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USM HALLER: UN PARADIGMA DE SIMBIOSIS ENTRE ARQUITECTURA E INDUSTRIA

USM HALLER: A PARADIGM OF SYMBIOSIS BETWEEN ARCHITECTURE AND INDUSTRY

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INTRODUCTION

The Swiss architect Fritz Haller (Solothurn, 1924 - Berne, 2012) is recognised today for his contribution to the design of industrial buildings and for his collaboration with the industry to develop modular construction systems that can be applied to buildings of diverse uses. His involvement in industrial architecture started in 1961, with the commission for the headquarters of the steel profile manufacturing company USM in Münsingen (Switzerland). Haller designed a modular construction system in steel for that project, tailored to the company's production needs, which ultimately turned into a commercial product in itself (MAXI system). This was followed by two more, conceived for buildings with other uses (MINI and MIDI systems).

The article focuses on the analysis of the USM-Haller systems, with the following aims:

- Understand their origin in a specific historical and architectural context.
- Compile information with regard to the three construction systems to get to know them in detail.
- Identify their singularities in the context of industrial architecture.
- Evaluate, retrospectively, the importance of USM systems in the architect's career, as well as their contribution to subsequent architecture.

To do so, we have consulted mainly sources from the era, such as articles authored by Haller himself in the journal *Bauen+Wohnen*, as well as subsequent articles from other journals, monographic studies and academic publications. 3D models were created for to present the detailed description of the three construction systems, based on which explanatory axonometries have been generated.

BACKGROUND. INDUSTRIAL ARCHITECTURE AND MODULAR CONSTRUCTION SYSTEMS

Industrial architecture underwent a notable transformation in the decades of the 20th century before the creation of USM-Haller systems, driven by several pioneering figures. In the United States, the buildings of Albert Kahn for the automobile and aeronautics industries embodied the Ford principles of pragmatism and adaptability to the production p.34 process, prioritising the utmost flexibility, to adapt to future requirements of the constantly changing industrial processes. In architectural terms, this was translated into the search for diaphanous horizontal space, the use of light, enveloping exostructures, the section as the defining technological element of the space, and the floor plan layout determined by the structure[1]. In Europe, Walter Gropius renewed the image of industrial architecture in his Fagus Factory, in 1913, with a glazed façade that would go on to become a characteristic feature of this kind of architecture.

The changing needs of industrial processes encouraged the exploration of prefabrication and the use of modular construction systems, and became more widespread in the post-war period, due to the need for fast construction. Germany was the first European country in which architects were actively involved in the development and use of new industrial construction systems[2]. Two prominent driving forces were Walter Gropius and Konrad Wachsmann.

Gropius was fundamental as an advocate of standardisation and prefabrication in architecture, promoting, both from the Bauhaus and the Deutscher Werkbund, the role of architects in the development of industrial products. In the United States, together with Wachsmann, he developed the *Packaged House*, considered a paradigmatic design of the prefabricated home.

For his part, Konrad Wachsmann, who specialised in wood construction and who created several prefabricated systems beginning in the 1920s, and his book *Wendepunkt im Bauen* (1959), were touchstones of construction with industrial components in the post-war period[3]. His designs for the US aeronautic industry laid the foundations for the standardisation of elements and the construction of spatial structures with wide spans. Wachsmann was the leading theorist for Haller, as well as a mentor. After they met in 1959 at a seminar on industrialisation in Lausanne[4], they kept in close contact over the years, exchanging knowledge and theoretical ideas.

In France, as well as Le Corbusier[5], Jean Prouvé is considered the great forerunner of industrialised architecture, with his early examples of prefabricated building in aluminium and steel in the 1930s, such as the flying club in Buc[6], the BLPS detachable house and the *Maison du Peuple* in Clichy. His 1954 aluminium Centenary Pavilion in Paris, with its long, modulated façade, was probably an aesthetic model for Haller in the design of the Münsingen factory (figure1).

