the doctrinaire, rigid and absolutist attitude toward the design process which characterized Le Corbusier's approach throughout his career. They also demonstrate his exceptional capacity for adaptation, transformation, assemblage and iconic creation.

It is the intention of this paper to explore the background and evolution of the concept of ventilation in Le Corbusier's architecture, and the systems and eiements through which it was implemented, ending in the Primitivist phase with the development of the undulatory window wall and the device to which Le Corbusier gave the name "l'aerateur."

"MANUFACTURED EXACT AIR" : 1920-1928

Le Corbusier's work of the 1920s showed a bold, innovative, and aesthetically influential strategy for handling the environmental issue of natural daylighting; his work of the 1930s a new approach to solar control. By contrast, the way in which he dealt with the issue of ventilation in buildings during both of these periods involved two diametrically opposed strategies, one purely mechanical but manifestly utopian, the other commonplace, conventional, but naturally powered. At this early stage in Le Corbusier's mature career, ventilation as an environmental issue was in fact relegated to a very low level of overall priority. Ventilation was to be dealt with either by relying on resolutely traditional and natural methods (for residential buildings or other small-scale projects using conventional operable windows), or by total mechanization (in large-scale projects by means of then-unbuildable air-conditioned and hermetically sealed buildings). The focus, during this period, clearly remained on the daylighting or sun lighting of interiors. In 1929, Le Corbusier underlined this attitude, announcing that *"**la fenêtre est faite pour eclairer,*** non pour ventiler" ["windows are for light, not ventilation;" emphasis is Le Corbusier's].' During this early "High Tech" period, the machine constituted Le Corbusier's main metaphor for architecture, and it was not until after World War II that the theme of "ventilation" would emerge in his work as an aspect of architecture worthy of transformation into an environmental element, to be expressed as a separate, visible, architectural "statement."'

In the smaller-scale projects completed in the 1920s, two different types of operable windows were used, i.e., casement-style steel sash, or sliding wood windows. Casement type operating sections were by far the most common type

of operable windows utilized in this period. These usually appear either as vertical panels within large areas of the *pan* de verre (glass window-walls), or as one-piece operable sash, in square shaped "punched" openings which occur in solid walls. The casement style also appears in the form of single tall and narrow vertical operating panels, inserted at intervals within runs of otherwise fixed industrial vitrage d'usine ("factory", or greenhouse glazing), made up of closely-spaced vertical steel T-section mullions.

This industrial glazing is the same kind of window wall the architect would use in his Citrohan house projects, as well as most of his villas of the 1920s. A variant on this type (for which Le Corbusier took credit) as to separate a single, operable, glazed panel from its usual location amidst a wall of such fixed industrial glazing, and using it as an isolated element placed within a tall narrow slot. It would be punched in an area of solid walling, a window-type usually reserved for areas requiring privacy but relatively little light, such as toilet rooms, bathrooms or stair-wells.

For large-scale projects, Le Corbusier by 1928 was advocating the use of two technically sophisticated mechanical systems: the *mur* neutralisant ('neutralizing wall') and 1'air exact (occasionally and interchangeably described as respiration *exacte).* Air exact was an elementary form of closed-circuit air conditioning, invented by the French engineer Gustave Lyon, and designed to provide correctly humidified air at exactly 18" C. (64.4" F.) in all seasons.[3] The former was adapted by Le Corbusier from double-glazing systems traditionally used in areas of Europe with extreme winter weather, such as Switzerland or Russia. It consisted of a double layered cavity wall (glazed or opaque), filled with fast-moving hot or cold air depending on the season. This moving air was to be blown vertically between the two layers of the double wall from a central machine room.

Le Corbusier advocated these systems as the means for rendering the "glass box" habitable in all climates and seasons, providing the perfect machine age environment not only in Europe but everywhere on the globe. This claim was clearly based on a thorough misunderstanding of the physical principles involved. For example, neither doubling of a glass wall, nor a flow of cooled air between the two layers could have had any appreciable effect in reducing radiative transmission of solar heat into building interiors. Rather than detecting any flaws in these concepts, the architect proposed using the systems for two of his major large-scale projects in the late 1920s: a dormitory/shelter for Paris, and a major governmental office building for Moscow.

