

HISTORY OF CONSTRUCTION CULTURES

8

VOLUME 2



edited by

João Mascarenhas-Mateus
and **Ana Paula Pires**



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HISTORY OF CONSTRUCTION CULTURES



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History of Construction Cultures

Editors

João Mascarenhas-Mateus

Universidade de Lisboa, Portugal

Ana Paula Pires

Universidade dos Açores, Portugal

Co-editors

Manuel Marques Caiado & Ivo Veiga

Universidade de Lisboa, Portugal

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Introduction: *History of Construction Cultures*

We are what we build and how we build; thus, the study of Construction History is now more than ever at the centre of current debates as to the shape of a sustainable future for humankind. Embracing that statement, the present work takes the title *History of Construction Cultures* and aims to celebrate and expand our understanding of the ways in which everyday building activities have been perceived and experienced in different cultures, times and places.

This two-volume publication brings together the communications that were presented at the 7ICCH – Seventh International Congress on Construction History, broadcast live from Lisbon, Portugal on 12–16 July 2021. The 7ICCH was organized by the Sociedade Portuguesa de Estudos de História da Construção (Portuguese Society for Construction History Studies – SPEHC); the Lisbon School of Architecture, University of Lisbon; its Research Centre (CIAUD); and the College of Social and Human Sciences of the NOVA University of Lisbon (NOVA FCSH).

This is the first time the International Congresses on Construction History (ICCH) Proceedings will be available in open access format in addition to the traditional printed and digital formats, embracing open science principles and increasing the societal impact of research. The work embodies and reflects the research done in different contexts worldwide in the sphere of Construction History with a view to advancing on the path opened by earlier International ICCH editions. The first edition of ICCH took place in Madrid in 2003. Since then, it has been a regular event organized at three-year intervals: Cambridge (2006), Cottbus (2009), Paris (2012), Chicago (2015) and Brussels (2018).

7ICCH focused on the many problems involved in the millennia-old human activity of building practiced in the most diverse cultures of the world, stimulating the cross-over with other disciplines. The response to this broad invitation materialized in 357 paper proposals. A thorough evaluation and selection process involving the International Scientific Committee resulted in the 206 papers of this work, authored by researchers from 37 countries: Australia, Austria, Belgium, Brazil, Bulgaria, Canada, China, Dominican Republic, Ecuador, Egypt, Estonia, France, Germany, India, Iran, Ireland, Italy, Japan, Mexico, Netherlands, New Zealand, Norway, Peru, Poland, Portugal, Puerto Rico, Russia, Serbia, Spain, South Africa, Sweden, Switzerland, Thailand, United Arab Emirates, United Kingdom, United States of America, and Venezuela.

The study of construction cultures entails the analysis of the transformation of a community's knowledge capital expressed in the activity of construction. As such, Construction History is a broad field of knowledge that encompasses all of the actors involved in that activity, whether collective (contractors, materials producers and suppliers, schools, associations, and institutions) or individual (engineers, architects, entrepreneurs, craftsmen). In each given location and historical period, these actors have engaged in building using particular technologies, tools, machines and materials. They have followed specific rules and laws, and transferred knowledge on construction in specific ways. Their activity has had an economic value and belonged to a particular political context, and it has been organized following a set of social and cultural models.

This broad range of issues was debated during the Congress in general open sessions, as well as in special thematic sessions. Open sessions covered a wide variety of aspects related to Construction History. Thematic sessions were selected by the Scientific Committee after a call for proposals: they highlight themes of recent debate, approaches and directions, fostering transnational and interdisciplinary collaboration on promising and propitious subjects. The open sessions topics were:

- Cultural translation of construction cultures: Colonial building processes and autochthonous cultures; hybridization of construction cultures, local interpretation of imported cultures of building; adaptation of building processes to different material conditions;
- The discipline of Construction History: Epistemological issues, methodology; teaching; historiography; sources on Construction History;
- Building actors: Contractors, architects, engineers; master builders, craftspeople, trade unions and guilds; institutions and organizations;
- Building materials: Their history, extraction, transformation and manipulation (timber; earth, brick and tiles; iron and steel; binders; concrete and reinforced concrete; plaster and mortar; glass and glazing; composite materials);

- Building machines, tools and equipment: Simple machines, steam operated-machines, hand tools, pneumatic tools, scaffolding;
- Construction processes: Design, execution and protective operations related to durability and maintenance; organization of the construction site; prefabrication and industrialization; craftsmanship and workshops; foundations, superstructures, roofs, coatings, paint;
- Building services and techniques: Lighting; heating; ventilation; health and comfort;
- Structural theory and analysis: Stereotomy; modelling and simulation; structural theory and structural forms; applied sciences; relation between theory and practice;
- Political, social and economic aspects: Economics of construction; law and juridical aspects; politics and policies; hierarchy of actors; public works and territory management, marketing and propaganda;
- Knowledge transfer: Technical literature, rules and standards; building regulations; training and education; drawings; patents; scientific dissemination, innovations, experiments and events.