FRITZ HALLER AND THE USM COMPANY: AN INNOVATIVE COLLABORATION

After a few years working in Holland, Fritz Haller set up in 1949 as an architect in Solothurn together with his father, Bruno Haller, and was the designer of several school buildings that had an impact on the national and international specialised media. Jürge Joedicke included it in what he called Solothurn Schule (Solothurn School), a scene with a p.35 clear Miesian influence[7]. Mies van der Rohe's architecture is based on extreme formal simplicity, the predominant use of steel and glass, and the incorporation of innovative elements based on modular construction and prefabrication.

In 1961, the USM company, founded in Münsingen in 1885, passed into the hands of Paul Schärer, the founder's grandson, who decided to relocate the company's headquarters [8]. Attracted by Haller's buildings[9], he chose him for the design of the new headquarters: a flexible building that was to house the administration offices and production lines, and to be able to adapt in the future to the different manufacturing processes and changes in the industry. Under this premise, Haller designed, in collaboration with Schärer and based on his previous experience with prefabricated elements in school buildings[10], a flexible modular construction system with a steel structure.

In his description of the design for the Münsingen plant one can already identify the desire to conceive a "system" of more universal use:

"*The space had to be created solely from assembly parts, so that subsequent changes or extensions could be made simply and without the need for refurbishment work. Construction elements were sought that were as universal as possible, in order to be able to assemble different industrial buildings from basic units, housing the widest possible variety of uses. This effort to build a universal industrial hall could be the starting point for the industrial production of economical, flexible and fast-to-install building elements for industrial buildings.*

First, the common constructions of the day were examined, and their advantages and disadvantages were analysed. Next, we tried to define guidelines for the planning of manufacturing spaces based on trends in technological development. Different types of house lighting were compared, with measurements in concrete examples. The dimensions required in production were compared with the basic dimensions of the constructions"[11]. **p.36**

Following Haller's vision, the design of the Münsingen factory was the seed for the creation of the USM-Haller family of commercial building systems: MAXI (1961), MINI (1962) and MIDI (1972) (Figure 2).

The three systems, conceived as open,[12] were based on the same principle of reticular structure of steel profiles, but adapted to different scales, levels of complexity and programmes of use. Each system had elements and assembly systems that allowed the buildings to be adapted, expanded or reduced over time, both in terms of the general volumetry and the interior distribution.

THE "USM HALLER" SYSTEMS IN DETAIL

MAXI steel construction system

The MAXI system (developed from 1961, first used in a construction project in 1963)[13] is used for the construction of single-storey warehouses, with large distances between pillars. It is mainly designed to create industrial plants for any type of production, in which it is required to be able to make extensions or future additions. The system consists of a load-bearing structure, exterior façade and roof (figures 3 and 4).

The load-bearing structure is distributed in a reticular manner in plan, with spans of 9.6, 14.4 or 19.2 metres, and can function as a unidirectional or bidirectional structure. In the first case, it supports loads of up to 300 kg/m2 and, in the second, 350 kg/m2[14]. Within this modulation, the structure can be freely expanded. The pillars, made up of four L-shaped profiles joined by plates, have a floor plan dimension of 45 × 45 centimetres, and a variable height, always a multiple of 0.6 metres. The lattice beams, made of welded steel profiles, have a total depth of 1.2 metres. The composite shape of the pillars facilitates the meeting between them and the trusses, which are fitted between the two L's and supported by profiles welded to the pillars (Figure 5).

The façade is resolved with vertical T-profiles, between which removable pieces of 2.40 ×1.20 m are inserted, **p.37** made either of glass or opaque insulating plates, as well as doors or other elements. Although the modulation in height is 1.2 meters, it is also possible to insert half-height bands (0.6 metres).

The roof consists of self-supporting reinforced aerated concrete slabs, 4.80 m long.[15] For natural lighting, **p.38** 2.40-metre-wide skylights are provided on the ceiling, with glass that darkens when the sun shines and remains transparent on cloudy days, ensuring optimal light output.[16]

MINI steel construction system

The MINI system (developed from1962, first used in a construction project in 1965)[17] allows the construction of one or two-storey buildings, with spans of up to 8.4 metres, such as single-family homes [18], workshops, school pavilions, laboratories, commercial establishments, exhibition halls, etc.