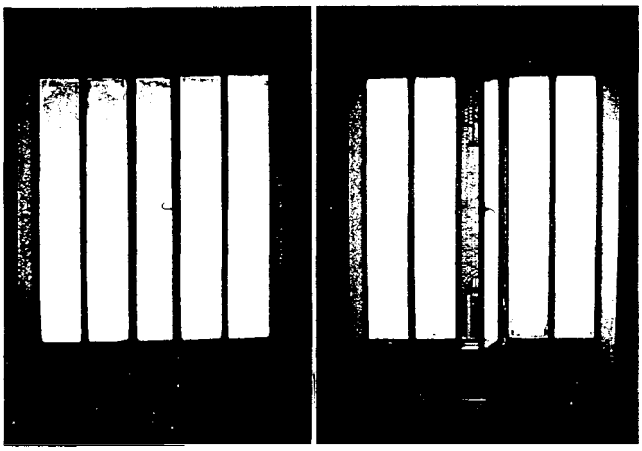


Fig. 1. Le Corbusier, Villa La Roche, Paris, 1923: Vitrage d'usine (factory glazing), with operating panel closed (left) and open (right). (Photos: H. Sobin).

The clients for both projects balked at anything as radical or experimental as the sort of totally manufactured indoor climate Le Corbusier proposed. One of the buildings (the Centrosoyus building in Russia) was built without incorporating either of the two mechanical systems, but included the double curtain wall (including operable sections).[4] The other building, the Salvation Army Shelter in Paris, was built without either the second glass skin (for the mur neutralisant) or the refrigerated cooling coils (for the air exact). As executed, however, the building retained its 10,500 square feet of south-facing single glazing containing only four very small operable sections. Nothing else was modified to compensate for either of the elements of the original design which had been omitted from the executed project. The building appeared to be an environmental success at its inauguration during the particularly cold winter of 1933-34. But by the following summer, serious environmental difficulties had developed: the hermetically sealed all-glass, south-facing wall turned the building into an unventilated inferno. After a long and bitter legal battle with both clients and the Paris Prefecture, Le Corbusier was officially ordered, in March, 1935, to incorporate 41 more operable sections in the south facade.[5] This experience undoubtedly encouraged the architect to accelerate his development of the *brise-soleil* device (a development underway since 1933). But it also must have served as a reminder of the critical importance of ventilation in buildings: *l'air* exact and the mur neutralisant henceforth gradually disappear from his later writings and projects.

"INTO THE WOODS": LE CORBUSIER'S REDISCOVERY OF NATURE: 1929-1945

By the beginning of the 1930s, Le Corbusier (and modem architecture in general) had experienced two serious rejections in major international competitions: the League of Nations (1927-29) and the Palace of the Soviets (1931). The same years brought a major stock market crash (1929) and the start of the Great Depression. With these factors furnishing the economic and professional context, the architect appears to have begun to lose faith in his earlier machine-oriented philosophy, and in Reyner Banham's phrase, Le Corbusier "took to the woods."[6] Parallel to this loss of faith in the machine, there is evidence of a new awareness of the human body and organic form in his painting. His architecture also began to change, shifting away from a reliance on

mechanical solutions toward a greater acceptance of working with materials readily at hand. Hermetically sealed, heavily-glazed designs, using utopian high tech mechanical systems gave way to passive methods, allowing for more interaction between building interiors and the natural environment. Rough surfaces and natural materials increasingly took the place of smooth machine-made finishes. Thin, tightly stretched planar elevations were replaced by more complex, sculptural facades, forming a protective transition zone between inside and outside.

Le Corbusier now began to travel widely, often to some of the world's pre-industrial or less developed regions. Soon his writing, and then his architecture, began to reflect an almost obsessive interest in the vernacular building traditions of "primitive" cultures and regions, particularly in their use of form, and approach to environmental issues. Of special importance was a series of visits to North Africa, including Morocco, Algeria and Tunisia, in 1931-1936. Observations made on these visits once again caused Le Corbusier to begin to question architectural solutions for generalized, world-wide application, and to start to realize that an International Style might not call forth an International Climate! What he saw in North Africa suggested that a design approach suitable for hot climates and developing regions should consider the use of architectural methods of climate control. In particular, the Saharan oases and medinas were an absolute revelation, revealing the existence of a world of poetic replies to the question of how to create livable human environments in a harsh desert by simple non mechanical means. These observations were soon to find their echoes in Le Corbusier's own projects, including three unbuilt but influential projects in the mid-1930s for Algeria, plus another project in that colony, executed in wartime.' During the second world war, the resources of the highly industrialized economy of France were reduced to the level of a preindustrial society. Responding to the limitations of that context in 1942, Le Corbusier designed a self-build system, called the Murondins, for refugee housing and schools, using thick walls of sun-dried adobe blocks or pise, and grass-covered sod roofs supported by branches over rough log beams. These structures would have relied entirely on simple wood stoves, and natural ventilation.

