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Proceedings of the Third International Congress on Construction History

Brandenburg University of Technology Cottbus, Germany
20th – 24th May 2009

THIRD INTERNATIONAL CONGRESS ON CONSTRUCTION HISTORY, COTTBUS, 20TH – 24TH MAY 2009

Concept and Realisation

Chair of Construction History and Structural Preservation, Brandenburg University of Technology Cottbus

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Front: Construction of the Zeiss Planetarium, 1924. [Picon: L'Art de l'ingénieur. Paris 1997]; Collapse Mechanism of a dome according to Poleni. [Benvenuto: An introduction to the history of Structural Mechanics. New York 1991]; O. H. Ammann during Construction of the Washington Bridge. [Picon: L'Art de l'ingénieur. Paris 1997]; Kathedrale St. Peter in Exeter, Devonshire. [Picon: L'Art de l'ingénieur. Paris 1997]; Baumeister Moritz Ensinger, 1482. [Landesmuseum Mainz]

Verso: Selected images of Cottbus and its environment taken by Roland Wieczorek, BTU Cottbus

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Welcome to the Third International Congress on Construction History!

Following the successful congresses in Madrid (2003) and Cambridge (2006), now, in May 2009 the *Brandenburg University of Technology Cottbus* has the honour of hosting the *Third International Congress on Construction History*. Like the meetings in Spain and Great Britain, the Cottbus Congress intends to transcend the constraints of traditional cultural and disciplinary boundaries. It is open to contributors associated with all disciplines focussed on and around the worldwide movement of construction history.

With just a cursory glance at the papers, one cannot help but notice the impressive breadth of this movement, both in terms of content and method. The fact that, meanwhile, more and more practising engineers and architects are maintaining a dialogue with historians reflects the increasing shift in construction practise from building new to developing existing structures; in this field, an intelligent and appropriate intervention is hardly imaginable without knowledge of the history of construction. But – construction history is far more than that. Since the end of the 20th century a distinctly professional attitude has been observed. One cannot resist the impression that a new discipline is in the process of establishing itself, transcending traditional academic demarcations. It is history of architecture, history of technology, history of science, archaeology, not to forget restoration of historical structures, yet it does not fit into any of these categories.

If we understand construction as a highly interconnected process between creativity and routine, between craft and science, between invention, innovation and tradition, or in other words as the never ending process for developing a specific link between nature and culture - then the role of construction history is no more no less than to provide an explanation of the act of producing this hinge in all its cross-linkages, interdependencies, and processes of interchange, right up to the use of practical applications and technology. If the process of construction in its fascinating entirety constitutes construction history, it thus concerns far more than the narrow technical question of "how it was made?" It concerns a wide range of different practices of building and it has to recognise them as the results of different human and historical conditions.

Understood in this way construction history is an open-ended adventure - the adventure of discovering the act of constructing as a deeply human and subjective process, or, to quote the initiators of the 2006 Cambridge Congress: "... to understand the way human beings have approached building." Construction history in this sense is the challenge to meet human beings, to encounter the *homo faber* again and anew across the millennia. In doing this we are confronted with the genealogy of such central aspects of twenty-first century technical culture such as progress, identity, responsibility, quality of life. Understood in this way construction history in all its facets turns out to be no less than a technical anthropology. We do hope the Cottbus Congress will afford the opportunity for a serious reflection on construction history in this sense and the great questions regarding it - its cognitive interests, its subject matters, its methodology, its agenda and – last but not least – its potential significance at the beginning of the twenty-first century.

The Congress would not have been realisable without the engagement and constant support of a wide range of colleagues, friends and institutions. We cordially want to thank all our sponsors and collaboration partners for their generous sponsorship and benefits as well as the Brandenburg University of Technology Cottbus for its engaged backing. Special thank goes to our friend and colleague within the Berlin-Brandenburg Construction History Group, Andreas Kahlow for his help and assistance, to the colleagues of the National Support Group and to all members of the International Scientific Committee who double peer reviewed about 400 abstracts and 200 papers submitted to ensure a high scientific quality among all contributions. Last but not least, we want to express our sincere thanks to all members of the Chair of Construction History and Structural Preservation at the BTU Cottbus and its fantastic Organising Committee, and first of all to Volker Wetzk. It's more than two years ago that we started our work without any premonition of the problems waiting for us. Due to the Organising Committee's unfailing dedication and enthusiastic work now, finally, the Congress is ready to begin.

In the name of the organising team and all supporters we cordially welcome our guests. We are sure the Cottbus Congress will offer you an open forum for presenting the broad field of research into construction history as well as discussing the numerous themes and questions connected with it. And we also hope that among paper sessions, keynotes, panel discussions and excursions, there will nevertheless be plenty of time and opportunity for what modern science needs: The vivid exchange of concepts, ideas and experience among international academics, practicing engineers and architects, building researchers and archaeologists from across the world.

Prof. Dr.-Ing. Werner Lorenz, Cottbus
Chair of Organising Committee

Dr.-Ing. Karl-Eugen Kurrer, Berlin
Chair of International Scientific Committee

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Gas-lighting in Italy during 1800s. Urban plants and monuments devices between construction history and questions of safeguard.

