A FACTORY FOR WELL-BEING", INNOVATION IN THE HEATING SYSTEM AND THE CURTAIN-WALL IN LE CORBUSIER'S SALVATION ARMY "CITY OF REFUGE", PARIS 1933.

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The Salvation Army's "City of Refuge", built in Paris in 1933 by Le Corbusier, materialized a social utopia. Conceived as an airtight controlled environment, this building introduced into a socially aware context the technological systems later found in upscale building and system programs such as luxury hotels and cruise ships.

Le Corbusier wanted to implement two theories he developed at that time: the "neutralizing wall" (a double-glazed façade with an air cavity that can be heated or cooled) and the "exact breathing" system (a purified circulating air system at constant temperature), in what was planned to be a "factory for well-being." [1] As demonstrated in our research, the "neutralizing wall" was never truly considered for this project. The architect quickly replaced it with a single curtain wall, one the first built in Europe. On the other hand, he maintained a reduced version of the "exact breathing" system. The logic of these systems remained mostly coherent in spite of the budgetary cuts.

On the occasion of a forthcoming restoration, we had the opportunity to carefully study the technical aspects of the design, especially the glass façade and the heating system, by searching the building and the archives building on the research made by B. B. Taylor[2]. Our conviction is that the building conservation programme should not only concern the visible aspect of architecture but also the conception of the environment and its control. In other words, the devices and machines that enabled the building to function are also worth preserving. This paper will examine the heating and ventilating systems in conjunction with that of the glazed envelope, as they reveal the social, financial, and technical limits of the building's design and help highlight its transformation.

Le Corbusier developed several utopian urban projects between 1922 and 1935 based on multistory blocks disposed on open ground such as the "project for a contemporary city", the "plan Voisin" for Paris, and the "linear city". In all of them, he imagined glazed buildings facing all orientations except North. To him, the glass façade enabled one to triple the width of the building and thus open up ground distribution and networks: it was the key element of the contemporary city. Adapting this conception to the Parisian context, he disposed the different parts and functions of the City of Refuge in a very original manner. He implemented the main block perpendicularly to the street, clearing a complete glass façade facing South. This unique envelope sheltered various functions, such as a childcare center, individual

rooms, and dormitories, linked by a very efficient circulation. The idea of multi-purpose buildings, that he will develop later in his work, found here one of its first expressions. At the lower levels, the succession of low volumes, the porch, the rotunda, and the annexes, are articulated along the sequence of entry, spanning the passage between interior and exterior. They contrasted with the vertical mass of the dormitories.

The glass façade

The large glass membrane (1,000 m²) accentuated the contrast between the different parts of the program. The choice of an airtight glass wall can be easily explained in the context of the 1930s, when the search for hygiene and the fascination for the machine were prominent[3]. Thanks to the greenhouse effect, the glass façade was an easy way to provide thermal comfort and save energy - the shortage of fuel during WWI was still in mind - as well as maximizing daylight. Eliminating the operable windows was a means to protect the interior of the building from atmospheric pollution due to the coal coming from the nearby railways, to prevent residents with fragile health from air draughts by keeping the inside warm. Glass was also considered a clean material. A kind of morality and social control was associated to transparency, which enabled sight of the interior of the building from the exterior. It provided little intimacy to residents, in spite of the different types of glass: frosted or clear in the central part of each floor depending on the program and the altitude, wired glass for the sills, and patterned glass for the clerestory. This monumental glass wall was technically possible thanks to the recent innovations in glass fabrication such as the Slinguff and Bicheroux process and the inauguration of a new Saint-Gobain factory near Paris in 1920[4].

As we mentioned above, no traces of a double glass membrane can be found in the archives, since the solution was probably eliminated for financial reasons. The curtain wall technology, chosen instead, was not developed in France at that time. Until then, it had been only used for department stores (notably in Nantes by Henri Sauvage in 1925) or workshops. Based on summary sketches made by the office in 1931, several firms tended for the construction. Two of them were retained, Menuiseries Métalliques Modernes (MMM) and Dubois & Lepeu (D&L), the latter in charge of the glass façade of the Swiss Pavilion in Paris. The fenestration contract was split into two: on one hand, “the large frame” attributed to MMM, on the other, the façade on Chevaleret Street, given to D&L.

