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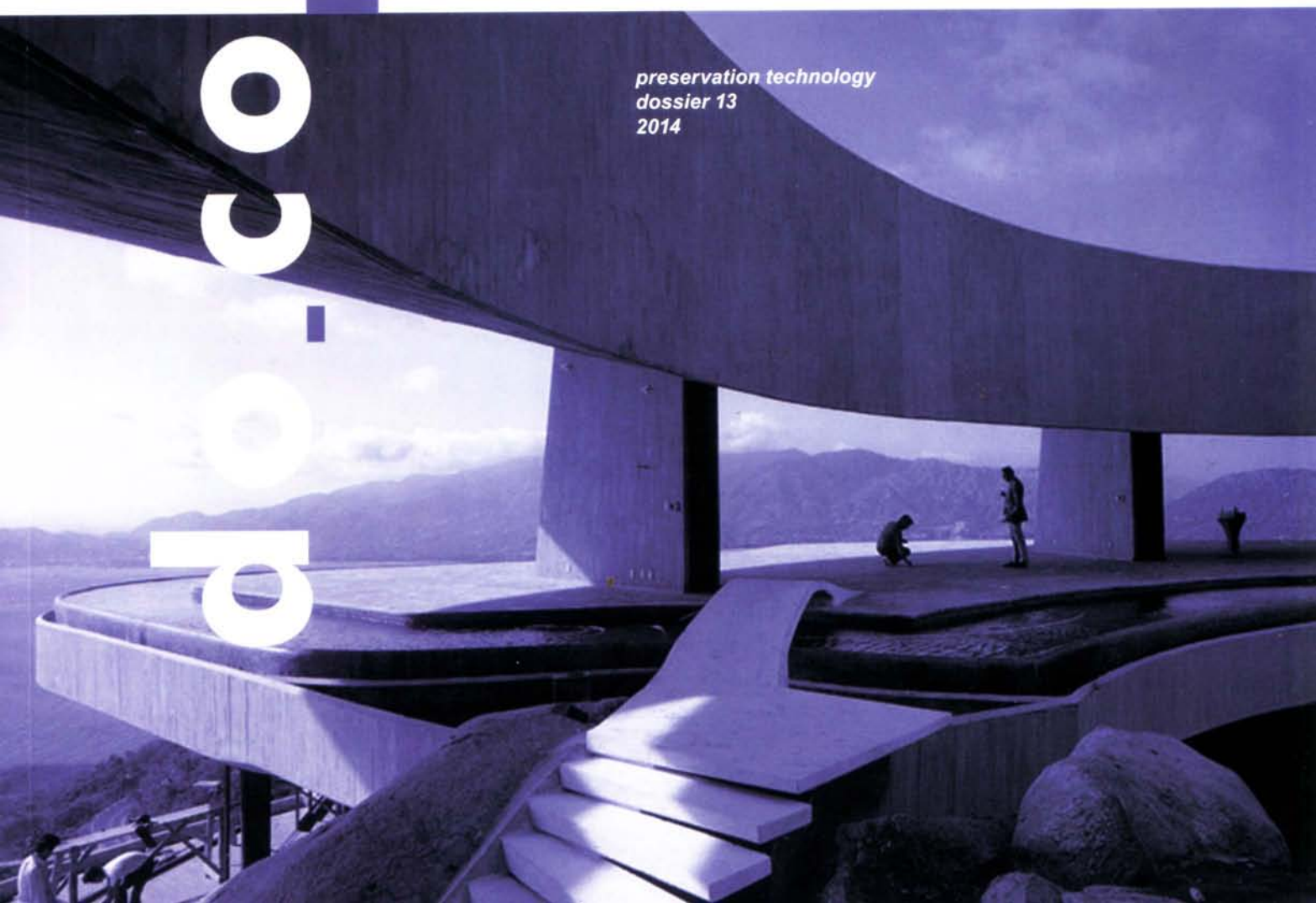

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The glass façade and the heating system of the Salvation Army "City of refuge": from conception to restoration

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Introduction

When a historic building is renovated, it is generally a question of technical update as well as material conservation and restoration. The architects and engineers are entrusted with the task of implementing the least destructive and noticeable intervention while complying with today's building standards. In this respect, the technical equipment such as electrical wiring, plumbing and heating is subject to frequent updates. The same goes for the façade: the glass and the window frames of old buildings cannot be reproduced today and are frequently replaced by up-to-date products.

But what happens when the technical devices are an integral part of the historical value of the building? It is the case for the ongoing renovation project of the Salvation Army "City of refuge" built in Paris in 1933 by Le Corbusier. For decades, this icon of modern architecture, a well-known pioneer building in glass façade and environmental control, has undergone a slow degradation due to improper maintenance and transformations contradicting its nature. The project we will discuss here shows that the approach to the conservation and restoration of historical monuments in France is constantly evolving. Today, our knowledge and sensitivity to issues of technology allows us to adopt a more scientific method and develop a greener project at the same time.