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ABSTRACT: After an overview on the diffusion of the gas-light system through Italy, the paper focuses on Mantua, a typical middle town with a great urban and construction history as it was the Renaissance Capital of the Gonzaga dukedom.
The story of the gas system in Mantua has been reconstructed with the instruments of the archive research while particular attention is for the gas-light plant realized since 1864 to 1886 for the Alberti's S. Andrew Basilica, where many rests (e.g. lamps, pipes) are still visible.
This gad-light plant is a great example to analyze the way an eighteen industrial device had been installed (often with many difficulties) over the fragile monumental structure of such a building, determining a sudden modification in the perception of the great architectonic interior of the Basilica and the decay of its marble floor and frescoes painted walls.
Nowadays, the restoration purposes of the Basilica interior, meets the historical value of this gas-light plant which has to be considered as a more recent step in the five-century construction history of the Basilica and, thus, has be preserved itself.

The main steps in the history of the lighting systems are quite known since the end of the 18th century: Ami Argand (1750-1803) presented his innovative oil lamp in Paris in 1786. This lamp improved the efficiency of the traditional combustible (oil) by a flat, tubular-shape section wick instead of the traditional candlewick. This system was a slight novelty, however it represented a great innovation and forecasted the idea of obtaining light burning a mixture of oxygen (air) and combustible (oil) that, after a few years, would have been so important for the effectiveness of the gas lamps. Argand equipped his lamp with a further device to drive the wick up and down, regulating the mixture of air and oil and, therefore, the intensity of the flame and the consumption of oil. The same importance had the glass cylinder which protected the flame from drafts, improving the vent due to the "*flue effect*" and, consequently, its efficiency (Elton, 1964).
Philippe Lebon (1767-1804) was probably the first to employ gas to obtain light. His *Thermolamp* was a kind of big stove producing warmth and light simultaneously, by burning a coal-gas mixture obtained from the distillation of wood. Lebon's Thermolamp matched the two main uses of energy in the house, warmth and light, by a self-produced form of energy. Furthermore, the domestic pipe network which distributed gas through the house, anticipated the following wider applications of the same system.
At the very beginning of the 19th century, the industrial development awakened the interest toward sources of light more suitable than candles and oil, to guarantee the continuity of the work inside the factories. Historians agree on the name of William Murdoch (1754 -1839), a mechanical engineer at the *Boulton&Watt Foundry* in Soho-Birmingham. He carried out experiences about the production of gas from different kinds of coals and gave a powerful demonstration of the new lighting system, illuminating the *Foundry* with two strong gas flames, during the celebrations for the Peace of Amiens in 1802.
Thanks to men like Frederick Winsor (1763-1830), the system quickly spread to the urban scale. In 1806, he founded the National Light and Heat Company in London which started to illuminate a small district of the city the following year. In 1812 he obtained his first public assignment with his society *The Gas Light and Coke Company* and, in 1819, he left London to export his model in Paris, demonstrating that Murdoch's first prototype, was ready for an urban-scale application. The coal-gas mixture was to be used to illuminate entire cities, both for private and public employment.
On this point, the diffusion of the gas-lighting systems was generally connected to the development of an industrial tissue both for the necessity of combustible both for the opportunities to sale the by-products of distillation (coke, ammoniac waters, tar). England was the European leader in this field, followed by France, Belgium and Germany. The proximity with the industrial activities, the necessity of a gas work and a pipe network characterized gas light as a typically urban phenomenon. While it spread in the urban regions (in

England, almost every town with more than 10.000 inhabitants has been illuminated with gas since 1826), candles and oil lamps have been kept in use for ten's years in the countryside and particularly in the backward parts of Europe. (Falkus, 1967, pp. 494-508).
Argand's oil lamp has been used to illuminate the interiors of private and public buildings since 18th century In Italy. The gas system started to illuminate both the streets and the single buildings in the north of the Country, since the first half of 19th century. (Mondini, 1977). Then, the gas-lighting system has kept in use for more than 100 years, resisting to the brief and experimental season of the arc-lamp and to the wide – even if not so quick - advent of electricity. As the gas system did not suddenly substitute the oil lamps, similarly electricity did not suddenly substitute gas. The new technology and the old one, in fact, has often kept in use side by side even for many years. (Cordovil, 2008, pp. 30-35).
It must be noticed as the early history of gas lighting in Italy coincided with the political season called "Risorgimento", when the several little states in which the Peninsula was divided in, were progressively collected in a united Nation between 1848 and 1870. This political background had surely affected to slacken the spreading of an industrial policy in comparison with other European countries (e.g. U.K., France, Germany) where, at the middle of 1800's, an earlier settlement of central forms of government allowed to plan national programs of industrial development. Therefore, gaslight spread through Italy considerably in delay both by the political fragmentation and the backwardness of a widespread industrial tissue.
As a consequence, there were a "double speed" in the diffusion of the gas-light system: a quicker one in the main industrial city of the North (Silvio Pellico translated the Accum's treatise in Milan in 1817), where the proximity to the rest of Europe favoured the formation of an industrial tissue; a much slower one, and often uncompleted, in the little towns and, particularly in the Southern Region.
The main city in Piedmont, Tuscany and Lombard-Venetian State, have been gas-lighted since the beginning of 1840's (see tab. 1)