The main difference between the two contractors laid in the profiles they used: the standard U, L, T and Z steel profiles for D&L, and a special steel drawn profile for MMM. The windows and locksmith elements were pragmatically distributed between the two enterprises, following imperatives of visual unity and cheapest cost, in spite of their apparent randomness. Originally developed for smaller windows, these profiles were adapted to the height of 3.20 m thanks to a frame of vertical steel stiffeners, distributed every 3.80 m. Each unit was divided twice vertically to match the 1.90 m width of each room and three times horizontally in modules of 1.06 m. The system is held at each floor by embedded bracket and covered by a sheet-metal coffer. Adding complexity, the curtain wall was inclined to respect the urban planning bylaws. Apparently, this curtain wall met the expectations of the users in terms of

solidity and protection against air and water, since no complaint appears in the archives, contrary to the D&L's frame, which had to be stiffened afterwards.

The solar and light protection was added after the client's complaints. Wooden sliding shutters, similar to those of the Swiss Pavilion, were implemented in the interior of the dormitories, and curtains were installed in the other rooms. The efficiency of these devices in terms of solar protection were insufficient. In 1944, a bomb destroyed the glass façade completely, giving way to a new façade project, made by Le Corbusier in 1950-52.

The heating system

In 1931, several companies, Leroy, Sulzer, Tunzini, Zaniroli, Castiaux, explored solutions for the central heating and cooling systems. Construction having already begun by this date, the location and size of the service spaces were fixed, including that of the two chimney flues and of the six ventilation ducts. Sulzer, Leroy and Tunzini proposed four different solutions, from traditional radiator heating to complete air conditioning systems[5]. In this last, very detailed proposal, the firm hoped to place a heating and cooling source in the basement, to filter the air coming from the roof, and to dispatch the warmed or cooled air throughout the building using ducts[6]. Air conditioning was rare in France before the war, and the attention given to the proposal reveals the firm's determination to implement its system[7]. The architect and the client chose at first Zaniroli and Castiaux[8]. They finally selected Castiaux, probably because the simplified system it proposed, at 470.000 francs, was the least expensive. By contrast, for their air conditioning systems, Sulzer had asked for 1.640.000 francs, Leroy 1.250.000 francs and Tunzini 978.000 francs. As B. B. Taylor pointed out in his study on the building, these figures were out of proportion with the building budget that oscillated between 4 and 5 million francs[9]. After Castiaux faced financial difficulties, the Compagnie de Chauffage par le Vide, or CCV, took over the project[10]. It implemented a sensible solution that privileged mixed heating: a vacuum-driven, low pressure steam circuit fed cast iron radiators directly and, indirectly, forced air heaters. Although known in France, vacuum-driven low pressure steam heating, common in tall buildings in the United States, was rarely used[11]. Mechanical hot air heating deployed at the Salvation Army was unusual in French residential buildings, even if it had been known since the eighteenth century, although one did find it in factories[12].

Le Corbusier's idea of heating his building with warm air at a constant temperature in order to minimize cold drafts also originated in France. In 1777, Jean-Simon Bonnemain, the inventor of hot water heating system, had first implemented this system for hatching eggs and rearing chickens in all seasons, a task that required constant temperatures. Le Corbusier apparently followed the recommendations of the marquis de Chabannes who, in his first book on heating of 1815, stressed "the purification of the air, the prevention of dampness, the equality of temperature and suppression of draughts of air"[13].

At the City of Refuge, eight steam heating circuits were planned but only four were implemented. Three oil burning boilers, a vacuum pump, and hot water tanks occupied the basement. The fresh air coming from the roof, after being filtered, was distributed by forced air heaters into the rooms. The larger spaces in the building (the

dormitories, the dining room, the hallways, the meeting room) were also heated by forced air heaters. The blowers were located either inside the space to be heated or underneath the floor with registers, as was the case in the circular entrance pavillon, the hall at the pilotis level, the meeting room, and the elderly women dormitory. The staircase was heated by two blowers placed on the first floor. The individual rooms for mothers and their children and the childcare centre were heated by blowers located at both ends of the corridors. The ducts were inserted into a counterceiling along the corridors and registers were placed in the wall above the door in the rooms. The offices, apartments, the room for supervisors, the room dedicated to the princess of Polignac (the principal donator) were equiped with standard cast iron radiators heated directly by steam. Most of these small spaces had opening windows.[14] The heating system seemed to function properly, even if the Salvation Army thought the consumption of oil and electricity was too important. Most of the issues, however, occurred during the Summer. [SHOULD INCLUDE REFERENCE TO AN ILLUSTRATION HERE]

The Problems

In the Summer, blowers disconnected from the heating system provided ventilation. Rooms were thus given fresh air, although Le Corbusier suspected that the Salvation Army saved electricity by shutting down the blowers. It remains unclear how the air circulated in the large spaces, such as the dormitories. On floors 3 to 6, the individual rooms serviced by a corridor were ventilated by registers above the doors, creating a slight overpressure. The air left the room underneath the door to the corridor and exited the building through grilles set in the breast walls of the small courtyards. This system was apparently not sufficient. In the childcare centre on the 5th floor which, unlike the dormitories, operated during the day, the temperature could rise to 33°C. The replacement of the air conditioning system by forced air ventilation may have made sense financially but certainly did not technically.