REESTABLISHING THE CONDITIONS OF NATURE: 1946-1965

By 1945, Le Corbusier's philosophy of the 1920s had undergone an almost complete transformation. He had by now come to consider himself "an enemy of air conditioning", and had come to believe that the unchanging quality of environments provided by mechanical systems was actively unhealthy.[8] In the postwar years, Le Corbusier attempted to synthesize his new philosophy and the technical acquisitions of the 1930s into a more fully integrated kind of architectural environment which was more nature-oriented, able to take advantage of the challenges of a randomly varying natural environment, and far more capable of responding to that environment and to its occupants' needs without relying on expensive machinery than his earlier "High Tech" projects. He summarized this new attitude in 1953:

> To offset the effects of sedentary city life we need contrasts of various sorts — heat and cold, sun and shade, etc. — reaction to which provides an endless source of energy and vitality. Nothing is more dangerous than an absolutely uniform environment. Living in cotton wool...when you get up and open your door, you should be greeted by just that little shock of change, whether it be pleasant or unpleasant, which jolts you physically and mentally, providing a natural reaction...[9]

These sentiments indicate that a radical change has taken place in the architect's thinking, when compared to his earlier advocacy of a totally manufactured climate.

One of the first opportunities to apply these new ideas came in 1945, when Le Corbusier was commissioned by the Ministry of Reconstruction to design, at Marseilles, a large-scale collective housing prototype for postwar France. Completed in 1952, the Unite *d'Habitation* at Marseilles was the first project of Le Corbusier's to be built after the war, and the first executed example by Le Corbusier of the *brise-soleil* concept. A bureau *d'études* was set up for the project, possessing the sort of engineering expertise needed for a project of that magnitude. Its up-to-date HVAC design included mechanical exhaust for bathrooms and kitchens, connected to two main evacuation updraft ducts which terminated at the roof deck in prominent, funnel-shaped, concrete *cheminées* de ventilation which contained the exhaust fans.

The Unite also included a simple forced-air heating system, using a simple type of diffuser called the *Véga*, a patented device produced by the French HVAC firm, Etablissements Neu. The device is similar in concept and size to the type of adjustable air nozzle used today in the passenger compartments of commercial jets. An adjustable finned metal "spider" is pivoted centrally within a framed circular air delivery opening, linked to that frame via a

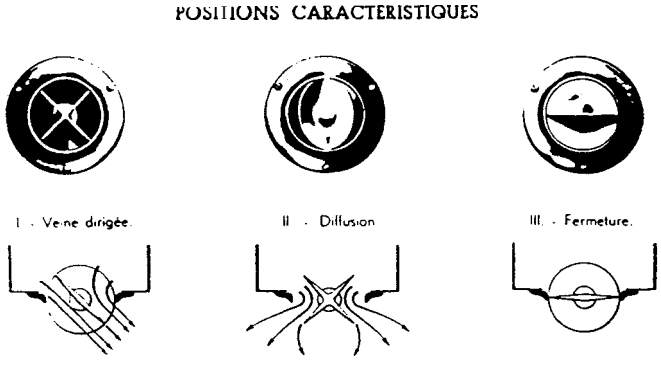


Fig. 2. *Vega* diffuser: typical operating positions (Ets. Neu catalog).

flexible ball-joint. The spider is adjustable to modify airflow in any one of three ways: either directing the aiming angle of a single jet of air; splitting the main jet into two jets, one on either side; or closing off airflow entirely.

In the early months of 1951, within a year of completing the Marseilles project, Le Corbusier began a long-term contract as chief architectural consultant for the design and construction of Chandigarh, a new capitol for the newly-formed state of the Punjab in northwest India, a contract which called for him to make two trips to Chandigarh a year. Besides the overall city plan, his work included the design of four major government buildings, two museums, and two university buildings.

