

OVENS OF MANUFACTURED GAS:
THE INCORPORATION OF NEW TECHNOLOGIES IN SPANISH GASWORKS
(1842-1960).

Francesc X. Barca Salom
Universitat Politècnica de Catalunya

1. Introduction

In 1826, the chemist Josep Roura (1787-1860) performed a test in which he used gas to light up a classroom at the school of design of the Llotja de Mar in Barcelona. This experiment took place some decades after William Murdoch (1754-1839) had used gas to illuminate his home in Redruth (Cornwall, UK) in 1792. Murdoch's experiments and those of Philippe Lebon (1767-1804) in 1798 were subsequently applied to lighting. Roura, who had studied chemistry in France, learned the principles and techniques of production and applied them to his experiments in Barcelona and Madrid (Fabregas, 1993: 38).

It should be noted that the phenomenon of gas does not begin with Murdoch and Lebon. Research into coal gas began in the mid seventeenth century and some references to it were published by the Royal Society and the Academie des Sciences. But it was Murdoch who pioneered the industrial production of coal gas for lighting in Britain. However, in France, gas production from wood lost momentum owing to the premature death of Lebon with the result that industrial applications were delayed.

In his experiment in Barcelona, Roura used other organic materials to obtain gas for lighting. However, coal prevailed over the other materials and was used for more than a century.

The initial industrial applications of gas were in the textile factories as subsequently occurred with electricity. The use of gas for lighting resulted in the extension of working hours and in an increase in output. However, where gas came into its own was in the lighting of streets and squares. The first street lighting was installed in the Pall Mall in London in 1807 by the National Light and Heat Company. In Paris, gas was introduced later. In 1820, Luxembourg Palace and the Odeon Theatre were illuminated. In Germany, Hanover was the first city to have a gas plant in 1825. In Belgium the first city to be lit by gas was Brussels in 1818. In Austria it was Vienna in 1833 and in Italy it was Turin in 1837.

Street lighting triggered the development of the gas industry in Spain. This industry developed through installations that mainly used the method of coal distillation. Nevertheless, in times of coal shortages or economic hardship, other organic materials were used despite their poor calorific value and lighting power.

Using gasholders for storage and subsequently compressors for distribution, it soon became possible to deliver gas through networks. These networks were often introduced into cities before running water. Gas was therefore installed into the buildings first for lighting, and then in kitchens and bathrooms, paving the way for thermal applications.

This paper is divided into two parts. One part is concerned with the evolution of gas technology based on coal distillation applied to the production phase, i.e. ovens. The second part is focused on gasworks in Spain in an attempt to throw a light on the technology applied. To this end, five stages were established.

The present work has not been easy given the fact that technical information is scattered in numerous articles. As regards gasworks in Spain, obtaining information about the technological characteristics has been difficult since the surviving documents are mainly

focused on accounting. Secondary sources centre on business history and devote little attention to technology. Another source of information is legal documents but these provide too vague a description of the plants. We therefore consider the present study as a starting point and it is hoped that new data will add to the knowledge of gas plants in Spain.

But before focusing on the development of this technology and studying its application to different Spanish factories, it is necessary to establish when and where these gasworks were installed. It is well known that Barcelona in 1842 was the first town to be lit by 53 gas lamps in the Ramblas. After Barcelona, other factories were built in other towns as shown in table 1. This table also shows the main promoter and the year in which each gasworks started production.

It should be noted that when the first gasworks was built in Spain, many innovations had already been implemented in Europe and, what needed to be done was only to transfer and adopt the necessary technology.

The first statistics about manufactured gas in Spain may be traced to the year 1901. These concerned the tax imposed on the use of gas for lighting. This information included the consumption of gas, the annual sales of products and some details necessary for collecting this tax. But there are no data prior to that year. Table 2 describes the situation of the gas industry in Spain in 1861. This table was prepared using local information about the gasworks and gas distribution.

Over the years these factories upgraded and modified their facilities, replacing the retorts that had deteriorated through wear and tear or changing the heat generation system or introducing heat recovery to improve performance. Attention has been focused on these changes in an attempt to determine the technologies used and the manner in which they evolved in the Spanish gas industry. In this way it is possible to determine which foreign innovations were implemented and which inventions were developed.