Beyond technical issues, the negative reception of the hermetic wall can be explained from social and cultural points of view: the possibility of opening windows appeared necessary for some residents as it did to the administration. It might have been an expression of what is called now the sick building syndrome. Furthermore, one can easily imagine the problems that people with fragile mental states faced in airtight spaces.

The Salvation Army complained bitterly to Le Corbusier about the excessive heat, each party supported by its own team of experts. After numerous exchanges they decided to find a solution, consulting engineers proposed a water cooling system that unfortunately proved to be too expensive[15]. In the end, as claimed by B. B. Taylor, forty sliding Windows were opened in the glass wall[16].

The transformations

In 1950-52, Le Corbusier offered to repair the façade destroyed by the bombing, and designed a new façade were he experimented with concrete sunshades or “brise-soleil” that he developed notably in India. The frames were replaced by wooden windows with a small operable piece and a masonry sill. Disheartened by the choice of the façade colors made by the Salvation Army, Le Corbusier resigned from his

consulting position in 1952. Slightly modified during the 1975 renovation, the wooden frames were replaced by aluminum in 1988, and the sills were covered with aluminum sheet panning.
The original heating plant and the distribution networks have been totally destroyed at an unknown date. The implementation of the current radiator system negated the architectural qualities of the building. Since 1994, the City of Refuge is heated by the Parisian district heating system (CPCU) using low pressure steam . This technology might facilitate the return to a system closer to that used originally. Despite the destructions, it is still possible to find significant traces of the ventilation ducts around the building such as filled-up floors openings, grilles, and registers[17]. Those traces confirm that the original system was close to the technical specifications and the few changes described in the letters exchanged between the architect and the CCV. They point to a captivating history of technical innovation.

We hope that a better understanding of the innovative qualities of the original thermal conception of the City of Refuge will not only enhance our understanding of Le Corbusier as a master of Modern Architecture but also make apparent the necessity of a sensitive restoration of this important work to make available to future generations the architect's utopian vision.

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[1] Justin Godart (FLC J1-20-20)
[2] Brian Brice Taylor, *Le Corbusier, the City of Refuge Paris 1929-1933*, University of Chicago Press, Chicago, 1987
[3] Traisnel Jean-Pierre, *Le métal et le verre dans l'architecture en France, du mur à la façade légère*, Thèse de doctorat, Paris 8, 1997.
[4] Carré-cousaris Anne-Laure, *Construire en verre : de nouveaux matériaux pour l'architecture, 1881-1937*, Thèse de doctorat, Paris 4, 1998.
[5] Those three firms were very well known at that time, there were member of the Union Chamber of heating system manufacturers
[6] Technical specifications and plans describing the different projects are stored in Le Corbusier Fondation
[7] The studies required to answer the invitation to render were important and must have cost money to the firms.
[8] Zaniroli worked previously for the Salvation Army on a female shelter in Paris, and Castiaux was in charged of the heating of the Pessac Le Corbusier's housing estate
[9] B. B. Taylor, p. 96

[11] Missenard André, *Chauffage et ventilation* (handwritten), 1932, 166 p. (Archives AICVF). Charlent Charles, Bourcier Lucien, *La pratique du chauffage central*, Garnier Frères, 1928, p. 219-220
[12] The Glass House by Pierre Chareau (1883-1950) in Paris (1928-1931) used also a mechanical hot air heating system, a direct one. Le Corbusier was often visiting the construction site
[13] Chabannes Jean-Baptiste marquis de, *Explanations of a new method for warming and purifying the air in private houses and public buildings*, Schulze & Dean, London, 1815, p. 5-8
[14] B.B. Taylor, on the contrary, claims that all rooms equipped with radiators had opening windows
[15] More than 100.000 francs
[16] p. 123, any how we have not found any evidences of that choice
[17] Successives visits to the archives and the building allowed to find those traces