Table. 1: development of the early gas plants for public lighting in Italy

Torino	Venezia	Milano Firenze Padova	Genova Bologna	Trento	Cremona	Mantova
1838	1842	1845	1846	1859	1861	1864

Economy moved slowly toward industrialization in the Southern Regions which delayed in receiving this technical innovation. Even the old capitals, Rome and Naples, never reached the same levels of consumption as the northern towns, where the growing industrial tissue fostered the economic activity induced by the production of gas. Province Towns Governments were interested in gas lighting moreover to improve public safety during the night. Urban installation were often made with the purpose to support the political power, helping the police to keep the order. The idea to gas-light a business, developed only in the second half of the Century. In the main northern cities, grant authorizations were progressively awarded to private companies to build the gas-work and, later, to install a pipe network to supply public lighting.
The industrial backwardness of Italy is confirmed also by the monopoly of the Italian gas-works which were built and managed by foreign societies, in particular French, Belgian and German. Gas plants were built by foreign workers and managed by directors who were trained in foreign works. Particularly, the Union des Gaz was a true multinational company and operated mostly in the main northern cities like Milan, Genoa and Bologna.
Private companies invested for the construction of a gas-work before they have obtained a concession for public lighting. As in many cases, several years passed since the construction of the gas-work to the moment the City Council issued the grant for public lighting, many companies incurred debts and bankrupted. The length of the agreements and the strong determination to keep them effective, has contributed to maintain gas lighting in use even for 40 years, after electricity has been available. Furthermore, on the technical side, the use of the Auer's mantles since 1890's, made the gas flame more performing and bright, contributing to keep the system in use for long, even until the end of the 1950's. (Penati, 1972). However, gas had been slowly ousted by incandescent bulbs in public lighting since 1900's, due to the better efficiency, power and safety of the new system. On the technical side, electric lighting borrowed from gas the idea of a distribution system separated from the place where the combustible (or the source of energy) has been produced and the one it has been consumed. Therefore, the swift success of electric lighting could be considered mainly as the improvement of an existing technology by the reduction of its defects (Schivelbusch,1983, Chapter 1)
It is interesting to consider the history of the gas-lighting systems from the point of view of Mantua, an Italian middle town in the north of the Country characterized by an important urban history as it was one of the main Capitals of the Italian Renaissance, under the Gonzaga dukedom. Its dimensional, territorial and, above all, historical characteristic Mantua a perfect case-study to reflect about how the gas system spread through the historically formed Italian tissue during the eighteen century. After the beauty of the Renaissance, at the end of seventeenth century, several chronicles described Mantua as an important Hapsburg barracks fortress in the north of Italy: any productive economy was supported, the towns laid in misery and was far from the eco of the economic and industrial revolution which had already interested other parts of Europe and was to involve Italy.
Nevertheless this backwardness, a first public lighting was adopted along the main streets in 1802. It was composed of one hundred seventy-two lamps supplied with olive oil. The town city was lighted in 1842 by 246 reverberators (a sort of lamp endowed with parabola) burning rape oil which was cheaper than the olive one. While these devices based on traditional oils has been kept in use for years (even until last century) to illuminate many peripheral neighborhood, the first gas plant for public lighting was completed in the central