The historical research we conducted as experts of the 20th century construction history helped the restoration team led by the French architects François Chatillon and François Gruson. It enabled us to understand and evaluate the innovations that were originally implemented in the building. Since few of the original materials and devices remain today, it was a real challenge to appreciate and describe the systems. The archives provided by the Le Corbusier Foundation comprising hundreds of drawings, correspondence and pictures coupled with on-site investigations have revealed the richness and sophistication of the façade construction and the heating systems of the City of refuge. It is to be noted that we relied on existing historical research that was extremely helpful[1]. However, the thorough analysis

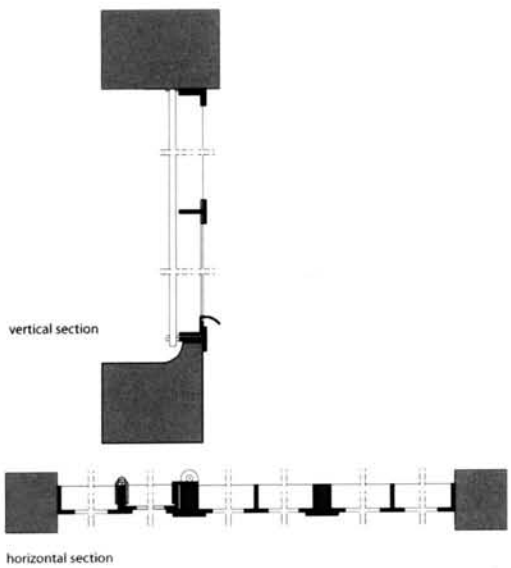

Fig. 1: Atelier Ozenfant (1922). Plan and vertical section of the horizontal window on the 1st floor. The frames are formed of assembled standard angles and T-shapes. Thicker steel mullions support the casement bolt and strengthen the frame. Flat sheets screwed on this mullion reconstitute a rabbet. Drawing VF according to the working drawing FLC07830

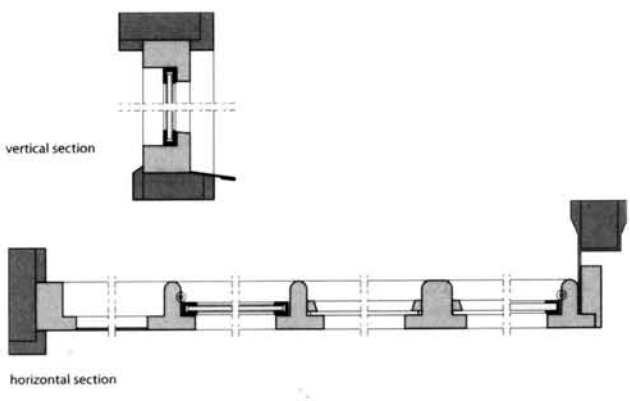

Fig. 2: Window detailing of the Cook villa (1926-29), showing the wooden mullions that replaced the steel profiles probably for economic reasons. The operable glass pane is simply rimmed with a thin folded steel sheet shaped in a U. In this case, the glass is not considered as the filling of a frame but as the structural element. Drawing VF, according to FLC08315

1 A book was particularly useful and saved us a lot of time and energy: Taylor, B. B. (1980). Le Corbusier, La cité de refuge Paris 1929-1933.

Fig. 3: Photo of the façade, Salvation Army City of Refuge, architect Le Corbusier, 1933. ©Archives de la Fondation Armée du Salut

of the as-built drawings compared to the contractors' estimates, had never been conducted before, and it is the primary documentary source of this study.
In this paper we will share our findings and answer the following: How were the original technical devices of the building executed? How would they perform? How innovative were they regarding the technological context? What were the origins of the devices in Le Corbusier's work? Why and when were they modified? What were the options of the ongoing restoration project regarding this matter?

THE GLASS FAÇADE

The origins of the glass façade in Le Corbusier's 1920-1930s work

In the years 1920-30, Le Corbusier developed two types of openings for façades freed from the load bearing part by the use of post-and-beam structure. On the one hand, the "ribbon" window allowed a better distribution of light in the room and a better view towards the outside. This can be seen in the "purist" villas built during this period[2]. On the other hand, Le Corbusier also developed the "pan de verre" or glass wall. As this "pan de verre" was inherited from the traditional façade of artists' workshops, it was natural that Le Corbusier first used it for this purpose, in the Ozenfant painter home and studio (1922). This project displayed the same window frames that were generally implemented in workshops and factories. The posts and transoms of the "ribbon" windows and the large glass façades were made of the same industrial 25 and 35 mm L-, T- and U-shaped hot-rolled steel profiles. Due to their large dimensions, the frames of the large windows of the studio had to be reinforced by 20x80 mm-thick steel mullions[3].