The system consists of a load-bearing structure with intermediate slabs, and an exterior envelope (figures 6 and 7). The structure, consisting of columns and beams made of cold-formed sheet metal profiles, allows unlimited horizontal extensions. For the joints between columns and beams, special triangular stiffening profiles are added

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(Figure 8). As in the previous case, the external envelope allows, within the modular division, the quick replacement of windows, doors or other elements when required.

MIDI steel construction system

The MIDI system (developed from 1972, first used in a construction project in 1980)[19] it is designed for the construction of multi-storey buildings with a strong presence of facilities, such as schools, administrative buildings, laboratories or hospitals[20].

Its development, later than the other two systems, is based on the integration of all the components of the building as a systematic and geometrically coherent whole, including, in particular, the spatial arrangement of pipes and other
p.41 installations, coordinated under a facility planning scheme. The ARMILLA installation model, developed by Haller in a research project at the University of Karlsruhe[21], is fully integrated into the overall MIDI system.

The load-bearing structure has a reticular distribution in plan with more variable spans, respecting a minimum module of 2.4 meters and reaching 16.80 meters [22]. It works as a unidirectional structure of gantries, which can alternate their direction. The pillars are circular steel tubes, also of variable height, always a multiple of 0.6 meters. The double trusses are 1.2 metres deep (Figure 9). The meeting between the two is made by means of a square frame or capital, welded to the pillar, to which the trusses are screwed by means of structural bolts (Figure 10)[23].

Common philosophy of the MAXI – MIDI – MINI systems

The USM-Haller family of construction systems is designed from the perspective of operability and interoperability. Although each of the subsystems tries to provide solutions to different architectural spaces, the common philosophy is
p.42 totipotency[24]: to enable the widest possible spectrum of functions, over and above the typical determination of specific elements. The three systems complement each other and can be easily combined. To do this, they use a common module of 1.20 metres, both in plan and height (Figure 11).

On the other hand, in all three systems, design decisions can be seen that go beyond geometric and structural optimisation, even at the cost of an increase in the number of supports or the amount of material. For example, the aim is to unify the dimensions of the beams, even in different load situations. In the MINI and MIDI systems, the beams are designed in two pieces to be able to maintain the same construction criteria at special points, such as the edges, and their openings allow the integration of the technical installations in them.

USM Haller modular furnishing line

To the three architectural systems treated, we must add a fourth, intended for furniture, which is, in fact, the most popular and iconic of them all. It was created in 1963 with the approach of "*transferring the idea of modularity of the construction system of the factory from the macro-to the micro-space of furniture*"[25]. It is based on a three-dimensional grid of metal tubes, connected by a small sphere, and panels that make up walls and shelves.

The ball joint, a chrome-plated brass dial with a diameter of 25 mm, is the central element of the entire system. Six threaded holes allow the system's tubes, with a diameter of 19 mm, to be connected in the three dimensions of the space and in both directions, creating an orthogonal system with a variable modulus. The tubes, with lengths ranging from 100 to 750 mm, and the ball joints, are always visible from the outside, as a continuous line (Figure 12)[26].

The extreme flexibility of their configurations, together with their material robustness and the intact continuity of
p.44 their design over the decades, gives these pieces of furniture great durability.

APPLICATION IN INDUSTRIAL ARCHITECTURE

Although they are designed for application in different types of buildings, it was in industrial architecture that Haller systems most clearly demonstrated their effectiveness and versatility[27]. The possibility of adapting to future changes and expansions evidenced a lucid vision of the needs of industrial architecture, while expressing a modern aesthetic consistent with this function.

The USM headquarters in Münsingen was the true test laboratory for the MAXI, MIDI and MINI systems. All three systems were used in some of the buildings and pavilions that are still part of the complex (Figure 13), and at the same time, a large part of the components were produced in the factory itself. The complex is currently considered heritage, as it is included in the inventory of cultural property of national and regional importance of Switzerland (KGS), in category A of national interest[28].