streets of Mantua with a certain delay if compared with the main northern cities (Milan, Turin) but contemporary with other middle-towns, as the near Cremona, where gas lampposts arrived in 1861.
The Municipality of Mantua authorized Ludwig August Riedinger to build a gas-work in a east area of the town, near Porto Catena , in February 1863. Riedinger founded its enterprise in Augsburg (Germany) with the chemist and hygienist Max Joseph von Pettenkofer which had improved a method to extract gas-light from wood. Riedinger built its first gas-work in Munich in 1851 and, in 1879, he had completed twenty-five gasworks in Bavaria and forty-two in Europe, two of them in Italy (Brescia and Trento).
L. A. Riedinger signed a thirty-years Grant with the Town Council on the 29th December 1864. This agreement assigned him the sole right to supply gas to illuminate any street or building into the town. He started to realize the urban gas network since January 1864, laying meters of cast iron pipes, siphons, valves, candelabrum and brackets.
A new Grant was signed in 1899. It allowed Riedinger to install thirty-six arc lamps to lit the most central streets and to built a small electric station (near the urban river called Rio) to supply these lamppost and produce electricity to be sell. During 1910's, electric incandescence has been soon experimented in Mantua and both public and aristocratic buildings were equipped with an electric devices in spite of its high costs.
It has been noticed how in this case, as was happened after the introduction of the gas-light system, electric lighting had not suddenly supplanted the gas one. This has been updated with the Auer systems and kept In use for long. In fact, in 1902, despite the availability of a modern and more suitable way to illuminate, the most central streets of Mantua were still equipped with new 450 gas lampposts. The Local Authority municipalized the gas service in 1908. The consequence was the reduction of the price and a brief lengthening of its kept in use.
While the progressive development of the gas network throughout the city made the gas-light system to be perceived as an unavoidable public service, after having completed the gas network in 1864, the Gas Company signed few contracts to illuminate single buildings (both private and public). In fact, most of them were still not equipped with the technical devices necessary to be connected to the gas network. Anyway, the most relevant public buildings, like the Bibiena Theatre, the School of Design, the Academy Palace, the Town Hall, the Fireman Barracks, the School of Music, were progressively provided with a gas device, and started to be more available after the sun set. This way, the pipe network spread through the historical tissue that characterize most of the Italian towns, producing a new contrast between the new technology and its devices and the old materials of which streets and buildings are made. Similarly, several palaces, churches – and also many private shops – started to illuminated with the gas system and many of them were equipped with a gas system even before the town gas-work was completed.
Among these buildings was the S. Andrew Basilica, a Renaissance masterpiece built since 1472 according to the indications of Leon Battista Alberti, on a site occupied by a Benedictine monastery, of which the 1400s bell tower still remains. The building, however, was finished only 300 years later and. Though later changes and expansions altered the original design, the Basilica is still considered to be one of Alberti's most representative works.
The façade is based on the scheme of a Roman triumphal arch. It is largely a brick structure with hardened stucco used for the surface. It is defined by a large central arch, flanked by Corinthian pilasters. A novel aspect of the design was the integration of the giant order with a lower even Corinthian order, a stylistic choice which finds a correspondence with interior. The nave is roofed by a barrel vault, one of the first times such a form was used in such a monumental scale since antiquity, and quite likely modeled on the Basilica of Maxentius in Rome. Alberti most likely had planned for the vault to be coffered, much like the smaller barrel vault in the entrance, but lack of funds led to the vault being constructed as a simple barrel vault with the coffers then being painted on. Originally, the building was planned without a transept, and possibly even without (the actual) dome. This phase of construction more or less ended in 1494. According to Eugene Jonson, the Basilica has been built during four camping:
(1472-1494) 1st campaign: construction of nave and west porch under the supervision of Luca Fancelli, the Florentine architect and sculptor, pupil of Alberti. (1597-1600) 2nd campaign: construction of the transepts, choir and large crypt. (1697-1704) 3rd campaign: vaulting of transepts and choir. (1733-1785) 4th campaign: construction of dome according to a design of Filippo Juvarra. c. 1780: restoration and decoration of interior under Paolo Pozzo. (Johnson, 1975, pp. 1-6)
This wide church was originally commissioned by Ludovico II Gonzaga to contain a wide number of pilgrims during the feast of Ascension when a vial (which is supposed to) containing the blood of Christ, is brought up from the crypt to the nave to be displayed to the believers and then brought out along the streets of Mantua in a procession. The relic is called Most Precious Blood of Christ and is preserved in a couple of urns, the Sacred Vessels. According to the tradition, it was brought to Mantua by the Roman centurion Longinus. It was highly venerated during the Renaissance and has a great number of followers even today. Beside the religious reason, the purpose of the Duke, was to build a wide holy space (Mantua had already a cathedral) to be destined to his own celebration in front of the entire population.
This articulated construction history has modeled a building very different if compared with the original project by Alberti, particularly for its interiors. The baroque cupola is the main alteration of the original interior design which did not foresee the dome and was based on the regular rhythm of big and little chapels, corresponding to a dark element (pilaster) and a bright one (windows). Most of the widows, furthermore, has been reduced or closed since 18th century, making the nave muck darker than in origin. Nowadays, entering the Basilica,

visitors fell a wide and dark space. Walking through the nave, eyes are quickly dazzled by the bright light entering from the wide windows of the dome, making an unintentional and unfortunate illumination set.
As a consequence, several lighting systems have been installed in the Basilica since the end of the first camping. Candles have kept in use for the religious lighting near chapels and altars till nowadays. They have progressively been supported by other kinds of lamps supplied with vegetable oil, designed to improve the general level of light inside the Nave and to better illuminate both the Mass and the various religious celebrations, both to enlighten the building itself. The symbolic significance of the bright flame in Christian liturgy accounts for the wide use of oil and wax until the beginning of the last century. In fact, the Basilica was lighted with oil and candles until the middle of XIX century. Even if archives documents do not attest a specific use for both combustible materials, oil was probably employed to illuminate the nave, vault, apse, presbytery, while candles have been employed near the altars and chapels, to lit the liturgical and votive functions.
The Vestry Board of the Basilica, did early control the lighting efficiency of each types of lamps in comparison with their cost and, after these tests, decided to install or adopt a new lighting system. It was a necessary caution, considering the width of the church.
The sacristan made the first experiment to compare the consumption of the lamps in the crypt in 1822. They were: four Argand lamps, six triple-wick oil lamps and four small oil lamps. It came out that Argand's lamps consumed about thirty-five oil weights in comparison with the twenty-four weights for the six triple-wick oil lamps and the two weights for the small ones. The annual consumption of oil was about one thousand three-hundred and fifty three kgs since 1834 to 1840. This simple experiment highlights how much attention was attributed to the high costs for the illumination of the Basilica and to the relationship between the consumption of oil and the light results. In fact, the annual expenses for oil worried the Vestry Board above all. In the annual budget of the Basilica, they came just after the upkeep, restoration and decoration costs. (ASDMn, 219/1). To make these expenses monitored, they were registered lamps-by-lamps in 1841 (ASDMn, 219/2). See tab. 2.