Once again, as with his visits to North Africa in the early 1930s, the total, immediate and very personal experience of a face-to-face contact with a hot climate encouraged Le Corbusier to undertake a sequence of observation, experimentation, and analysis, leading to a design response. Staying at the Taj Hotel in Bombay, in November, 1951, while at the start of his second bi-annual visit to India, he conducted a series of experiments on the beneficial cooling effects of airflow, gauging the influence of various adjustments of door and window openings, using his own bodily reactions as the "measuring instrument". His conclusions, summarized in several sketches, was to propose an innovative type of window wall made up of three different components These included (a) several ranges of large, operable solid wood panels, providing light when open and identified as "2" in the sketch; (b) a limited number of glazed "hole-in-wall" type windows and identified as "3" in the sketch, providing constant daylighting; and (c) a series of tall, floor-to-ceiling slots, narrow enough to qualify as "anti-theft", identified as "1" on the sketch and labeled as providing *"ventilation."*[10] This appears to be the first record of Le Corbusier's "invention" of a device which would soon become part of his standard design vocabulary, labeled as the *aerateur,* or "aerator."

Within a few weeks of his return from India, at the end of 1951, Le Corbusier was designing a one-room vacation *cabanon* for himself on the Côte d'Azur near Monte Carlo.

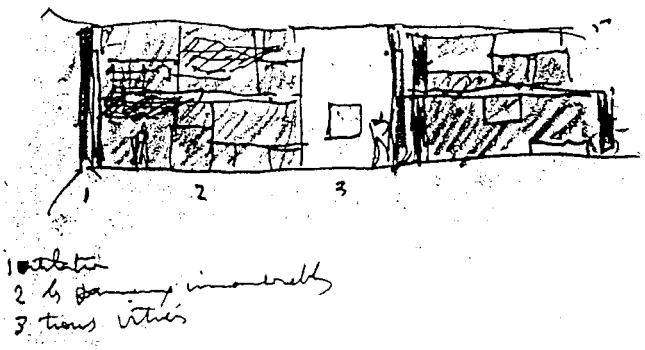
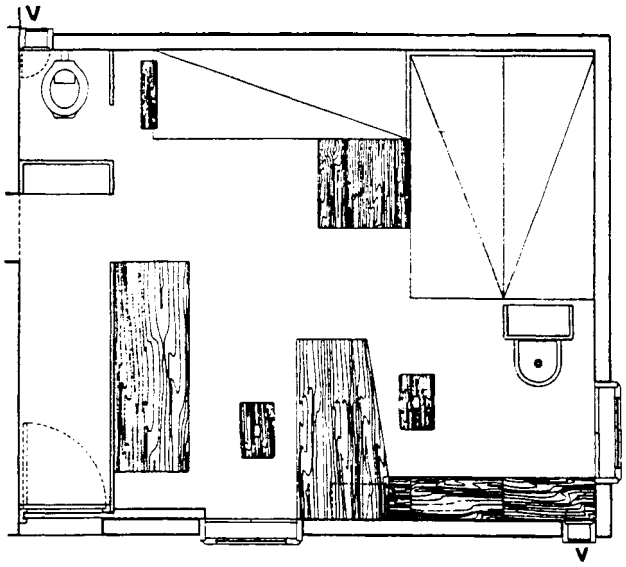


Fig. 3. Le Corbusier, notebook sketch dated 27 Nov. 1951, showing first record of "ventilation window" idea. The "1" indicates a typical "ventilation-slot" (Camet Nivola 1, p. 215, Fondation Le Corbusier, Paris).

It was in the design of this small unit that the tall, narrow ventilation slot, previously sketched in Bombay, made its next appearance: Le Corbusier appears again to have been "experimenting" on himself for the purpose of trying out new ideas. An early plan of this small hut, published in Volume 5 of the *Oeuvre complete,* along with photos of the completed structure, showed two of the devices, placed at diagonally opposite comers of the space. The devices are identified in an accompanying text as ***ventilations-moustiquaires*** (fly-screened ventilators). The text goes on to add that the devices had "met all expectations...the system will henceforth be applied in India for both public and private projects"." Each of the *dements verticaux de ventilation* (vertical ventilation elements) is labeled on plan with small bold-face "V's", and described in a legend as *fenêtres* ***de*** *ventilation* (ventilation windows). Hinged to the interior vertical edge of each slot is a full-height solid wood panel or door, for closure. The implication is that this arrangement would, through the use of the simplest means, provide a perfect cross-ventilation in rooms, even in the more challenging climates of India.

Le Corbusier has by now effectively "appropriated" the shape and (in part) the function of these "ventilation windows" from his own earlier use of narrow, vertical, casement-types of operable elements, elements initially borrowed from the example of 19th century *vitrage* d*'usine* (factory or greenhouse glazing). A major change from its earlier use, however, is that the element is now *solid,* rather than transparent, helping to clearly distinguish or separate it visually from light-giving elements of the facade.