The main building, built in 1961 with the MAXI system, with a single height above ground of 6 metres, and a distance between supports of 14.40 metres, offers the flexibility required for the various manufacturing processes, as Haller and Schärer had carefully studied based on the needs of the company itself and the analysis of other industrial
p.45 buildings[29]. The office pavilion, built in 1965 with the MINI system, is also an open-plan space with one floor above ground, which follows the open office model[30].

The constant modernisation of machines and changes in production processes led to a series of expansions over the decades, always using the USM-Haller steel construction system. Since 1998, the extensions were no longer planned or carried out by Haller, but by the company's architects, which is indicative of the true standardization and universality of the system.

Following the experience of the Münsingen construction site, both the MAXI and MINI systems and the modular furniture system became commercial products. Soon, other companies commissioned Haller to implement it in their new buildings. The flexibility of the system allowed variations to be made to the original design to adapt to the specific needs of the companies, generating buildings with spatial characteristics different from those of the Münsingen factory (Figure 14).

FROM A MODULAR CONSTRUCTION SYSTEM TO A THEORETICAL MODEL OF ARCHITECTURE AND THE CITY

Haller's systemic approach had its manifestation beyond professional practice, moving from his modular designs to his facet as a teacher, researcher and theorist.

As mentioned above, Haller's theoretical activity was closely linked to the ideas of Konrad Wachsmann[31]. In 1966, after five years of intense performance with industrial buildings, the then director of the Construction Research Institute of the University of Southern California, invited the Swiss architect as a visiting professor. There, Haller conducted research on mathematical-geometric models applicable to architecture; specifically, "*on the properties of salient points in regular geometric systems*"[32]. Its objective was to study "*the fundamental problems that every designer of complex modular systems constantly and repeatedly faces: the geometric coordination of the system components, the formation* **p.47** *of their connections, the safety of tolerances and the control of forces in the static system*"[33].

In the research, Haller worked with cubes composed of equal cells connected by nodes. With the help of models, he established different relationships, analogies and geometric conditions for each node, depending on its location within the cube, and came to look for a universal mathematical description for these nodes that would be applicable to all systems.

Haller also explored the urban scale, although always with a purely theoretical approach. His utopian urban system, first published in 1968[34], it was based on the geometric organisation of post-industrial city space at various scales, from basic units to clusters of 61 million people, which were expanded in a second version in 1975[35] to a "total city" of more than a billion inhabitants. In them, different communication systems and adaptations were considered according to social, climatic and economic conditions. Transport infrastructures and technologies, based on rigorous prior studies of existing or developing technical systems, played an important role in the model.

In the *totale stadt* geometric order is more important than quantification or dimensioning. The model focuses on the "coordinated geometry" of the construction elements, the "knots" where the functions are located, and the "movements and flows" that occur in these systems.

At the time, the project was not widely recognised by the architectural community, it was even branded as totalitarian for its excessive rigidity and rationalisation[36]. However, in retrospect, its coherence within the architect's track record has been recognised and it is often mentioned as a part of the history of urban planning in Switzerland.

FRITZ HALLER'S ARCHITECTURAL LEGACY AND THE USM-HALLER SYSTEM

The USM-Haller system was one of the first Swiss prefabricated systems designed for industrial buildings. The earliest modular systems developed in the country, existing since the 1940s (Durisol, NILBO) were designed for single-family homes or small buildings[37]. In 1955, the first system designed for large spans was born, the Isler system, a closed system in a concrete structure[38]. It is followed chronologically by the MAXI system, with completely different characteristics: in a metal structure, adaptable to multiple reticular compositions in plan, and conceived as an open system, easily combinable with its own and non-system elements.

The contribution of the USM-Haller family of systems is not so much its early appearance as its level of versatility, flexibility, and interoperability, offering solutions to both the specific needs of the industry and other uses, and representing, as has been described, "*what is perhaps the paradigmatic example of systems integration architecture in Europe*"[39]. To do this, Haller worked from a systemic perspective, where the important thing "*is not so much the form generated as its morphogenesis*"[40].