The thematic sessions selected were:

- Form with no formwork (vault construction with reduced formwork);
- Understanding the culture of building expertise in situations of uncertainty (Middle Ages-Modern times);
- Historical timber constructions between regional tradition and supra-regional influences;
- Historicizing material properties: Between technological and cultural history;
- South-South cooperation and non-alignment in the construction world 1950s–1980s;
- Construction cultures of the recent past: Building materials and building techniques 1950–2000;
- Hypar concrete shells: A structural, geometric and constructive revolution in the mid-20th century;
- Can engineering culture be improved by construction history?

Volume 1 begins with the open session “Cultural translation of construction cultures” and continues with all of the thematic sessions, each one preceded by an introductory text by the session chairs. The volume ends with the first part of the papers presented at the open sessions, organized chronologically. Volume 2 is dedicated to the remaining topics within the general themes, also in chronological order.

Four keynote speakers were chosen to present their most recent research results on different historical periods: Marco Fabbri on “Building in Ancient Rome: The fortifications of Pompeii”; Stefan Holzer “The role of temporary works on the medieval and early modern construction site”; Vitale Zanchettin “Raphael’s architecture: Buildings and materials” and Beatriz Mugayar Kühl “Railways in São Paulo (Brazil): Impacts on the construction culture and on the transformation of the territory”.

The editors and the organizers wish to express their immense gratitude to all members of the International Scientific Committee, who, despite the difficult context of the pandemic, worked intensively every time they were called on to give their rigorous evaluation of the different papers.

The 7ICCH was the first congress convened under the aegis of the International Federation of Construction History, founded in July 2018 in Brussels. Therefore, we are also very grateful to all the members of the Federation, composed of the presidents of the British, Spanish, Francophone, German, U.S. and Portuguese Societies and its Belgian co-opted member. A special thanks is due for all the expertise and experience that was passed on by our colleagues who have been organizing this unique and world significant event since 2003, and in particular to our predecessors from all the Belgian universities who organized 6ICCH.

The editors wish to extend their sincerest thanks to authors and co-authors for their support, patience, and efforts. This two-volume work would not exist but for the time, knowledge, and generosity they invested in the initiative.

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Pursuing comfort in late 19th century school buildings in Milan: Technical knowledge and role of the enterprises

A. Grimoldi & A.G. Landi
Politecnico di Milano, Milan, Italy

ABSTRACT: After 1860, in European states, laws made public education compulsory and the obligations, which had already been sanctioned for nearly a century, were made effective: until then, they had hardly been applied. Urbanization was advancing ever further and the increase in the population required the construction of large school buildings in the cities. The best-known architects of the time participated in the implementation of a new building type. Ventilation was essential for the hygiene and heating was necessary to pursue school comfort. School construction stimulated the evolution of techniques, both in studies and in production. In Italy, studies in applied engineering promoted the development of a specialized mechanical industry in Milan, which met the high needs of the city and the region, attaining a dominant position in the rest of the kingdom. The city archives keep extensive documentation on the construction of the Milanese schools, the application of new technologies and the company roles and strategies in applying them.

1 INTRODUCTION

In the ancient Duchy of Milan, compulsory education dated back to the end of the 18th century. By the decree of Count Gabrio Casati, formerly mayor of Milan (1859), the newly founded Kingdom of Italy extended this obligation to its entire territory and attributed municipalities with the burden for school management, from the cost of personnel to the maintenance or construction of school buildings.

In cities, school classes were often located in private homes, rented and adapted, or in the monasteries or even the oratories of brotherhoods, suppressed at the end of the eighteenth century and, from the mid-19th century onwards, in purchased aristocratic residences.

The need for adequate buildings was soon encountered and became unavoidable when the Coppino law (1877) made effective the obligation established in 1859. Faced with the financial difficulties of municipalities, subsidized loans were granted for school buildings by law no. 4460/1878, establishing minimum requirements for new buildings and subsequently reiterated by law no. 5616/1888 (Grimoldi, Landi 2019).

The hygiene and functionality of spaces actually took crucial importance and gave ample space for the application of technological planning, in particular for centralized heating and natural and artificial ventilation. The Milanese experiences are particularly significant.

2 AIR HEATING, A PECULIAR MILANESE ACHIEVEMENT

The city had its own tradition in the heating sector. In the 18th century, large Milanese majolica stoves or simply brick stoves were commonly used, and hot air heating, known in the nineteenth century as *calorifero*, was installed in the Palazzo di Corte in 1750 (Forni 1997), before then spreading to every large house in the entire region. Meanwhile, the system had evolved: the first brick stoves were gradually replaced by cast iron furnaces and then all the improvements proposed by Meissner in the 1920s-30s were implemented (Forni 2017). A furnace heated a brick “chamber”, having sufficient thickness to ensure good insulation. The heat of the smoke was also exploited, making it circulate along iron sheet ducts, which sometimes crossed the chamber in several turns. Both the brick and iron components were affected by the heat and its variations. The joints were sealed with clay and had to be constantly renewed: the combustion gases and smoke were not to enter the hot air ducts through cracks and diffuse into the heated rooms. To avoid introducing too hot and dry air, the exchange surfaces between the furnace and the air, as the exchange chambers, had to be very large.