Table. 2: lamps and oil consumption to illuminate the Basilica in 1841

WHICH LAMPS?	HOW MUCH TIME?	HOW OFTEN?	HOURS IN ONE YEAR	CHARGE (FIORINS) IN ONE YEAR
CHURCH				
28 oil lamps	One hour in the evening	Everyday	9.123	
4 oil lamps	Daytime	Everyday	17.320	
1 oil lamp	Night and day	Everyday	8.760	
2 oil lamps	Night and day	Saturday and Sunday	2.196	
1 oil lamp	Daytime	Tuesday and thursday	1.248	
			39.149	1.223
CRYPT				
12 oil lamps		Everyday	29.856	
21 oil lamps			52.248	
2 oil lamps	Day and night	Everyday	17.520	
4 "Argant" oil lamps	Until 8:00 in the morning	Everyday	3.572	
			103.196	3.771
SACRISTY				
1 "Argant" oil lamp	about 2 hours	Everyday	730	86
				5.080

The light intensity in the Basilica has progressively increased since that moment: the crypt was lighted by twenty-five lamps, while six small lamps were placed around the altar. Further lamps were in the nave. The vestrymen ordered "to fill thirteen Argand lamps behind the chandeliers better illuminate the imagine of the Beata Vergine Concetta during its celebration in 1844. Both traditional and Argand oil lamps could be easily moved from a chapel to another one, adapting the lighting scene to the several liturgical and solemn occasions.
Till that moment, lamps were supplied with olive oil. In 1844, it was experimentally replaced with a sort of purified rape oil, locally produced and cheaper than olive. Nevertheless, three years later, the Vestry board decided to come back to olive oil, although its price increased to fifty-six cents for pound in 1851 and more to sixty-four after 1852. The rape oil was abandoned because it produced acrid smells and smokes and, in spite of its convenience, the light it produced was less bright and efficient. Later, other vegetable oils, "Lupino and Metillo" were tested but results were negative because of the smoke which was really detrimental to the painted walls and *smeared even the believers' clothes* as stated by Father Tasselli in 1864. (ASDMn, 217/ April 1864).
After this period of experiments with oils and lamps, in 1860 a first organic plant was installed to illuminate the wide nave and transept. It was made by oil lamps and composed by:
"59 single-arm brackets, 2 triple-arm iron brackets with gilded leaves, 1 small iron bracket fixed with screw on the marble round terrace, 2 brass leaf lamps with their brass chains and red cordons, 3 lamps on the Madonna Tedesca, S. Carlo and B. V. Concetta altars"
A design of this plant has not been conserved, but its description testifies as, since that moment, the church was equipped with a uniform and fixed lighting system. The fifty-nine single-arm brackets had to be fixed to the