With this focus, defined as structural[41] or mathematical[42], one recognises the philosophy of Konrad Wachsmann, **p.48** which we can also find, for example, in Max Bill[43]. Some characteristics of the USM systems are present in the exposition pavilions of Expo 64, designed by the Zurich-based architect. The elaborate designs of the knots of its metal structure are reminiscent of both those of Wachsmann and the USM-Haller systems (figure 15).

The changes that occurred in subsequent decades - postmodernism, questioning of the technological paradigm, and a growing formal pluralism - did not facilitate the transmission of Haller's ideas, based on a vision of technical progress and the search for universal solutions. However, in Switzerland, from the 1980s onwards and unlike other countries, there was a trend towards reduction and minimalism[44], who found in Haller's buildings, and the Solothurn school in general, the appeal of minimalist architecture in steel and glass inspired by Mies van der Rohe, meticulous in details, finishes and modular proportions. A trend, developed mainly in the German-speaking part of the country, which was described as *Swissbox* or "Swiss essentialism".

However, Haller's influence is clearest among followers of industrialised architecture and the integration of prefabricated systems. A corroborated influence [45] in this vein are some buildings by Norman Foster, through the

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structural engineer Anthony Hunt, a collaborator of the British architect and an admirer of Haller's work. Team 4's Reliance Controls Electronics factory in Swindon (1965-1966)[46], has been compared to the USM factory built three years earlier [47], just as the Büchli house, designed by Haller with the MINI system, bears similarities to the structure of the Fosters' house in Hampstead.

CONCLUSIONS

Haller's interest in industrialised construction, which has been present since his professional beginnings, is the result of a favourable historical and architectural context, in the 1950s and within the School of Solothurn. A context of transformation and technological optimism, which, in Haller's case, was driven, especially, by his relationship with Konrad Wachsmann, in whom the Swiss architect found support for his work and theoretical support for his ideas.

Faced with the commission for USM's industrial equipment in 1961, with concrete requirements in terms of flexibility and transformation, Fritz Haller was forced to develop a rational and systemic approach as an architect. In the design process of the MAXI system, later complemented by the MINI and MIDI systems, Haller made design decisions not only based on geometric or static optimization, but also operational and interoperable, such as maintaining a constant 120 cm module in the three subsystems, the effort to reduce the number of different elements, and the careful design of the joints between pillars and beams.

p.49 Haller repeatedly focused on the question of "singular points," at different scales. In the case of MAXI-MINI-MIDI systems, it is identified, precisely, in the "nodes", joints between beams or between beams and columns; in the case of the iconic office furniture, it is the spherical connecting ball joints that provide a solution to the entire system; In their urban project of the *Totale Stadt*, they are the connection points of the transport systems. His theoretical research in Los Angeles also deals with "salient points" in mathematical terms. In this attention to nodes and salient points, the influence of Wachsmann is clearly identified, in whose spatial structures the points of connection are also a central theme.

Likewise, the desire, common with Wachsmann, to find solutions of general validity in architecture, taking it to the universal, prevails. The creation of a family of modular systems, linked together by means of compatible dimensions, which aim to jointly solve the widest possible spectrum of requirements, rather than independent systems to solve isolated needs, denotes an unusual system vision. Haller systems ultimately structured the architect's entire output over the decades, from the smallest scale to the largest, making each building fit into the overall system as a piece of the jigsaw. To this end, two necessary mechanisms are present: modulation and component standardisation.

From another perspective, USM-Haller systems are a successful example of teamwork and architect-industry collaboration. Although Haller is credited with creating the systems, the architect always recounts the design process using the plural, giving visibility to the collaboration with engineer Paul Schärer and the USM company. Both of them, designer and manufacturer, benefited from each other: for Haller, it was his most important and longest work in time, and defined him professionally as an architect, and later a teacher, specialising in industrialised construction. It also led him to develop a systemic approach and a constant search for universal solutions in all areas of architecture. In turn, for the USM firm, the building of its headquarters in Münsingen became its emblem, not only housing its industrial activity but also becoming a showcase of the products manufactured there. However, Haller's main legacy to the company was, undoubtedly, the design of the line of furniture that bears his name, and which is, sixty years later, its main product and its hallmark.