An air heater required continuous monitoring and adjustment. The stove could be placed in a room other than that to be heated, usually in a mezzanine, below the rooms, or in the cellars: this possibility was

much appreciated. The distribution of the heat was relatively simple, requiring only ducts in the walls, which were generally vertical. The changes in the direction of the ducts reduced the speed of the air, while attempts were made to increase its quantity and decrease its temperature. In the two editions of his pamphlet, Meissner (Meissner 1821) proposed ducting systems with horizontal tree paths of decreasing width, or diagonals; he even suggested the use of metal ducts within the wall cavities; however, these devices, which would have involved the implementation of cavities (similar to those required by the chimney flues in multi-storey rental houses), were not detected in all the cases studied. In the second half of the 19th century, sub-horizontal ducts in the cellars were frequent, with their length not exceeding fifteen meters (Ferrini 1876, p. 387) and formed by metal profiles that supported plastered tiles.

3 ITALIAN TECHNICAL LITERATURE AND ITS EUROPEAN REFERENCES

Attempts to eliminate the defects of these air heating systems had necessarily to focus on the production of heat in the stove. An effective synthesis of its ensuing implementation, especially in the German technical literature, is provided by Scholtz in the third edition of *Baukonstruktionlehre* by G.A. Breymann (Breymann 1893).

An extensive bibliographical survey on this subject is carried out in several languages by Hermann Fischer in the *Handbuch der Architektur*, the most extensive and complete manual of the late 19th century (Fischer 1881; 1890). Even if we cannot analyse Fischer's manual, it would be useful to understanding how, at that time, the expert technicians assimilated this technical evolution. In France, the fourth, posthumous edition of the manual by Péclet (Péclet Hudelo 1878) and by Planat (Planat 1880) played a similar role. Thus, recourse will be made to this general literature only if strictly related to the case studies considered.

Specialized publications, including those in English, circulated in Milan among the most up-to-date clients already in the first half of the 19th century. The cost of iron and the difficulty in providing coal – necessary to power sophisticated plants – hindered the development of the sector, in particular due to the lack of training of technicians. The *Museo Industriale* (Industrial Museum), founded in Turin in 1862 (Codazza 1873), was directed by an engineer, Giovanni Codazza, former Rector of the University of Pavia whose studies included the physics of heat (Ferola 1982). The collaboration between the Museum and the *Scuola di applicazione per gli ingegneri* (Application School for Engineers) in Turin and the foundation of the *Istituto Tecnico Superiore* in Milan (then named the Polytechnic) drew up the curriculum of studies for an industrial engineering degree. This model was proposed in accordance with an analogous course which had been taught in the Polytechnic of Vienna since 1815.

In 1870, Francesco Bongioannini discussed his thesis on heating and ventilation systems at the Turin *Scuola di applicazione per gli ingegneri* (Bongioannini 1870), with this then a novelty in the Italian technical literature. Bongioannini – an eclectic figure equally dealing with building services and the protection of monuments – concluded his manifold career as a superintendent for Education in Alessandria (Grimoldi, Landi 2019, p. 108). He finally published a collection of model projects for school buildings, including also heating system plants: circulation stoves heated the classrooms from the corridors (Bongioannini 1879).

Rinaldo Ferrini (Pozzato 1997), a professor at the *Milan Polytechnic*, was the author of the most systematic text, titled *Tecnologia del calore* (Ferrini 1876), which was translated into French in 1880 and also into German in 1887. The book was mostly updated on the French, English and German literature, even if lacking in bibliographical references, and described the state of the art in 1875, on the eve of significant changes. A very successful manual followed in 1886, published by Hoepli (Ferrini 1886), and intended for a wider audience of technicians.

The *Politecnico* – the fusion of the technical part of the famous magazine animated by Cattaneo with the *Giornale dell'Ingegnere* (1869) – devoted rare and short articles to heating and ventilation systems, either in the bibliographic review or in the “technological physics” sector, which also included both electricity and industrial plants. The author was almost always Ferrini. The famous physicist was not very interested in applications: for example, he only reported the air heater by Fischer and Stiehl (Ferrini 1883), which was already illustrated eight years earlier (*Stumme's Ingenieur* 1875).

Only at the turn of the century did he deal with steam heating and hot water heating but he pointed out conceptual problems that are still somewhat relevant today (Ferrini 1898). In proportion, the magazine *L'ingegneria civile e le arti industriali* – edited by Giovanni Sacheri since 1875 – seems more accurate although published in monthly issues of thirty-two pages, less than half of the *Politecnico* issues. Sacheri himself illustrated the *Eisenwerk Kaiserlautern* hot air system displayed at the Milanese Exhibition in 1881 (Sacheri 1882). In Italy, it was assembled by the *Besana e Carloni* company in Milan. Engineer Francesco Corradini defended the usage of finned tubes (Corradini 1882), while a text in two parts illustrates the advantages and disadvantages of the most common systems, and bears the signatures of the two owners of a famous company, founded in 1872 in Berlin, Hermann Rietschel and Rudolf Henneberg (Rietschel, Henneberg 1883). They were presented as Viennese, but Rietschel became professor at the Berlin Polytechnic in 1885: he founded the Institute that still bears his name today, and developed the teaching of technical physics (Usemann 1993). He was also the author of research on heating schools (Rietschel 1886).