In order to establish the typology of the factories and their relative dimensions, the statistical data on the consumption tax of gas for lighting (*Impuesto sobre el consumo de luz de gas, electricidad y carburo de calico*) published between 1901 and 1933 by the Ministry of Finance were analyzed. These data were incomplete because thermal applications were not included. Nevertheless, these statistics enabled us to establish three levels of plant size (table 3): small gasworks, medium-sized gasworks and large gasworks.

The same analysis was employed for the data for the period 1940-1960, the statistics of which are more complete. The factories may be divided into six groups in terms of volume of production as shown in the table 4.

There are considerable differences between the first classification and the second in terms of evolution and the aims pursued. However, a significant decrease in the number of gasworks is accompanied by a marked growth in gas production in Barcelona and Madrid.

Below we analyse the five most common ovens that manufactured coal gas and their implementation in gasworks in Spain. This implementation was divided into five periods according to the degree of development. Data are based on technical statistics, and on documents obtained from gas companies. The statistics were compiled in the 1940s by the Francoist Trade Union of water, gas and electricity. The documents were obtained from the archive of the Gas Natural Foundation in Barcelona. Although we cannot determine the entire evolution, it is possible to obtain a rough idea of the period during which coal was used as a raw material.

2. Evolution of gas technology production

The most widespread system of gas production consisted in distilling coal in retorts by heat. The gas obtained was composed of hydrocarbons (which were necessary for lighting) and unwanted substances such as carbon monoxide, hydrogen, hydrogen sulphide, ammonia vapour, carbon dioxide, water steam and tar.

After distillation in the retort, coke remained as a residue. The gas obtained was purified by condensation, washing and chemical processes before storage in gasholders and distribution to consumers (Darcel, 1878: 14), (Borias, 1890: 233).

The technology of gas production underwent a number of changes, which may be grouped into six phases: 1) directly-fired ovens, 2) recuperative ovens, 3) ovens of intermittent carbonization, 4) ovens of continuous carbonization, 5) water gas production, 6) cracked gas production.

In this paper, we focus on the first five phases until 1960. All the methods used the same technology based on obtaining gas by distilling coal gas or other similar products.

2.1. Directly-fired ovens

The first retorts were cylindrical and were made of cast iron 1.80 m in length and 30 cm in width and only lasted 8-10 months, after which it was necessary to replace the retort.

In 1828 John Grafton patented a refractory clay retort that was cheaper and lasted 2-3 years. Thereafter, Thomas Spinney modified this retort by constructing one large retort using refractory bricks. However, the most widespread model of oven was of 3, 5, 7 or 9 ceramic retorts between 2.10 m and 2.70 m long, in a D shaped section 40 and 55 cm wide and directly fired by coke combustion. Thus, coke was reused in the process (Schilling, 1868: 141).

Coke was the fuel used to achieve the high temperatures required in the distillation of coal. However, in some cases tar was employed. In an attempt to facilitate tar combustion, George Anderson designed an oven that consisted in channelling the residue along a sloping gutter to the combustion chamber that burned coke (Clegg, 1860: 140). Subsequently, injectors were employed to spray tar into the combustion chamber after mixing with steam and compressed air. An example of this injector was the one invented by Grebel (Grebel; Verdier, 1911: 30).

In countries where there were blast furnaces, such as Germany, the gas generated in these ovens was used to produce coal gas for lighting. The Siemens brothers designed an oven heated by gas generated in a gas producer in which the lean gas was obtained by subjecting the residual coke to a high temperature air stream (Shelling, 1879: 294-295).

The main feature of the Siemens oven was that the gas produced had to be mixed with air, known as secondary air, to generate the combustion for heating the retorts to produce coal gas. This secondary air was heated in a recuperator or a regenerator (Marchis, 1908: 8) (Deschamps, 1904: 138).