As well as being a leading figure in Swiss architecture of the 1960s and 1970s, Fritz Haller made an important contribution to industrialised architecture in the second half of the 20th century, in the design, the application and p.50 integration of prefabricated systems, and this has had an impact on the work of renowned architects also beyond the borders of Switzerland, such as Norman Foster and Richard Rogers.

In today's architecture, focused on sustainability and, as part of this, aware of the value of longevity and the importance of reducing waste, the characteristics of Haller's work, sixty years later, are rising values. Standardisation and adaptability facilitate reuse and help to achieve sustainability and waste minimisation objectives in a type of architecture, industrial architecture, which due to its use often undergoes changes over time.

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12 Open systems are considered to be those that allow construction in combination with components of other construction systems, or with their own subsystems (for example, for facades or installations), due to their standardised dimensions, construction method or connections. Moreover, open systems are not necessarily tied to one manufacturer (ICOMOS Suisse, op. cit. supra, note 10, p. 181).

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14 Ibid., p. 72.

15 HALLER, Fritz, op. cit. supra, note 11, p. 473.

16 Ibid.

17 WICHMANN, Hans, op. cit. supra, note 13, p. 138.

18 The best-known building constructed with the MINI system is the "Büchli house", private residence of the owner of the firm USM, Päul Schärer, built in 1968-1969 and currently listed as a building of heritage value.

19 WICHMANN, Hans, op. cit. supra, note 13, p. 102.

20 The most important commission built with the MIDI system is the training centre of the SBB (the Swiss state-owned rail company) in Loewenberg (1980-1983). The complex includes a training building, an engine room, a school building, canteen and two residential complexes.

21 From 1977, Haller was a professor with tenure in the University of Karlsruhe, and director of the Institute of Industrial Building Production, which until 1990 was called the Institute of Building Design (DRACH, Angelika; HOVESTADT, Ludger. Intelligente CAD-Systeme : Instrumente für die Planung und Verwaltung komplexer Gebäude. In: *Werk, Bauen + Wohnen* [online. Zurich: Organ des Bundes Schweizer Architekten, 1992, no. 79, dosssier 10: Fritz Haller, pp. 16-24) [retrieved: 30-09-2024]. Available at: https://www.e-periodica.ch/digbib/view?pid=wbw-004%3A1992%3A79%3A%3A883.

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24 SABATTO, Steeve. Zur Frage von Massstab und Ökonomie. Totipotenz und Automation bei Konrad Wachsmann und Fritz Haller. En: STALDER, Laurent; VRACHLIOTIS, Georg, op. cit. supra, nota 9, p. 140.

25 SCHÄRER, Paul, op. cit. supra, nota 9, p. 207

26 KLEMP, Klaus. *The USM Haller Furniture System. Design Classics Series*. Frankfurt: Verlag Form, 2002, p. 17. ISBN 9783931317430.

27 The MAXI system, the most widely used of the three, was employed almost exclusively for production sheds, with the exception of a single-family house. The MINI system was mainly used for office buildings linked to production plants, and for single-family homes. The MIDI system had a minor application, with a total of five works carried out, including several buildings for residential, administrative and educational use. The complete inventory of all projects, both executed and not executed, which included one of the three Haller systems, is included in: ICOMOS Suisse, op. cit. supra, note 10, pp. 167-169.

28 FEDERAL ADMINISTRATION OF SWITZERLAND. *Protection of cultural property inventory with objects of national importance (Federal Office for Civil Protection FOCP)*. Geographic Information Platform of the Swiss Confederation. Available at: https://api3.geo.admin.ch/rest/services/ech/MapServer/ch.babs.kulturgueter/9038/extendedHtmlPopup?lang=en.