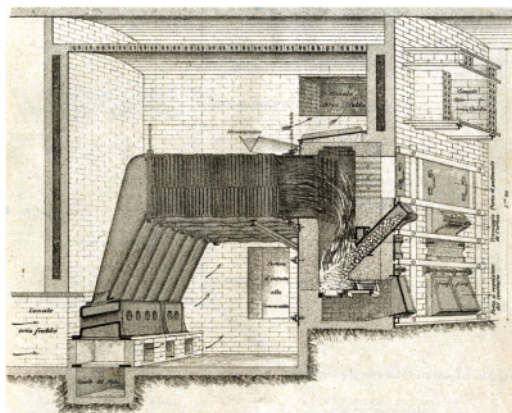


Figure 1. The *calorifero* (hot air heater by F. Corradini), in *L'ingegneria sanitaria*, no. 9, 1890, tav. 7.

A branch, the company *Kurz, Rietschel und Henneberg* operated in Vienna and realized many heating systems in public buildings (Usemann 1993, p. 155), including the Neues Rathaus (Weiß 1883) by Friedrich Schmidt, who was closely linked to the Milanese cultural *milieu*.

Sacheri himself presented an air heater – visibly derived from the *Eisenwerk Kaiserlauter* model – by his collaborator Corradini (Sacheri 1886), a mechanical engineer from Thiene, who graduated in Turin in 1876 (Curioni 1884, p. 238).

Specialized magazines, also entirely dedicated to civil construction, such as *Edilizia Moderna* – published in Milan since 1892 – or *Architettura Italiana* – published in Turin since 1890 – devote increasing space to heating systems but the demand in the sector had grown so much that Corradini had been able to publish a monthly magazine entitled *L'Ingegneria sanitaria* since 1890; he ran that magazine until 1905 when this merged with *L'ingegnere igienista*. In the issue of July 1890, Ferrini himself illustrated Corradini's air heater (Ferrini 1890), whose patent was sold to the G.B. Porta company and, in the same year, the *Politecnico* recommended this new magazine to its readers.

In half a century, the close relations between the technical *milieu* of Milan and Turin, among climate experts and companies, were strengthened. However, the approach quickly changed: in 1890 the magazine acknowledged the new low-pressure steam regulation system, implemented by the Körting company in Hanover: it allowed for varying the temperature in every singular *stufa* (stove) without introducing (or removing) the air (Gibelli 1890). There followed a further local improvement, which was carried out by the Milanese company *Piazza & Zippermayr*: the lower quantity of steam determined by the regulation of the “stoves” (radiators) activated a simple conical valve, which decreased the production of steam in the boiler. The owners themselves signed the article (Piazza & Zippermayr 1892). The valve eliminated the presence of a licensed stoker to control the boiler. The contrast

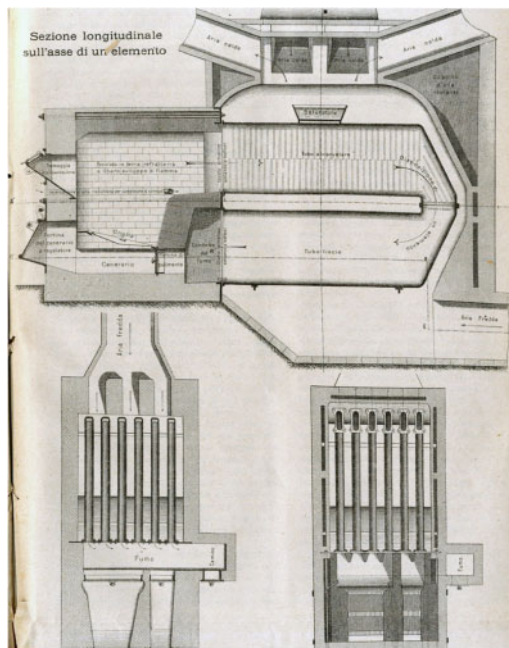


Figure 2. The *calorifero* (hot air heater patented) by the firm G. B. Porta, in *L'ingegneria sanitaria*, July 1890, tav. 7b.

between the technical evolution and the persistence of legislation lagging behind and hindering any kind of innovation, is well explained in the magazine *Edilizia Moderna* (Baseggio 1892) by engineer Nicolò Baseggio, a supporter of the new system and a future expert in accident prevention.

In 1895, Corradini reviewed – or better summed up – a book on heating systems by P. P. Morra, a professor of technical physics at the *Museo Industriale* (Ferraris 1906). It was a copiously illustrated 130-page extract (Morra 1895) from the *Enciclopedia delle Arti e Industrie*, coordinated by Raffaele Pareto and Giovanni Sacheri (Corradini 1895). The long article briefly deals with air-heaters and evaluates the high-pressure system – both steam and water – as outdated. In this last field, the Milan and Turin experiences were very scarce, and with the gradual abandonment of air-heating systems in private and public buildings.