Shortly after, Le Corbusier used the same industrial products for the large window of the Villa La Roche. But the "ribbon" window implemented in this house differed in design and material from the Ozenfant system. The steel stiffener was replaced by a wooden 35 mm T-shaped profile. This served as a rabbet for the fixed glass panes and the French window casements. These were made of a single sheet of glass having a thin U-shaped profile on the edges. The replacement of a metal part by a piece of wood is a crucial step in the search for the innovative and inexpensive building methods that Le Corbusier

Paris: L'équerre.

2 See Benton, T. (1984). Les villas parisiennes de Le Corbusier. 1920-1930. Paris: Ph. Sers / éditions de La Villette.

3 This part of the research is based on the book by Ford, E. T. (1991). The details of modern architecture (Vol. 1). Cambridge,MA: The MIT press, supplemented by an analysis of different projects that served for the article: Fernandez, V. (2012). "The simplification of the window frame: windows experiments in the work of Le Corbusier in the 1920s". In A. Guillerme, Nuts and bolts. Proceedings of the 4th International Conference Construction History (pp. 203-211). Paris: Editions de la Villette.

one hand, "the large frame" of the Cantagrel Street attributed to MMM, on the other hand, 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 32 mm hot-rolled steel profile, more expensive but more resistant, for MMM[15].

We assumed that the windows and metalwork elements were pragmatically distributed between the two contractors, following imperatives of visual unity and cheapest cost, in spite of their apparent randomness. Originally developed for smaller windows, the 32 mm "special" steel profiles were adapted to the story 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 was 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 appeared in the archives, contrary to the D&L's frame, which had to be stiffened afterwards[16]. This description was confirmed by the fact that we discovered one original window frame in the building. Located in the basement, under cover, it had been protected from corrosion.
It should be noted that entirely glazed buildings were still very scarce in the early 1930s. The City of refuge glass curtain-wall was one of the first of this size (1000 m²) built in Europe. In the context of a country in economic crisis, this technological achievement deserves to be highlighted.

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 was insufficient, as we will develop further.

THE HEATING AND VENTILATION SYSTEMS

The origins of the environmental control systems in le Corbusier's work

According to several authors, the first experiment Le Corbusier conducted in the field of environmental control laid in the villa Schwob, built in La Chaux-de-Fonds in 1916[17]. Together with the Sulzer company, he installed a hot water heating device in the cavity of a double window in order to reduce the cold wall effect induced by large glazed façade. It also limited the condensation and avoided air draught. In the single family home of the Weissenhof Siedlung built in Stuttgart in 1927, Le Corbusier also split the "glass wall" but did not implement the heating device in the cavity.

Le Corbusier also experimented with the double masonry wall. In the 1922 "houses for craftsmen" projects, the Pavillon de l'Esprit Nouveau and the Fruges town houses built in Pessac in 1925 he tried to implement the double-wall "isothermal" technique devised by Raoul Decourt. It was a double wall of projected cement (cement-gun) 4cm thick, with an air gap or a board of solomite (compressed straw) interleaved. The attempt to resort to this building technique for the Fruges project was unsuccessful[18].

In the 1925 "Call to the Industrialists" Le Corbusier stated that the glass walls were designed to illuminate and not to ventilate. In this respect he acknowledged that the ventilation should be mechanically controlled and elaborated on this in his projects for large buildings. The synthesis of the technical approaches of the 1920s, large glass façade, controlled ventilation and insulated double-wall, was carried out in the project for the great assembly hall of the League of Nations Headquarters, in 1927. The side walls of this room were fully glazed and the cavity created between the two membranes was utilized not only to isolate, but also to retrieve the stale air. Le Corbusier collaborated with Gustave Lyon, who was the acoustician and thermal engineer of the salle Pleyel, for the development of a ventilation and heating system they called "aération ponctuelle" (spot ventilation).

15 Special hot-rolled profiles appeared in France around 1925. The steel bars are first hot-rolled by multiple passes in a rolling mill that stretches the molten metal. The products are then either finished or semi-finished. In the latter case, they are processed anew in an oven at a lesser temperature and are stretched by rammers that push the metal, or pushed through the press. Stretching is used to calibrate the product precisely. It is for this reason that special profiles are more sophisticated than the standard elements such angle, flat, L or U. The air and waterproofing are improved by a double rebate (rabbet) and the setting of glass panes inside with screwed beading instead of putty. The fact that MMM originated from Lorraine, a coal and steel region that was occupied by Germany until 1918 might explain why their steel technology was better developed.

16 January 20, 1933, Pierre Jeanneret will ask D & L to estimate 335 meters of "36-42 protection bars secured by brackets 0.30 m distance from the cross piece of the large glazed wall side Cantagrel facade and facade Chevaleret" , estimates D & L, FLC J1-18-263.