If, as he said in 1929, "windows are for light, not ventilation," Le Corbusier had, by 1952, evolved what could



Le plan du Cabanon. V = fenêtres de ventilation

Fig. 4. Le Corbusier, plan of Cabanon, Cap St. Martin, 1952, showing *fenetres de ventilation* (ventilation windows) at each comer of the one-room structure *(Oeuvre complete,* 1946-1952, p. 79).

be, within his philosophy, an appropriate element for ventilation. Openable, it could provide ventilation to building interiors. And as a solid element, it was clearly legible as something distinct from a light-giver. On a modest scale, this exemplifies Le Corbusier's philosophy of unraveling, or separating out, the functions of architecture, then giving visual expression to each distinction by isolating as independent elements the individual components of a building (as here, even the components of the wall), seeking a different form for each function.

The ventilation window made its next appearance in the first of Le Corbusier's major buildings for Chandigarh, the High Court of Justice (1951-54).[12] In the High Court, they are conceptually similar to those used at the Cabanon, only taller (7'-5" from floor level), but maintaining the appearance of a narrow side-hinged flush wood door, located in a wood frame. It is clear that by about 1953-54, the "ventilation window" had become a standard constituent element of Le Corbusier's architectural vocabulary. From this time forward, the "ventilation window" appears in each of his major projects, whether or not the building is located in the tropics. In later projects, this element is often painted in bright colors, to call attention to both its opacity and its iconic qualities.

Its first application in a non-tropical location was at the Convent of La Tourette (1953-1959) in southeastern France." In the period of 1955-56, when intense design development was taking place on the La Tourette project, a group of other projects including the Maison du Bresil for Paris (1955-57), and the next Chandigarh project, the Secretariat (1952-57) were in more or less simultaneous design development. It was during this period that several important advances, offshoots and variations occurred in both the ventilation window and the *pan de verre* (window wall) themes.

The progressive changes in the concept of the ventilation device can be seen in a sequence of two successive detail plan-section drawings for typical window walls of the individual monks' cells at La Tourette. The earlier drawing, dated 12 September 1955, shows a tall (2 m 08) vertical, square element (27 cm x 27 cm on plan), labeled *"fente de ventilation en bois ou tôle pliée"* (ventilation slot in wood or sheet metal). The square element contains a hollowed-out, cylindrical interior within which rotate two airfoil or wing-shaped blades, spaced apart from each other and supported by a pivoting, star-shaped spacer or "spider" at the center. Pivoting the inner, drum-like component would have provided a more precise control of the volume of airflow than that possible with the earlier, more primitive "side-hinged flap" version. This amazingly sophisticated "drum" version of the ventilation window also appears to the author to represent another significant advance. Because its movable element is located *within* the opening, rather than *beside* the opening, the new design would allow the user to "steer", or direct the angle of airflow coming from the device and into the room. The quality of directional airflow control is reminiscent of the characteristics of the *Vega* diffuser, used by Le Corbusier in the Marseilles Unite (a *Vega* was installed in his office at 35 rue de Sevres, and he was photographed adjusting it about 1952).

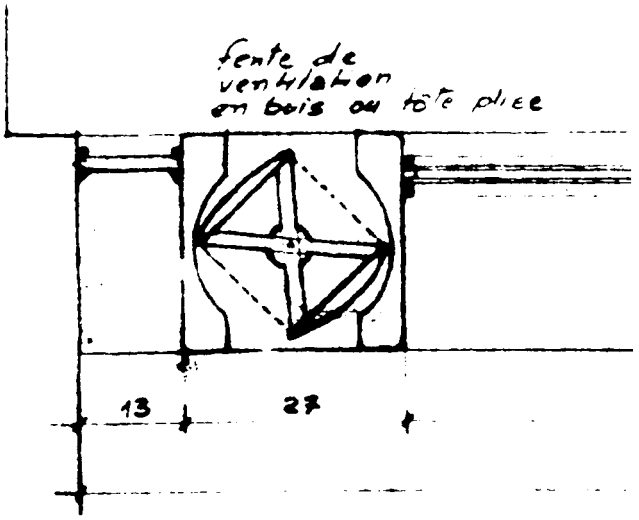


Fig. 5. Le Corbusier, Couvent de la Tourette, Eveux, 1959: detail showing "drum"-type ventilator, drawing dated 12 Sep. 1955 (FLC 988).