4 FROM THE FUMISTI TO THE ENGINEERS

In fact, the difference between a stove and an air heating system, according to an undisputed authority, Eugène Péclet (Péclet 1861), are conceptually limited. The former, even when it provided cavities to heat the air by convection (the “circulation stoves”) did not renew the ambient air, while the latter let in external air. It was, therefore, possible to make «caloriphères placés dans les lieux à chauffer» (Péclet 1861, pp. 338–346) and «caloriphères placés loin des lieux qui doivent être chauffés» (Péclet 1861, pp. 346–364). The exchange of air was essential for collective health

and school buildings were relevant in this regard: the great physicist wanted to write a booklet (Péclet 1846), describing a real experience he made with the help of a specialized engineer, Léon Duvoir. A large classroom was heated by two high cylindrical circulation stoves, placed on the platform of the desk, so that the teacher could check their functioning. They heated external air, while thin metal smoke ducts crossed the entire classroom horizontally, up to chimneys in the opposite wall.

In Northern Italy, until the mid-nineteenth century, the air heating system was integrated into the construction, and therefore a task for architects or civil engineers. The executors were simple masons, assisted, for the stove installation, by the *fumisti*, a very widespread Gallicism. This word designated skilled assemblers of refractory ceramic panels, sheet metals and cast pieces produced by local foundries. The *fumisti* worked within a brick construction, adapted on-site. This organization of work progressively changed after 1850, following a process already developed in France and Great Britain. The goal was to simplify maintenance, abolishing the annual renewal of seals and heating a greater quantity of air at lower temperatures. Supply had to be simplified by providing automatic fuel loading, with simple devices based on elementary physical principles. The exchange of the heat, produced by the fuel in the furnace and by the smoke in its loss of temperature, had to be concentrated in a somewhat sealed apparatus. Only leading industrial engineers could conceive of such furnaces-exchangers, produced and assembled by specialized mechanical workshops, participating in defining the design of the entire plant.

In Milan, the company founded by the Duke Antonio Litta in 1857, who had bought Chaussenot's French patent, set the pace (Landi 2017). The exchanger consisted of a furnace from which the smoke climbed up into a sort of cast iron hemisphere, before then descending through a double row of cast iron ducts into a similar lower hemisphere connected to the flue. Péclet was very sceptical about this apparatus, which produced a low performance in comparison with the high cost of the cast iron used.

In his book, Ferrini owes many illustrations to Péclet (Ferrini 1876); he makes very little reference to the subject and underlines the analogy with a "circulation" stove model, which heated both by radiation and by convection using the same device in smaller dimensions. It was a typical initiative of a world on its way out, where the high aristocracy of the Hapsburg empire also held the public role to support technological innovation; on the death of the Duke in 1866, the company, which had offices in Turin and Milan, continued to be run by Gian Battista Monti. He renewed production with the help of engineer Carlo Cochard, a large landowner from Adro, in the province of Brescia: he was an expert in applying heat to the processing of agricultural products. The company then passed to the engineer G. B. Porta and survived until the end of the nineteenth century. The advertising brochures not only illustrated the company patent, which dated

back to 1839, but also gave an idea of the business. The company could also take charge of the design. Customers usually had to provide plants and sections of the rooms to be heated. Until 1864, about 200 installations of very different sizes were executed, including nursery schools for the Municipality of Turin. In the same year, a "Litta heating system" was planned for the new large school building in Corso di Porta Romana in Milan (Archivio del Comune di Milano, hereinafter ACMI, Beni Comunali, Finanze, cart. 209), but it is not mentioned in the *brochure*. Not only were air heaters available, which however might coincide with circulation stoves in the current language, but also heaters with "heating" or even simply "interiors for fireplaces".

Bartolomeo Zanna had working experiences in Vienna until 1840/50, and in 1852 he started his company, while simultaneously opening a branch in Milan (Manfredi 2013, pp. 171-173; Manfredi 2017, pp. 52-53). The company was taken over by *Caligaris & Piacenza*, and was still active in the 1890s when it developed a type of air-heater mixed with air and steam (Corradini 1895, pp. 187-188).

Its qualities – as attested to by the Milanese prison of San Vittore in 1874 – were effective coordination, availability and rapid execution, while the technical background probably still linked to Meissner's texts. The proposals for elementary schools in Via Santo Spirito in Milan, and the contract (10 July 1878), describe three radiators in which iron and cast iron were quoted by weight, that is, an "iron serpentine", a flue passing from the furnace through the air heating chamber (ACMI, Beni Comunali, Finanze, cart. 220). The described works are disparate, including a "hot-air stove" and required numerous masonry works, including the demolition of an old air heater, as attested to by the final balance in 1879. In the same building, the subsequent steps of works include not only other heaters, but also some *Franklins*, a fireplace and another stove. For the schools in Via Santa Marta (ACMI, Beni Comunali, Finanze, cart. 224), the installation of an air and steam heater was negotiated in 1883: a single boiler produced the steam which in turn heated the air, condensing in special coils in mixing chambers at the foot of vertical ducts. Although the correspondence is incomplete, it would seem that, in the end, the Office of the Engineers did not trust the technical innovation suggested by *Besana e Carloni*, and turned to Zanna in 1885. The municipal engineers preferred a clearly antiquated (but reliable) solution or, more likely, an executor they had consolidated a relationship with, and therefore all the administrative procedures were simpler and faster.