17 See for example Alazart, J. (1961). De la fenêtre au pan de verre dans l'œuvre de Le Corbusier. Paris: Boussois, PVP

18 Rosellini, A. (2011). "Charles-Édouard Jeanneret, consulente tecnico della Société Française de l'Everite, 1917-20". Massilia. Annuaire d'études corbuséennes, pp. 8-29.

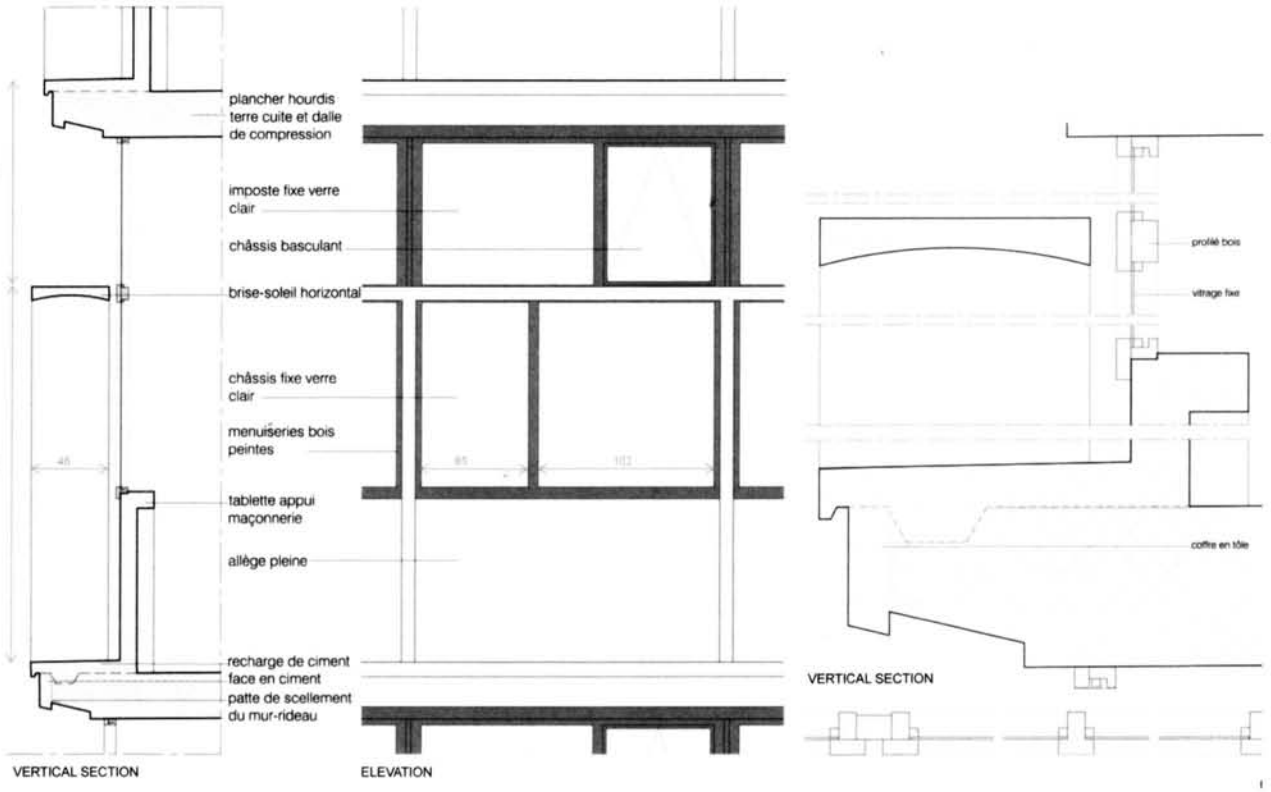

Fig. 5: Reconstitution of the 1952 façade detail. ©Vanessa Fernandez, according to the measured drawings elaborated in 1975 by P. Verrey.

For the Centrosoyus building in Moscow in 1931, Le Corbusier proposed to circulate air, warm in winter, cool in summer in the cavity of a double "pan de verre", hermetically sealed from the inside and the outside. He called this system the "neutralizing wall". Once reduced the radiating and thermal exchanges through the envelope by this "wall" repeated at each floor, a mechanical ventilation system, inspired by the system used by Gustave Lyon at the salle Pleyel, was implemented. This so-called "exact breathing" system provided each one with 80 liters of air per minute at the constant temperature of 18 °C[19]. At the Centrosoyus, the principle of double facades has been accepted, with difficulties however, the commissioners preferring "ribbon" windows to the fully glazed wall. Le Corbusier yielded on the creation of sliding windows in the "neutralizing wall" and the "exact breathing" system was never implemented.