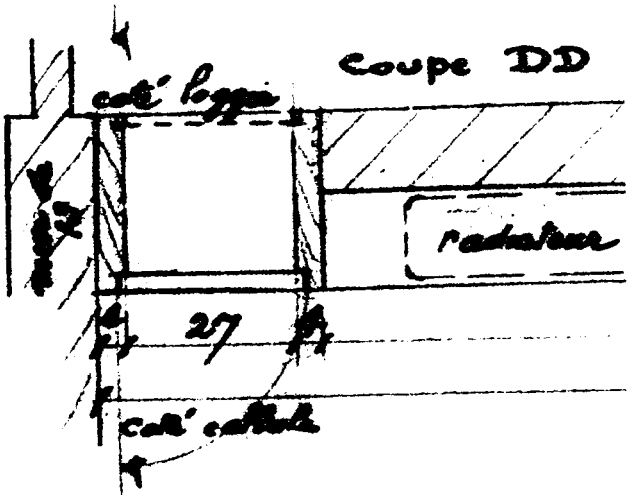


Fig. 6. Le Corbusier, Couvent de la Tourette, detail showing 'side-hinged' type ventilator, drawing dated 17 July 1956 (FLC 987).

Within 10 months, the first drawing was voided and replaced by a later drawing, dated 17 July 1956, showing a simple "side-hinged" flap, opening inwards into the room, and labeled "ventilation door." Probably because of cost considerations, Le Corbusier had pulled back from the more sophisticated earlier scheme, reverting to the simpler, "Cabanon" or side-hinged flap type of ventilation window, not only for the monks' cells, but also for most other locations in project.

In the early part of 1955, the Atelier Le Corbusier redefined the window-wall idea itself, in the form of the so-called *pans de verre ondulatoires* (undulatory window wall). This system was henceforth used in main public spaces of

Fig. 7. Le Corbusier, Couvent de la Tourette, interior of refectory with *pan* de verre ondulatoire; two (open) aerateurs are visible (Oeuvre *complète, 1957-1965*, p. 44).

buildings not protected by *brise-soleil*. The system consisted of full length fixed glazing, held in place via vertical concrete *bâtis* (precast struts or mullions), spaced out in ratios based on musical proportions and Modulor dimensions. At intervals, between selected pairs of struts, "ventilation windows" were inserted.[14]

By early 1957, Le Corbusier had begun to use the invented word of "aerateur" to refer to his ventilation windows. And at this time, a third type of aerateur was under development for the La Tourette project at the Atelier. This unit measured 3m 66 high by 26 cm wide, of brake-formed, unpainted aluminum, with a combination wood stiffener and handle at handrail height, and with the unmistakable shape on plan of an open-sided airfoil, vertically and asymmetrically pivoted. The general configuration of this aerateur represented a return to the concept of the "drum" type of unit previously tried (and rejected) in 1956: that is, a type in which the movable element is located within the opening, and not to one of its sides, allowing it presumably to shape the direction of airflow into the room. This "aluminum airfoil" type of *aérateur,* which managed to combine the "primitive" technique of natural ventilation with a machine-age shape and finish, was reserved for major public spaces, usually within areas of ondulatoire glazing. The aluminum airfoil type was also utilized in two of the buildings under design for Chandigarh, as well as in the main refectory at La Tourette.

Several of Le Corbusier's late projects utilized the asymmetrically pivoted type of aerateur, including two more