Additionally, in Turin, the Castellamonte furnaces, traditional producers of terracotta and majolica stoves, had extended their range of action to *fumisteria*, air heating, offering a composite product that aggregated metal, terracotta and majolica parts. Although the products were largely designed for private homes, public demands, centralized systems and, in particular, school buildings were also given great attention.

In 1882/83 the catalogue of the *fumista* Buscaglione proudly highlighted not only the date of the foundation of the company (1830) but also bore as an epigraph a passage from Narjoux's book (Narjoux 1877) on public schools in France and Britain. In 1895, Corradini deemed these products obsolete (Corradini 1895, p. 187).

5 FROM AIR TO STEAM

Conversely, like the *Società anonima Duca Litta*, other Milanese companies also based their fortunes on the application of foreign patents. The entirely cast-iron stoves had spread rapidly in the early decades of the 19th century, imported mostly from Bohemia and Moravia. Milan was the natural outlet of trade flows from Switzerland and Rhenish Germany. Business relations with the territories that were left to the Habsburgs after 1859 continued to be strong. The reference technology, however, was that of the new German empire which, after the two banking crises of 1873 and 1889/1893, had also become decisive in finance, and offered effective support to its companies. The German model, where the engineers, *Rietschel and Henneberg* or *Fischer and Stiehl* became entrepreneurs exploiting the innovations they had conceived, was reproduced on a smaller scale by Milanese companies. In turn, the commercial relations and the import of technologies from France decreased: while those with the English-speaking world remained marginal, although the language, the technical literature and their achievements were well known. Like Turin, Milan and its mechanical industry certainly played a prominent, though not exclusive, role in exporting their technologies and products throughout the kingdom. The air heater was an effective *passe-partout*: new, complex stoves could be purchased, while the distribution - more extensive but less specialized - remained a mason's work and could be carried out on site.

The best organized company belonged to Edoardo Lehmann. He was of Swiss descent, and settled in Milan in 1879. In 1886 he had completed his factory, which occupied an entire block next to the train track square of the Central Station, between the current streets Lazzaretto, Casati and Tunisia. Following the decline of air heaters, the company developed its own variant of low-pressure steam heating (Corradini 1895, pp. 192–193) and remained active until 1906, when *Haeblerlin Gerra & C.* took over until 1913 (Grimoldi, Landi 2019, p. 122). Lehmann proposed a Geneva patent, that of L.F. Staib (1812–1866), which dated back to the 1850s.

Péclet considers it a very well-studied patent, however it was subsequently perfected (Candolle 1867, pp. 288–90; Wartmann 1873, pp. 68–69). Bongioannini illustrates it and Ferrini describes and links it to the name of his successors Weibel (Weibel 2006) and Briquet. The pyramidal furnace facing upwards was contained in a cast iron parallelepiped with accordion-like sides. An inclined hopper allowed coal to be loaded

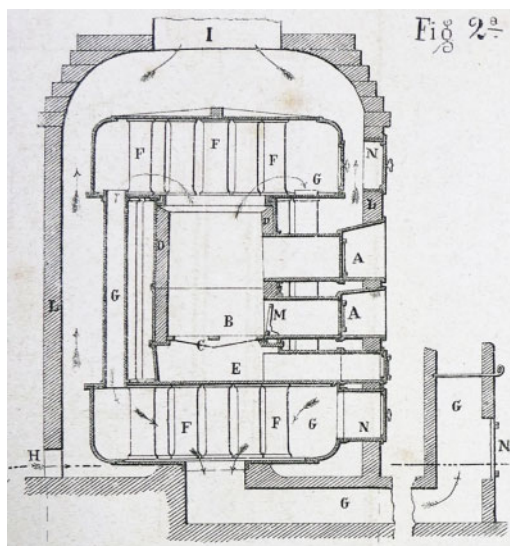


Figure 3. The *calorifero* (hot air heater) Litta, from (Bongioannini 1870, tav. 2, fig. 3).