But what Le Corbusier called his "inventions" were in fact the reuse of traditional techniques. Indeed, the double wall with heated air cavity, although energy consuming because of the heat losses, already had a long history in the 19th century. Although the systems were not invented by him, the interest of the Le Corbusier's solutions lied in the fact that they could be split-up.

In the description of the systems published in Précisions in 1930[20], it appeared that they were intended to be used in all orientations and all latitudes. Le Corbusier hoped somehow standardize the internal environment, thanks to the double airtight façade and ventilation at 18 °C. The building was inspired by the functioning of a lung, the city working as an organism.

At the City of refuge, despite Le Corbusier's discourse, there was no evidence of a projected "neutralizing wall". Presumably for economy reasons, technical feasibility and considerations for the French climate[21], Le Corbusier quickly replaced the "neutralizing wall" with a single curtain-wall. Nevertheless, in June 1931, Le Corbusier had the "neutralizing wall" tested by the glass company Saint-Gobain. The conclusions of this experiment were that, the heated cavity of the "neutralizing wall" needed to be isolated by a second layer of air created by an extra glazing in order to be effective.

A version of the "exact breathing" system, a forced-air heating system, was however implemented at the

19 Le Corbusier, Une maison, un palais : A la recherche d'une unité architecturale, Paris, G. Crès et Cie, 1928.

20 Le Corbusier, Précisions sur un état présent de l'architecture et de l'urbanisme, Vincent-Fréal et Cie : Paris, 1930.

21 Le Corbusier featured "neutralizing walls" for the projects exposed to harsh climate such as Switzerland (Villa Schwob, 1916 and League of Nations Headquarters, 1927) or Russia (Centrosoyous, 1931) but not for those located in Paris, apart from the Draegger printing shop in Montrouge (1929).

City of refuge, with great pragmatism over means and conditions (the initial contractor bankrupted during the construction). It should be noted that the air conditioning and the mechanically controlled ventilation were still rare during the interwar period in France, which explains why they were only partially implemented at the City of refuge.

The projected heating and ventilation systems

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. Le Corbusier wrote: "The contractor shall take into account the shafts (floor openings) that have been laid out in the floors for ducts and pipes. He will provide installation based on these crossing points. The ducts and pipes laid horizontally or vertically, in any kind and in any form whatsoever, shall in no case be hidden in the masonry wall, they will be rather clearly disconnected, especially visible and accessible on the ceiling that is to say, suspended"(FLC *J2-15-114*).

While heat engineer Victor Maubras declined the offer to work on the project[22], his colleague Auguste Beaurrienne provided documentation on his invention: the "Calopulseur" system he recommended for heating large spaces such as workshops[23]. Heating companies Leroy, Sulzer Tunzini, Zaniroli Castiaux were consulted to offer alternatives and submit estimates of costs[24].

Sulzer, Leroy and Tunzini proposed four different solutions, from traditional radiator heating to complete air conditioning systems[25]. The architect and the client chose at first Zaniroli and Castiaux. 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[26]. After Castiaux faced financial difficulties, the Compagnie de Chauffage par le Vide, or CCV, took over the project[27]. 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.

Context of the time in the field of heating

The forced air system proposed for the Salvation Army building was relatively reliable at that time in France in domestic architecture. The vacuum-driven steam was a heat transfer fluid, still rare, coming from North America where it was implemented mostly in high-rise buildings. However, its handling was taught by the heat engineer André Missenard in his lectures at the l'École Spéciale des Travaux Publics from 1932 to 1942[28]. The principle was to maintain throughout the installation a pressure less than one atmosphere, using a vacuum pump. Then, the heaters were always saturated with steam at a relatively low temperature between 45°C and 95°C. This heating system allowed for the use of standard heating units: boilers, radiators and pipes of current section. It had many advantages: very low inertia, a setting as accurate as for hot water heating, suitable for intermittent use[29]. The risk of frost being discarded, its effectiveness allowed for making savings during operation. Associated with modern skyscrapers, vacuum-driven steam heating irrigated this innovative building.

It is to be reminded that the warm air systems (without mechanical propulsion) dating back to the eighteenth century in France developed during the nineteenth century in theatres, auditoriums, libraries and luxury homes. The forced air version, subsequent to the introduction of the electric motor, after 1880, spread predominantly in the industrial sector[30]. The forced

22 Victor Maubras, Traité pratique de fumisterie, chauffage, ventilation et chaudronnerie concernant le bâtiment avec de nombreux exemples, tables et résultats pratiques (Treaty practice of fumisterie, heating, ventilation and boiler for the building with numerous examples, tables and practical results), Paris, G. Fanchon, 1908. The author is also the author of a contribution to the first congress of the heating and ventilation of residential buildings in Strasbourg about: what are the current methods that seem to be required for the ventilation of large rooms, p. 146.