base of sixty pilasters in which the interior of nave, transept and presbytery is scanned in (except the pilaster where the pulpit is).
Four years later, in March 1864, the Basilica received an estimate for "a brass petroleum machine (lamp) with its tube". New experiments were made to compare the light of the new combustible with the oillamps system, already installed in 1860. A month later, Father Tasselli, the accountant of the Basilica, stated that "oil lighting with reflectors dazzles your eyes. Instead of illuminate objects, (this light) obscure them, making them almost invisible". Contrary to the clear, inodorous and steady petroleum flame which is "constant and bright, does not need reflectors and does not need to be touched...the new petroleum lamps do not need a frequent or special maintenance".
As a consequence, on 21st April 1864, forty-two petroleum lamps were installed in Basilica, according to the drawing by the foundry-man Agostino Marazzi. These brackets were to be fixed not far from the fifty-nine oil lamps brackets already installed four years before. These new brackets were fixed at the base of the pilasters, just above the cornice of the pedestal, where coupled iron supports are still visible in the wall. We had not elements enough to say if the new petroleum system would immediately substituted the oil one, or if they were kept in use side by side. However, the Board of Ecclesiastic Goods established that fourteen oil lamps were to be kept employed to illuminate the liturgical celebrations. Petroleum seemed to be cheaper than olive oil, and Ecclesiastic Board hoped to safe enough money to integrate the system with twenty-eight further lamps which, added to the other forty-two, would have formed a completed plant in order to follow the numbers of the pilasters and to not offend the "even classical rhythm of the interior". (ASDMn, 217/21st April 1864).
Spring 1864 was a crucial period for the internal illumination of the Basilica. The German enterprise Riedinger was realizing the first gas network in Mantua, after it had completed the gas plants in Trento and Brescia. Beside the grant to illuminate the streets, Riedinger obtained the exclusive concession to supply gas both to public and private users. This part of his business was promoted by hard discounts to the new users who would signed a contract while the pipe network was still under construction. According to this commercial policy, Riedinger sent to the Vestry Board an early offer to illuminate the Basilica with six gas bracket-lamps on 21st April 1864, the same day when they approved the installation of the forty-two petroleum lamps system. (ASCMn, 14).
The Vestry Board hesitated for a while: at the beginning of 1864 they had already spent much money to renew the lighting system of the Basilica. Nevertheless, although a few churches were to be illuminated with gas in Lombardy in that period, there were still doubts about the practical efficiency and safety of gas lighting and about the opportunity to employ the new system inside churches. In fact, the illumination of these buildings requires different performances and characteristics in spite of what a theatre, palace or a civil monument needs. The impression of the bright, white-blue light produced by the gas flame, should have seemed very far, hard to combine with the well known, warm and flickering flame of the candles and the oil lamps. At the end of the eighteenth century, the Argand's innovation had improved the traditional oil lamp, setting up the regulation system, but without altering the principle of its functioning: light kept to be produced by a movable yellow flame yellow, till very similar to the fireplace's one, which had to be periodically supplied with oil. The light produced by the gas flame was deeply different and its effects on the architectonical interiors would have appeared much more difficult to be controlled. (Schivellbusch, 1983, Chapter 2)
However, the interest for the new technology made Father Tasselli write to other churchwardens in the Austro-Hungarian Reign (Trento, Ljubljana, Zagabria, Innsbruck) asking information about their experiences with the employment of gaslight inside churches. He obtained that in 1864, any church in Innsbruck was equipped with a gas device while gaslight was installed in the Cathedral of Trento. Even if it was not used during liturgical ceremonies, the positive results of its functioning convinced Canons to enlarged the plant to the sacristies.
On April 1864, the Vestry Board was to be convinced to install gas light inside the Basilica and shortly afterwards a further estimate was asked. The gas plant was composed by eight cast-brackets for the two main narthexes, forty-five cast-brackets for the internal pilasters and other devices for the sacristy and secondary rooms. The complexity of the new lighting plant, compared with the ones previously installed, is testified by the description enclosed to the estimate, which analytically described every single item of the plant. Finally, on 10th June, the Board for the Ecclesiastic Goods approved the installation of the gas light plant in the Basilica, moreover considering the economic advantages on the following consumption and, particularly the discount obtained because the system was installed during the laying of the urban network. Probably for the same reason, gas-light was almost simultaneously installed even in, the S. Peter Cathedral, the other main churches of Mantua. (ASDMn, 1153).