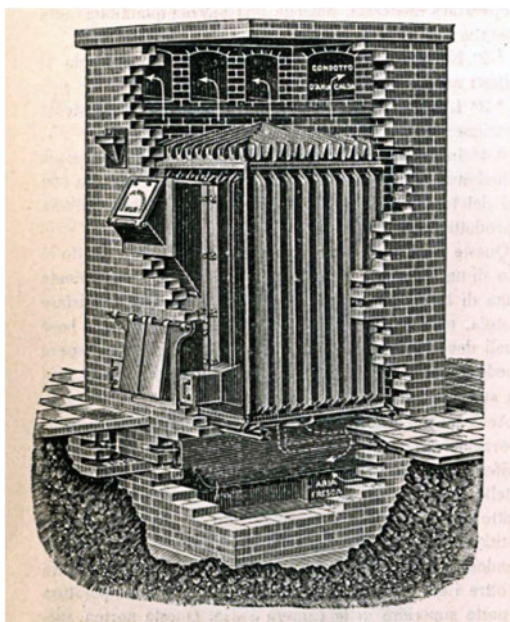


Figure 4. The *calorifero* (hot air heater) Staib, by Edoardo Lehmann in Milan, in *L'ingegneria sanitaria*, n. 9, 1895, p. 174.

every eight or twelve hours. The smoke lingered in this vast combustion chamber and was drawn under the furnace. The particular profile of the perimeter walls increased the exchange surface and the heat at a lower temperature was transmitted to a more abundant quantity of air that circulated in a masonry chamber, formed by a double wall in solid bricks inside, and perforated bricks towards the outside.

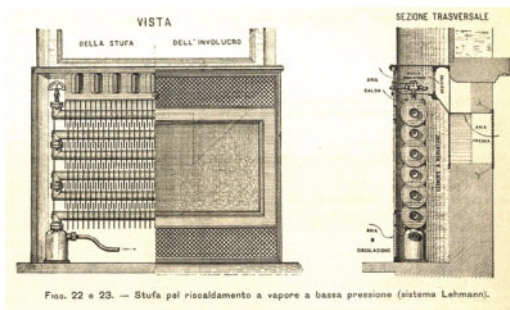


Figure 5. Low pressure steam heating system by Lehmann, Milan, the “stoves”. In *L'ingegneria sanitaria*, no. 10, 1895 p. 189.

A similar solution was developed in France by *Girardeau & Jalibert*, who also recommended it in a special version for schools (Planat 1880, p. 337). These apparatuses resolved the lively debate on the finning of pipes and more generally of containers in the 1870/80s.

Finned pipes were also introduced into the Litta-Chaussonot radiator, a difference that enabled a Turin company, Carlo Crivelli, to circumvent the patent (Corradini 1882). As often happens, the contenders aimed at different objectives: the transmission of heat did not significantly increase, because the fins decreased in temperature towards their ends. According to Planat, the heat exchange did not increase over 50% by doubling the surface by means of fins. However, the temperature decreased over a greater extension with this a useful effect for a good heater performance.

The ownership of a patent was a commercial resource: the specificity and exclusive use of the technical solution allowed the assigning of public tender contracts even against lower bids: thus, Lehmann was awarded the heating of the school complex in Via Anfossi (1888) and also of the schools in Via Galvani (ACMI, Beni Comunali, Finanze, cart. 214, f. 8) Boito and Ferrini had accepted this heating system on the basis of its technical superiority. In their opinion, the problems of regulating low-pressure steam heaters had not been solved yet even though endorsed by the Municipal Health Commission (November 24, 1887); so they rejected a single steam boiler to feed the air system, which was also proposed, in this case, by the *Besana & Carloni* company (ACMI, BC-Fi, cart. 227, f. 7).

Lehmann, as a system builder, proposed a mechanical summer ventilation system. He was not favourable to passive ventilation systems, which the two renowned scholars instead recommended. Boito had precisely followed the instructions contained in his colleague's book (Ferrini 1876, p. 451) in designing the school's ducts in Padua, and also in via Galvani he had envisaged special air intakes at the level of the floors integrated into the design of the façade.

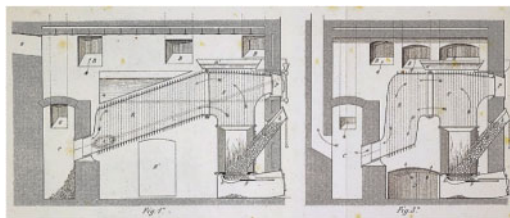


Figure 6. The *calorifero* (hot air heater) by *Eisenwerk Kaiserlautern* represented in Italy by the firm *Besana e Carloni*, in *L'ingegneria civile e le arti industriali*, 1882, tav. 7.

The most reliable competitor, the *Besana e Carloni* company owned a large factory in Via San Rocco in Porta Romana, in the district where companies producing railway materials were located. Their representative office was in the centre, in Via Torino, in the former Giuseppe Besana's office, one of the two engineering partners who founded the company, for directly carrying out projects that were formerly entrusted to various craftsmen. The 1888 Besana list of works includes numerous hospitals, and the contract, just received, for the heating system of the Roman headquarters of the Bank of Italy. They could count on a real national network of correspondents in the main cities and on other engineers who collaborated first on the projects and then on the direction of the works (in Turin, that representative was Francesco Corradini). The company had already added high and low-pressure steam heating to air heaters. In the offer letter directly addressed to Camillo Boito for the school in Via Galvani, Giuseppe Besana claims to produce all the necessary material in his own factory, while, in his opinion, other companies just assemble all the imported pieces; he concludes with a biased apology of the protectionist policy, pursued by the *Sinistra* then in power. More specifically, Besana presented his company as a “precision foundry”.