23 Victor Maubras and Auguste Beaurrienne represented important figures from the community of thermal engineers. The latter, who visited the U. S., was a member of ASHRAE (American association of heating engineers) and regularly reported from overseas technical developments, such as air conditioning.

24 Le Corbusier worked with the company Castiaux in Pessac and the company Zaniroli has made sanitation facilities and the heating in the "Palais de la femme", Palace of woman, in Paris 11th district, a building owned by the Salvation Army. André Leroy was president of the trade association of heating by water and steam, the company Tunzini found in 1906, executed the heating and ventilation system of the Printemps department stores. Sulzer is one of the largest heating companies in Switzerland, settled in Winthertur, founded in 1841; they owned at that times several offices in France.

25 These three firms were very well known at that time, there were member of the Union Chamber of heating system manufacturers.

26 B. B. Taylor,op.cit., p. 96.

27 FLC J1-18-207, FLC J1-18-31.

28 André Missenard, Chauffage et ventilation, 1932, 166 p., manuscrit lectures.

29 Most part of the building was intermittent heated.

30 The Glass House by Pierre Chareau (1883-1950) in Paris (1928-1931) also used a forced air heaters, a direct system. Le Corbusier often visited the construction site. (B. Bijvoet collaborated in this project. Note of Ed.)

Fig. 6: Photo of the façade, Salvation Army City of Refuge, 2010 ©Vanessa Fernandez

warm-air heater embodied an effective comfort and the image of the machine in the hygienist universe of the Salvation Army's building.

Le Corbusier's idea of heating his building with warm air at a constant temperature in order to minimize cold drafts also initiated in 18th century 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, advised "the purification of the air, the prevention of dampness, the equality of temperature and suppression of draughts of air"[31].

The heating system of the City of refuge

At the City of Refuge, eight steam heating circuits were planned but only four, longer 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 "Thermon". The blowers were located either inside the space to be heated or underneath the floor with registers, as it was the case in the circular entrance pavilion, the hall at the pilotis level, the meeting room, and the elderly women dormitory. Two blowers placed on the first floor heated the entire staircase. Blowers located at both ends of the corridors heated the individual rooms for mothers and their children and the child-care center. The ducts were inserted into a counter ceiling along the corridors and registers were placed in the wall above the door in the rooms[32].

The offices, apartments, the room for supervisors,

31 Jean-Baptiste Chabannes (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.

32 Le Corbusier's quotation, see note 14, FLC J2-15-114.

the room dedicated to the Princess of Polignac (the principal donator) were equipped with standard cast iron radiators heated directly by steam. Most of these small spaces had opening windows[33]. The chosen fuel was oil, supposed to be the "modern" clean fuel, producing no waste and that did not require staff. This fuel was "almost" gainful because of dramatic increases in coal prices in the aftermath of the First World War[34].

The heating system seemed to function properly, even if the Salvation Army thought the consumption of oil and electricity was too important[35]. Most of the issues, however, occurred during the summer with the airtight glass façade.

We can establish a social interpretation of the distribution of spaces between radiators and hot air blowers; *radiators served offices, rooms and apartments dedicated to the staff and the Princess de Polignac.* Radiators, devices well known by the privileged classes, were socially "valued" and recognized as an effective system. Le Corbusier's choices of thermal comfort for the City of Refuge as seen through the eyes of the "hosted" must have been quite different from those of the Salvation Army staff. Indeed for this population, continuous thermal comfort throughout the building is something quite new. They were unlikely to have had access to a central heated place unless they had been in prison or had been hospitalized. The modest population's heating means at this time remained the fireplace, fitted or not, and industrially produced stoves, like Godin stoves. Similarly, primary schools were mainly heated by stoves, as well as cafes and other community spaces accessible to popular population. The heating in the small bedrooms, dematerialized due to hot air, should have been seen as a little "magic" by this population accustomed to cold and damp rooms. In the dormitories, the presence of "pulsairs" blowers was probably surprising, but probably more by their efficiency than as technical objects left uncovered.

Indoor climate issues

Without an air conditioning system, considered too expensive, blowers, disconnected from the heating system, were supposed to provide ventilation during the summer[36]. Rooms were thus given fresh air coming from the roof, although, Le Corbusier suspected that the Salvation Army disconnected the blowers in order to save electricity[37]. How the air circulated in the large spaces, such as the dormitories, was simple but maybe insufficient. On floors 3 to 6, single rooms served by a corridor, were ventilated by registers above the doors, creating some overpressure. The air left the room pushed under the door into the corridor and exited the building through grilles set in the walls of the small courtyards. This system was apparently not sufficient as well. In the childcare centre on the 5th floor which, unlike the dormitories, is used during the day, the temperature could rose to 33°C[38]. With a glass curtain wall, 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[39]. After numerous exchanges they decided to find a solution, consulting engineers proposed a water cooling system that unfortunately proved to be too expensive[40]. In the end, as claimed by B. B. Taylor, forty sliding windows were opened in the glass wall[41].