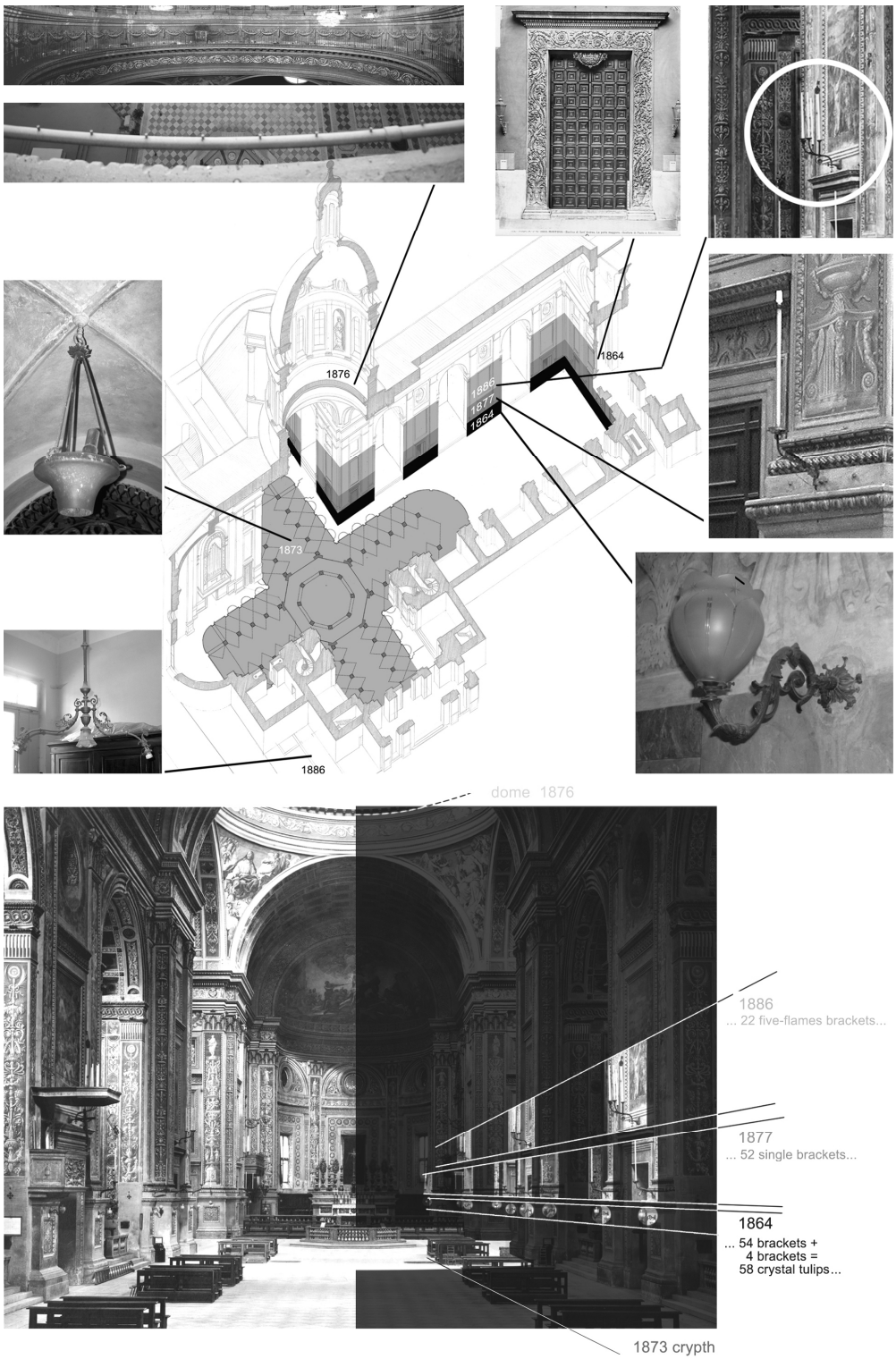

Figure 1: Development of the gas-lighting plant in S. Andrew Basilica in Mantua (1864-1886)

The agreement between the Vestry Board and the Gas company was for a quick work inside the Basilica which had not to be any damages on painted walls and marble floors and, where impossible, they had to be immediately restored to the original aspect by the gas company.
The final budget lists the singular items of the gas plant:
"54 brackets model n°61, 2 brackets n°3, 1 lira n°2 with gas burner model Dumas, 1 fixed bracket n°X, 4 bracket n°3, 1 fixed cornucopia n°16, 2 chandeliers n°8 with two burners, 4 brackets n°7 with lanterns, 1 angle bracket n°8 with lantern, 58 crystal tulips"
The fifty-four brackets were placed over the squaring in the pilaster pedestals; other components were in the S.S. Sacramento Chapel over the southern wing of the transept, in the apse, in the sacristy and in the porticos. The installation was mostly completed before August 1864 because the local painter Giovanni Ridondi painted *with three hand of glue and milk dye the pedestal of the pilasters* with the necessary reparations to the plaster, ruined by the laying of the gas pipes.