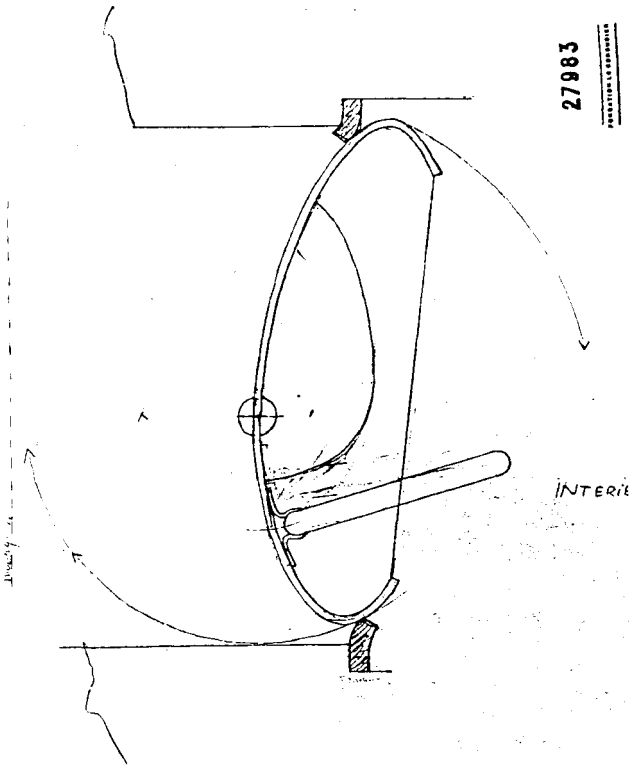


Fig. 8. Le Corbusier, aluminum 'airfoil' or wing-type *aérateur*; plan-section, showing curved wood stiffener/handle, cane-bolt to lock wing into position, and '3rd-point' pivot (circled) (FLC 27983).

major buildings at Chandigarh, the Secretariat (1952-1957), and the Assembly (1952-1960), the Maison du Bresil (student housing) at Paris (1954-1957), and Carpenter Center for the Visual Arts at Harvard (1959-1963).[15]

As the key component in an overall comfort ventilation system, the *aérateur* reached the zenith of its development in the Chandigarh Secretariat. Built without air conditioning, (except for the ministerial suites), natural ventilation was even more critical to the building's environmental success. ***Aerateurs*** were liberally placed in the exterior ***ondulatoire*** glazing on both facades of the building. But there remained the problem of creating good airflow through both banks of office accommodation either side of the central, double-loaded corridor, while still preserving sufficient acoustic privacy between the corridor and the offices. The final design, arrived at with assistance from the acoustical consulting department of Philips Lamp Co., utilized special fixed ***aerateurs*** for use along the corridor walls. These consisted of 43 cm wide openings, equipped with sound-baffles in the form of "H's" on plan, with their interior surfaces lined with thick, sound absorbing material.[16]

CONCLUSIONS

In that portion of Vol. 7 of the ***Oeuvre*** *complète* devoted to the Secretariat, Le Corbusier includes a short description of the ***pan de verre ondulatoire.*** Written shortly before his death, it reads as an "environmental last testament", summing up what he has learned about environmental factors (especially ventilation) and their control." This text portrays the undulatory wall as the definitive answer to what Le Corbusier describes as "the problem of the window", fulfilling as it does the three necessary functions of the environmental envelope:

(1) *éclairer* (to light);

(2) ***aerer*** (to air);

(3) *ventiler* (to ventilate).

Le Corbusier then goes on to explain how the undulatory wall fulfills each of these missions:

(1) (Day)lighting is achieved by nonoperable ***pans de verre,*** glazed with clear or translucent glass, fixed into concrete;

(2) ***Aeration*** is obtained by means of "vertical full height ***aerateurs,*** or aerators, 27 cm (11 in.) to 43 cm (17 in.) wide, capable of being opened gradually, as desired, over their full height, providing an immense natural cross-ventilation, powered by differences in air density as between one facade and another, caused by temperature differences during the course of the day, depending on the position of the sun."

(3) Ventilation, to be obtained "during hours of extreme heat in the tropics: we must counter the effect of air temperatures in excess of body temperature, by means of a powerful ***Courant d'air,*** provided by fans placed on the floor or suspended from the ceiling".

This text does represent a real advance in Le Corbusier's attitude toward ventilation, demonstrating that he has now realized that the concept actually involves two very separate functions. Yet here we have another, final example of the rigid, almost obsessional way in which he categorizes functions, designs an element to satisfy each function, then gives each element its own distinctive form and expression. *"**Aeration**"* is so narrowly defined by Le Corbusier that the element designated to provide it, the ***aerateurs,*** can only be used to provide what amounts to dilution ventilation, and is not thought of as useful to create air movement for direct body cooling. By the same token, ventilation, or what amounts to cooling air movement, is only to be provided by fans (which are not even a component of the ***ondulatoires!).***

As used by the Atelier Le Corbusier, the vertical ***aerateur*** remains more effective as the exposition or expression of a principle than as a real solution to the specific problem of natural comfort ventilation in buildings. When used as Le Corbusier used it, solely as a vertically-oriented inlet device, the *aérateur* typically creates a narrow pattern of airflow on plan.[18] If the device is located near or adjacent to an interior cross-wall, the jet of incoming airflow will adhere to that wall, due to relative pressure differentials. Either result may often, of course, be preferable in cool or cold climates (e.g., France) or seasons, as it permits dilution ventilation without undesirable drafts. But in warmer climates, a more even pattern of distribution is desirable, across as large a proportion of interior spaces as possible. From a functional standpoint, this suggest that if oriented horizontally rather than vertically, an ***aerateur*** would be more effective as a provider of comfort air movement; but this would have violated the repetitive, purely vertical rhythm of the undulatory wall.