THE TRANSFORMATIONS

The façade and the "brise-soleil"

In 1944, a bomb destroyed the glass façade completely, giving way to a new façade project, developed by Le Corbusier in 1950-52. This project enabled him to explore new solutions with regards to

33 B. B. Taylor, on the contrary, wrote that all rooms equipped with radiators had opening windows.

34 The difficulty of finding staff added to the rising price of coal.

35 Mr. Lavergne wrote: "The heating during the winter period is entirely satisfactory both from the economic point of view as well as regards to the ventilation that is established simultaneously with the heating", FLC J2-5-233.

36 Le Corbusier wrote: "The renewal of the air volume will vary depending on the power of the blowers (pulsairs) between 2 and 3 1/2 times per hour, but a renewal of a minimum of two times per hour in the summer will be insured", FLC J1-18-25 to 30.

37 The architect wrote: "The directors of the refuge, wanting to save money at all costs, only rarely do the fans turn", FLC J1-20-257.

38 Former Commissioner Peyron wrote: "Do you know that in summer the temperature rose to 33° and the children dragged on the ground questing for air?", FLC J2-5-37.

39 FLC J2-5-3 to 6, FLC J2-5-238 to 41.

40 More than 100.000 francs, FLC J2-5-232 and 233.

41 B. B. Taylor, p. 123, "the architects have agreed on the principle of practicing various openings in the façade of the nursery. Hence, the experiment can be made if this method is positive or negative". Similarly, "mothers and children rooms and the child care will possibly be ventilated by the establishment of small horizontal blinds; one room has been fitted this month". FLC J2-5-233.

reducing solar heat gains. 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".

The story of the "brise-soleil" device is now well known through several publications[42]. Le Corbusier developed a system of opaque protections for the glass wall associated with natural ventilation for Barcelona, Algiers and Rio de Janeiro in the late 1930s. After the war, Le Corbusier did not completely abandon the idea of the "neutralizing wall", as evidenced by its proposal for the UN headquarters in New York in 1947. But he learned from his mistakes and incorporated a solar protection to the façade of the City of refuge. This awareness can also be attributed to its collaboration with André Missenard[43]. In the inter-war years, scientific publications had reported thermal studies under the guidance of professional associations, including a study on solar heat gains in residential buildings[44]. Le Corbusier would widely use the shading devices in the post-war projects, such as the "Unité d'habitation" in Marseilles or at the convent of La Tourette, etc.

It is therefore not surprising that, offering his services to the Salvation Army to renovate the building, Le Corbusier made a project that incorporated a concrete "brise-soleil" on the South facade. Iannis Xenakis, then collaborator of Le Corbusier's office, studied the depth of the device with graphic solar studies[45]. Despite an initial geometric blueprint that defined the optimal depth of the shading device to 70 cm, the executed protections were only 46 cm deep. The large glass panes of the two façades were fully replaced by new wooden frames laid on light masonry spandrels, set back from the edge of the floor. The design of this façade differed from the original one. The geometric divisions of each panel created a square in the center, filled with fixed glass, and an operable casement in the clerestory. Le Corbusier also advised the Salvation Army for the polychrome façade, supposed to recall the colors of its flag.

We know that as the result of this work, Le Corbusier ceased his "friendly participation, begun 20 years before". It is because of the lack of compliance with his recommendations, especially the yellow color painted on the 7th floor façade panels which he did not like.

Slightly modified during the 1975 renovation, the wooden frames were replaced by aluminum sliding sashes in 1988, and the spandrels were covered with aluminum sheet panning. This alteration changed the appearance of the façade, in spite of the designation of the building as a Historic Monument in 1975. The last two floors of the building kept their original steel frames, odd and modified, until 1975. They were then replaced by new steel frames rather similar to the original ones, apart from the masonry spandrels. They were still in place before the 2013 renovation work.

The original heating plant and the distribution networks have been totally destroyed at an unknown date and replaced by the company Delbost-Metz & Cie[46]. The implementation of the current radiator system negated the architectural qualities of the building. Since 1992, 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[47]. 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.

The ongoing restoration project

The ongoing restoration of the City of Refuge allowed for an interesting debate on the façades and heating -ventilation systems restoration. Despite the fascina-

42 Le Corbusier himself told the story of the "brise-soleil" in Le Corbusier. (1946, janv-fév). "Problèmes de l'ensoleillement. Le brise-soleil". Techniques et architecture, pp. 25-28. Reyner Banham considered the "brise soleil" as a major invention in the field of architectural device for controlling environment. Banham, R. (1969). The architecture of the well-tempered environment. London: London press. Daniel Siret analyzed the genealogy and the efficiency of this device. Siret, D. (2002). "L'illusion du brise-soleil par Le Corbusier". Langages scientifiques et pensée critique. Cerisy and Siret, D. (2004, Octobre). "Généalogie du brise-soleil dans l'oeuvre de Le Corbusier : Carthage, Marseille, Chandigarh". Cahiers thématiques(n.4), p.169-181.