To attain an economic equilibrium, a large amount of other activities, in addition to civil and industrial heating systems, were required. The company supplied bathrooms, kitchens and special cast pieces to order. It probably imported the most sophisticated apparatuses from Germany, despite the protectionist faith of its owners. For hot air heaters, *Besana e Carloni* was a patent holder on behalf of *Eisenwerk Kaiserlautern*. a company specialized in metal heating appliances. The system was made up by an exchange chamber crossed by an inclined smoke duct and the furnace used the long-life loading system for column circulating stoves, patented by a professor at the Karlsruhe Polytechnic, Heinrich Meidinger.

Other producers, working for the Municipality of Milan, had not yet made the leap yet from the professional practice to an enterprise. Guzzi and Ravizza are engineers, respectively mechanical and civil. Their activity began in 1870 as representatives of patents belonging to other holders and managing all of the procedures necessary to obtain the patent. They will

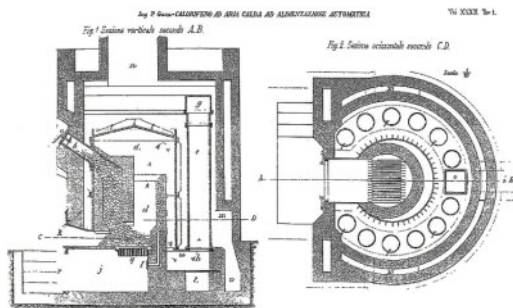


Figure 7. The *calorifero* (hot air heater) by the company Guzzi & Ravizza, in Milan in *Il Politecnico – Giornale ...*, vol. XXXIII, tav. 1.

take the final step towards the mechanical industry within the following two years but, in particular, they will deal with the equipment for the fledgling electrical industry.

Ravizza published several articles on the structural problems of rural buildings in the *Politecnico* magazine, while Guzzi repeatedly wrote in defence of patents and above all on the theoretical aspects of heat transmission; Ferrini himself considered him a significant interlocutor to the extent of sending him a public letter (Ferrini 1878). Guzzi also published a model of an air heater, with a circular plan with cast iron pipes, yet another reworking of the Chaussonot heater (Guzzi 1885).

Unfortunately, the accounting relating to the Lazaretto school heaters has not been preserved but the four heaters, one installed in each wing, certainly corresponded to this model. The upper part of the flues was flanked by the final part of the ducts, that went up into the spine walls, thus activating thermal ventilation. In summer, it sufficed to light a gas flame in the ducts. Fresh air flowed into the classrooms from the double-walled window sills. The air penetrated through an external circular grate and came out of an adjustable vent at floor level. The vasistas windows and sliding wooden shutters were also designed to regulate the heat exchange. Angelo Savoldi, the designer, had entrusted the thermal comfort to the constructive elements no less than to the system (ACMI, BC-Fi, cart. 223).

The next generation of school buildings will focus on a simplified construction to reduce costs, entrusting the ventilation to the windows, reduced from one-third to one-sixth of the floor surface (Ferrini 1892, f. VII, p. 5) and therefore having to focus on installation. The technical office however continued to use air heaters (*ibidem*, f. VIII, p. 6); but in the following year, in 1893, in the large complex of Via Ariberto, Piazza & Zippermayr, owners of the automatic boiler regulation system, created and implemented a low-pressure steam heating system, with “stoves” in 46 classrooms (ACMI, BC-Fi, cart. 216, f. 3). Only the maintenance costs of 1896 attest to the presence of a similar low-pressure steam heater, entrusted however

to the *Mussi and Koerting* company, in the schools of Via Pastrengo.

6 CONCLUSIONS

The *Statistica industriale della Provincia di Milano* was published in the Bulletin of the Ministry of Agriculture, Industry and Commerce in 1893; its information dates back to 1891, and enables the integration of printed advertising with comparable data. The six companies, Lehmann, Besana and Carloni, De Franceschi, Piazza and Zippermayr, Mussi&Koertning, employed 346 workers, a motive force of 132 HP, with 19 forges, 30 lathes and 78 machines of various kinds. The six companies producing railway materials employed 3,120 workers and 1,242 HP, hence, ten times more, while all of the other mechanical industries (including small items and other objects of use), employed 11,547 workers with 2,271 HP. The relationship between workers and motive force was similar to the railway material producers, while in the rest of the sector, technical and manual skills prevailed, as in the case of measuring instruments that require a high degree of expertise. However, the *Mussi&Koertning* company was in fact a representative office, of a large company in Hannover for the regulation of low-pressure steam heaters. The rapid success of the system led the German company to set up its own factory in Sestri Ponente, destined for the Italian market. This was managed by a member of the family and produced all the components, which had hitherto been imported. This relocation – as it would be called today – was one of the signs of the industrial launch in northern Italy. The diffusion of more sophisticated plants also marked a substantial leap forward in the size of companies, the organization of their production and their relationship with the applied research.

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