In tracing the evolution of ventilation concepts in Le Corbusier's career, we can see, at a scale smaller than that of the buildings themselves, that the same kinds of dogmatic, absolutist, rigid and ideological thinking was at work, just as it was with other aspects of his design process. In the case of the ***aerateur,*** just as with other design elements, what begins as a building component based on an originally environmental rationale, comes to have independent aesthetic status, that is, it becomes a symbol, formalized into a "design statement" or a convention, quite detached from its original rationale.

From an early focus on the machine as a model and metaphor for architecture, Le Corbusier's work progressed to the use of increasingly naturally-based solutions. It may also be said that Le Corbusier's evolution of environmental elements such as the *fenêtre* ***en longueur,*** the *brise-soleil* and the *aérateur,* all helped focus the attention of a whole generation of architects world-wide on the need to achieve thermal comfort wherever possible by natural and architec-

tural means. By these means, he also helped dramatize the importance of creating architectural environments capable of facilitating and reestablishing the essential contact between ourselves and the natural world, of seeking a greater sense of unity for architecture with respect to both human needs and natural forces, and elaborating an aesthetic of clearly legible forms capable of giving visual expression to architectural functions, human needs and natural forces.

NOTES

[1] Le Corbusier, *Precisions sur en etat present de l'architecture et de l'urbanisme* (Paris, 1929) 56.

[2] The concept of "ventilation", be it mechanical or natural, is associated with two major functions in architecture: (I) "code, or "dilution ventilation", concerned with the control of smoke, odors, dust and allergens; or (2) "comfort air movement", concerned with reducing dry bulb temperature (through cooling of the building fabric) or effective temperature (through direct cooling through airflow of the surface of the body). It is not clear if Le Corbusier fully understood the distinction between these two functions before the Chandigarh projects of the 1950s, at which time he began to confront both of these ventilation-related issues with the help of Andre Missenard, a French HVAC engineer, qualified thermal physiology expert and mechanical consultant.

[3] Le Corbusier, *Precisions* 64 ff.

[4] Jean-Louis Cohen, *Le Corbusier and the Mystique of the USSR: Theories and Projects for Moscow,* 1928-1936 (Princeton, 1992) 88-92.

[5] Reyner Banham, *The Architecture of the Well-tempered Environment* (Chicago & London, 1969) 155-162.

[6] Harris Sobin, "Le Corbusier in North Africa: the Birth of the Brise-Soleil," *Desert Housing,* eds. *K. N.* Clark and P. Paylore (Tucson, 1980) 153-173, at 153.

[7] Sobin, "Le Corbusier in North Africa," 157-159, 165-166.

[8] Le Corbusier, Carnet Nivola 1, Fondation Le Corbusier, Paris, 181 (entry dated 23 mars 1951).

[9] Le Corbusier, L'*Unite d'Habitation de Marseille* (Mulhouse, 1950), trans. G. Sainsbury as *The Marseilles Block* (London, 1953) 24-25.

[10] Le Corbusier, Carnet Nivola 1, 215 (entry dated 27 Nov. 51).

[11] W. Boesiger, *Le Corbusier, Oeuvrecomplete* 1946-1952 (Zurich, 1953) 78-79.

[12] W. Boesiger, *Le Corbusier, Oeuvrecomplete* 1952-1957 (Zurich, 1957) 56-77.

[13] W. Boesiger, *Le Corbusier, Oeuvrecomplete* 1957-1965 (Zurich, 1965) 32-53.

[14] Boesiger, 1957-1965, 78.

[15] Boesiger, 1957-1965, 78-101, 200-201.

[16] Le Corbusier, interview with author, Paris, 30 September 1961; author's personal observations, Chandigarh, April, 1962.

[17] Boesiger, 1957-1965, 100.

[18] Harris Sobin, *Analysis of Wind Tunnel Data on Naturally Ventilated Models, Appendix A: Test Data Catalog* (Tucson, 1983), at test VE 40 [VE022 MID AER 0 / VE 022 MID] of 141 8/66.