43 A thermal engineer with whom he developed the "climatic grid" tool that was used for Ahmedabad and Chandigarh projects in the 1950s. André Missenard, Polytechnician, taught thermics in different high schools, while running a business (Missenard-Quint) and a study desk. Author of educational resources, responsible for professional associations, he is the only French to receive the plate Rietschel in 1938 for his contributions to the theory of the resulting temperature. In 1955, with Le Corbusier's office, he will develop the climatic grid for the projects in Ahmadabad and Chandigarh.

44 Jeanne Mouret, André Nessi, Étude des apports de chaleur par insolation dans les bâtiments habités (Rapport n°5), Comité technique de l'industrie du chauffage et de la ventilation, section du chauffage et Société industrielle d'imprimerie, Paris, 1946, 94 p.

45 The sunshades were studied mainly by Iannis Xenakis. The project was entrusted to Pierre Jeanneret, who had supervised the building's construction from 1931 to 1933. Finally Mr. Guardian and Mr. Pollack supervised the renovation project after P. Jeanneret's departure for India.

46 Plans, Salvation Army archives.

47 Successive visits to archives and the building enabled us to find its traces.

tion the original glass façade may have inspired, the "brise-soleil" was acknowledged as an original part of the building, showing Le Corbusier's capacity to readapt his initial concept and experiment new solutions.

The materiality of the façade has been in debate for several months. The city of Paris historic commission, the Ministry of Culture conservators and Le Corbusier Foundation experts issued conflicting advice on what to do: should the replication of the original steel profiles or the wooden frames be preferred? Both techniques are very maintenance intensive. The decision was finally made to restore the main façades in the 1952 state with wooden sashes. The attic and ground floor levels that still retained the 1975 metal frames were to be restored to their 1933 state with metal profiles. The adopted approach integrated new insulated double glazing to all the windows. The documents found and analyzed were extremely important for the restoration. Fortunately, abundant layouts, descriptions and pictures enabled the architects to reestablish the original design of the windows, the railings and many other devices destroyed and reconstructed differently over time. This attention for the slightest detail, the exhaustive documentation of what is done will allow for an "archeological" approach to the restoration project. An interesting group of experts was created to help the architects solve many issues of preservation. The topics of the meetings are as diverse as the choice of the colors of the main façade, the compliance of the details with the original documents, the furnishing of the three bedrooms that will be restored to their original features, etc.

It is to be recalled that only the façades, the roof and the hall are designated as historical. The committee only elaborates upon these locations. The polychrome façade was a challenging question: photos dating from this period are in black and white, they do not provide valid sources for restitution. The probes taken on the spandrels, the correspondence and contractor's estimate of costs, letters from Le Corbusier were discussed to find a solution. The same goes for the restitution of the internal polychrome painting in the hall. The colored glass tiles of the porch – "verre Désagnat" of which not a single tile and very few information remained are to be reinstalled. But the model of the elaborated lighting fixture, called "X-ray" one of which we finally discovered after one year's research will not be restored.

Unfortunately, the building must undergo a very deep transformation. The bedrooms are considered too narrow in respect of today's standards, 1.90m instead of 2.50 m. Therefore, all the internal partitions will be demolished, a heavy decision since the façade rhythm is paced on the dimensions of the rooms. But this transformation will enable the owner to keep the original use of the building and this is very precious. In order mitigate the loss of the original layout, three historic bedrooms should be conserved and furnished according to the 1933 state. During the demolition, our historical team will perform an archeological survey and some original devices will be stored for a future project of a visitor center.

The projected heating and ventilation systems do not intend to reactivate the original air system, the hot water radiators being more cost-effective. Nevertheless, the new circuits will not disfigure the space anymore and archaeological evidence related to this innovation will be preserved as part of a comprehensive and global project.

More generally, a relevant improvement of the renovation process should introduce the study of technical devices (through back and forth research between archaeological evidence and archives) as well as other historical research for preserving the buildings of the twentieth century. This is especially true when comfort perception and innovation were important for the quality of the project.

CONCLUSION

As a conclusion, we hope that we pointed out the historical significance of the technical endeavors of the Salvation Army City of refuge. The ongoing restoration project took this aspect into account and developed a design that will allow for everyone to rediscover one of the icons of Modernity. At the same time, an archeological approach will certainly reveal other historical evidences and enable us to learn more about this building.