29 HALLER, Fritz. Fabrikhalle in Münsingen = Halle de fabrication à Münsingen = Factory shed at Münsingen. In: *Bauen + Wohnen* [online]. Zurich: Organ des Bundes Schweizer Architekten, 1964, no. 18, dossier 10, p. 394 [retrieved: 30-09-2024]. Available at: https://www.e-periodica.ch/digbib/view?pid=buw-001%3A1964%3A18%3A%3A1290#1290.

30 Bürohaus Schärer›s Söhne, Münsingen = Immeuble des bureaux, Schärer et fils, Münsingen = Office building, Schärer›s & sons, Münsingen. in: *Bauen + Wohnen* [online]. Zúrich: Organ des Bundes Schweizer Architekten, 1965, no. 19, dossier 8, p. 323 [retrieved: 30-09-2024]. Available at: https://www.e-periodica.ch/digbib/view?pid=buw-001%3A1965%3A19%3A%3A1077#1077.

31 GRASER, Jürg Martin, op. cit. supra, note 3, p. 267.

32 HALLER, Fritz. Von Eigenschaften ausgezeichneter Punkte in regulären geometrischen Systemen. In: *Bauen + Wohnen* [online]. Zurich: Organ des Bundes Schweizer Architekten, 1967, no. 21, dossier 11: Bauforschung, pp. 425-438 [retrieved: 30-09-2024]. Available at: https://www.e-periodica.ch/digbib/view?pid=buw-001%3A1967%3A21%3A%3A1390#1390.

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34 HALLER, Fritz. *totale stadt. ein model*. Olten: Walter Verlag, 1968.

35 HALLER, Fritz. *totale stadt. ein globales model. zweite studie.* Olten: Walter Verlag, 1975.

36 STADLER, Laurent; VRACHLIOTIS, Georg, op. cit. supra, note 9, p. 299.

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37 ICOMOS Suisse, op. cit. supra, note 10, p. 40-43; 103-107.

38 Designed by the engineer Heinz Isler, it consisted of concrete structures with a square base, with a cupular "shell"-type roofs. It was a closed system and was marketed and sold as an end product (ICOMOS Suisse, op. cit. supra, note 10, p. 81-83).

39 SOLÉ BRAVO, Carlos. *La casa de Norman y Wendy Foster en Hampstead. Tecnología y domesticidad entre los años 1960 y 1980*. Doctoral thesis. UPM, 2017, p. 153. Available at: https://oa.upm.es/45408/1/CARLOS_SOLE_BRAVO.pdf.

40 SABATTO, Steeve, op. cit. supra, note 24, p. 143.

41 MEDINA WARMBURG, Joaquín; LEOPOLD, Cornelie. *Strukturelle Architektur: Zur Aktualität eines Denkens zwischen Technik und Ästhetik*. Bielefeld: Transcript Verlag, 2012. ISBN 978-3-8376-1817-4.

42 FREI, Hans. Freiheit im Korsett. Die mathematische Denkweise in der Architektur von Fritz Haller. In: STADLER, Laurent; VRACHLIOTIS, Georg, op. cit. supra, note 9, pp. 124-139.

43 Wachsman was a teacher in the school of Ulm between 1954 and 1957, specialising in industrial architecture and teamwork, hence Max Bill's relationship with the German architect was a close one.

44 HIMMELREICH, Jørg. Alles bleibt anders? Beobachtungen zu zwei Jahrzehnten Schweizer Architektur. In: ANGÉLIL, Marc; HIMMELREICH, Jørg, eds. *Architekturdialoge : Positionen, Konzepte, Visionen*. Salenstein: Niggli, 2011, p. 120. ISBN 978-3-7212-0801-6.

45 Carlos Solé's doctoral thesis on the work of Norman Foster refers to "the influence that the work of the Swiss architect and industrial designer Fritz Haller exerted on the integration of systems in the "well-served building", through the structural engineer Anthony Hunt." (SOLÉ BRAVO, Carlos, op. cit. supra, note 39, p. 152.

46 A team of architects of which Norman Foster and Richard Rogers were members, which broke up in 1967.

47 SOLÉ BRAVO, Carlos, op. cit. supra, note 39, p. 369.