The plant was completed only in June 1865 when an engineer member of Vestry Board and another one , member of the Gas Society) signed the final test and the invoice of 3.439,68 Austrian Fiorins, over 6% respect the first estimate. (ASDMn, 217/ 27June 1864).
The gas light system introduced a great, deep novelties in the perception of the spatial hierarchy of the Basilica. The light and spatial relationships between the nave, chapels and altars, changed profoundly after the introduction of gaslight which, in fact, as the petroleum system, could not be used for the liturgical celebrations. Once the system was lighted, it was immediately clear that it could not be used during the daily Masses and celebrations, because the brightness of its flames was inadequate to the religious atmosphere. Nevertheless, its powerful light came useful during nigh-time celebration and, moreover, to illuminate the Basilica and making it available for visitors.
Problem were even for the physical relationship between the new device and the old structures.
The Vestry Board encountered the early difficulties during the installation of the gas system because of the damages it involved in the marble floors, plasters and ornamental apparatus.
More in general, the introduction of the gas system in the Basilica was a sort of "industrial invasion" of this space which was not designed and built for it. The Vestry Board tried to mitigated the effects of this invasion, for example adapting the cast brackets of the gas lamps, which design, a very simple "s-shaped" short pipe, was slightly enriched and decorated to be adapted to the flowered motifs of the pilasters in the nave. These lamps were produced by a local foundry and completed with a tulip-shape glass lampshade.
A further consequence was the dependence upon an exterior and industrial network which made the fuel availability suddenly dependent on the monopoly of the gas enterprise, while it had always been satisfied by the local free market. (See Schivelbusch, 1983, Chapter 1)
The plants had worked since summer 1865 when early problems involved the gas workers which were called to repair a gas leak on the pipe along the corridor near the Major Sacristy. (ASDMn, 217/(1865)).
Despites these little problems, the Vestry Board signed a credentials certificate to the gas company which was involved to install a gas system in another town. A few years later, another certificate was asked to be displayed to the Canons of Verona, interested in installing a gas system in their Cathedral. (ASDMn, 351/5th August 1872)
The primitive plant was enlarged in 1866, when the Vestry Board decided to install gaslight on the main façade, in order to harmonize the lighting of this part of the church with the one already working in the interior. Four brackets with twelve flames each were installed on the façade, to be lit just during solemn celebrations. One year later, even the Canon house was equipped with a couple of angular brackets with five flames each. (ASDMn, 217/2nd October 1866).
The crypt, the place were the Most Precious Blood of Jesus is Preserved, had been lighted with gas since 1873. The installation of gaslight in the crypt coincided with the restoration of its walls and decorations: twenty-one lamps were placed at "a proper distance from the Sancta Sanctorum" which, till that moment, had been softly illuminated with candles and oil. The plant was completed with twelve bell(or cup)-shape opaque glass lamps. One of them is still visible in the sacristy . (ASDMn, 217/, 25th June 1873).
The eighteenth-century dome was lighted with gas for the first time in the Corpus Domini day in 1876. A ring pipe was placed at the base of the drum and was equipped with 250 gas burners. This sort of giant lamp was provided with a special pipe rising from the street level along the external wall. The impressive image produced by that wide number of gas-flames was great, even if it was probably used only during particular celebrations.
In the same day, twenty big brackets were temporary placed in the nave to integrate the existing plant composed by the oil lamps and the tulip gas lamps at the pedestals of the pilasters. These new lamps were installed above the doors separating the nave and the little chapels, in the middle of the wide pilasters of the nave. The intensity of the light produced by these gas-chandeliers should disappoint the parish priest who stated that "the Basilica had been transformed in a theatre".
The lighting system of the wide nave was improved again in 1877, when fifty-two gas brackets were installed above the pedestals of the main pilasters, probably to substitute the petroleum brackets installed on April. They were linked with the piping system providing the fifty-two tulip lamps placed at the quote of the pedestals between June 1864 and June 1865. The parish priest had some doubts about this finale step toward the "gasification" of the and authorized the installation of two more brackets in the crypt with the condition that candles and oil lamps would have been, even partially kept in use. (ASDMn, 350/14thNovember 1877 and 27th march 1886).
On April 1886 the Milanese company *Brunt&Co* presented a project for twenty-two five-flame brackets to complete the gas system in the nave, in the placed, over the little chapels' doors, were the had been teste a few years before. Even without any certain archive reference, they were probably the ones we can see in the first photographic image of the nave (1900's approx.)
After the first installation in 1864, the lighting gas plant in the S. Andrew Basilica has been permanently improved during the following twenty years: the devices installed to illuminate the façade (1867), the crypt (1873), the dome (1876), the nave (1877 and 1887), have always been intended as independent installation which, year by year have formed a wide and organic lighting system.
In 1891 the Gas Company proposed the installation of six arc lamps in the nave. The Vestry Board rejected the project because these lamps were fragile and expensive and their extremely powerful light was difficultly suitable to be adapted to the equilibrium slowly obtained with candles, oil burners and gas lamps.

The Auer system was employed for the public lampposts in Mantua very late. The Auer system was based on the incandescence of a small tissue net applied on the edge of the gas burner which made the flame much brighter, thus reducing the consumption of gas to obtain the same level of illumination. The Gas Company contractually prohibited to use this sort of lamps, both to private and public users, thus the Auer system stared to be diffused just since 1909, when the Gas Company had got municipalized.
The gas plants of the Basilica was improved with the Auer system on December 1904 when the Gas Company supplied the lamps in the nave with forty-four Auer mantles. The system kept in use for years as testified by the several payments to buy the mantles which needed to be frequently renewed.
(ASCMn, 14/6thJune 1909).
The gaslight plant remained substantially unchanged until 1909, when a first electric device was experimentally installed during the annual *Festa della Riparazione*. Despite to the wide use of the incandescence, the gas system was to lose its convenience, in comparison with the new electrical technology which presented many other practical advantages. The Vestry Board started to be interested in electricity, looking for an alternative to the expensive gas bills and tired for the even more and more frequent maintenance expenses of the gas lighting equipments.
On December 1911 the president of the Vestry Board, after charging the gas workers to check again the gas system carefully, decided to "start the project, already thought for many times, to introduce the electric system to illuminate the Basilica".
(ASDMn, 708/17thDecember 1911).

CONCLUSIONS

The Italian gas-light season lasted almost one hundred years since 1850s to 1950s. The gas system did not suddenly substituted the traditional lighting system based on the wax, vegetable and mineral oils lams. The same process of progressive substitution happened when electricity took place since 1910's.
The history of gas-lighting has usually been told as a part of urban history. Nevertheless, the not-linear technological progress of its spreading, characterized both at the urban, both the single-building scale.
As the streets' tissue of the historical towns was cut by the gas pipe network, similarly ancient and monumental buildings were adapted to the technological novelty.
The S. Andrew Basilica was provided of an articulated gas-light plant since 1864 to 1886. The gas device of the Basilica has been studied by a direct survey of its rests still visible in the Basilica and by an historical research above the local archives.
The results is a new chapter in the long construction history of this monumental building which testifies a very recognizable eighteen-century sign on the monumental structures and surfaces and a sometimes hard relationship between them.
Nowadays, the main question concerns how to preserve this devices more than how to adapt them to the modern necessity of the Basilica and how to evaluate and repair to the consequence which their introduction had determined for the 1500's-1700's structures and painted frescoes interiors.

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