The know-how and terminology of heat recovery were derived from the technology of coke production. Initially, coke ovens were rectangular chambers. The air used in the combustion was circulated below the combustion chamber in order to recover the heat. Then, in other ovens the heat was recovered using horizontal ducts as in the case of the Appolt, Smet and Cope models. Thereafter, horizontal and vertical ducts were used. The Collin ovens marked the transition between the horizontal and vertical recoveries. Some models of vertical ducts included the Otto-Hoffmann, Koppers and Klönne ovens (Percy, 1864: 253-262).

The British made a distinction between the terms recuperator and regenerator. The recuperator was a heat exchanger consisting of iron or ceramic ducts in which hot smoke circulated inside and cold air outside or vice versa. The regenerators, however, were two symmetrical chambers in which the smoke was cooled or the air was heated passing alternately from one chamber to the other. These chambers were filled with refractory bricks that retained the heat on contact with the smoke. Air crossed the chamber after the smoke and absorbed the heat from the bricks (Damour: 1912: 315-356).

2.2. Recuperative ovens

The incorporation of gas producers to heat the retorts was undertaken in two ways. One way consisted in making use of the periodic renewal of the retorts in a directly-fired oven to install a gas producer in the combustion chamber. This was the case of the Parsy oven. The other way involved renovating the whole gasworks by introducing a new technology such as Lachomette ovens.

The Parsy oven was fitted with a gas producer and a recuperator that had to be installed in the small space occupied by the combustion chamber. For this reason, the gas producer had to be horizontal and the recuperator small. This model was easier to clean and a high yield was obtained. Moreover, the production of gas prevented the oven from cooling. But the main advantage of this oven was that it was cheaper to modify directly-fired ovens than build new ovens. The Parsy oven was designed in 1907 and was implemented around 1909 (Grebel; Bouron, 1924: 211), (Grebel, 1909, 412-414), (X.P.,1909: 208-210).

Before the advent of the Parsy oven, many factories had already replaced directly-fired ovens by those heated by gas producers. The first model was the Siemens oven, whose producer was located outside at some distance from the oven. Subsequently, the gas producer was located closer to the oven in order to facilitate the introduction of gas through the recuperator located under the oven.

These ovens were expensive and were only cost effective when gas production was high. For this reason, a number of systems such as Lencauchez & Ponsard, Gaillard & Hailot, Muller and Eichelbrenner were designed to simplify technology and reduce costs.

The gasworks at Dresden used the Hasse-Didier oven in which the gas producer was located outside and in which the primary air was heated by double walls that contained the ducts. The gas from the gas producer circulated vertically in the recuperator while the secondary air circulated through five horizontal ducts situated between the retorts.

In Munich, Schilling built another oven that incorporated the gas producer into the oven. This producer heated the primary air while the secondary air was heated in the oven. The producer also heated the water at its entrance in order to generate steam. Hence, the primary air incorporated into the gas producer contained water gas (Bancelin-Magnier, 1899. II, 203-238).

Another model was the Lachomette oven, which was patented in 1889. This oven consisted of a gas producer made of refractory material with a grill placed perpendicular to the gas outlet. This gas was conveyed into a recuperator that enabled the fumes to rise while the secondary air descended through the transversal ceramic ducts (Bertran, 1909, 213-215).

This oven was equipped with a vaporizer that introduced steam (produced in a small boiler) into the gas producer to prevent the formation of slag and the cooling of the producer. This increased the amount of hydrogen and carbon monoxide in the gas. In

1890, 30 Lachomette ovens were built for the gasworks at Lyon Perrache (Journal: 1890: 236-237).

The use of a gas producer with a recuperator to heat the retorts did not exclude the use of tar. In 1909 at the 36th annual meeting of the Société du Gaz Technique, Godinet, the director of the Lachomette et Villiers company, endorsed the use of tar in a gas producer because of its low cost. Hovine, who was present, declared that he had designed an oven equipped with a device that allowed the use of tar (X.P., 1909: 208-210).

His oven was heated by a Siemens gas producer, which generated gas from coke. It was equipped with a container placed on the oven in which the tar was collected and conveyed to the producer. The tar ran down the sloping walls and settled on the coke before vaporization. The gas contained a mixture of hydrocarbon that ignited on contact with the secondary air to heat the retorts. Hovine did not make any substantial changes to the Lachomette oven but only incorporated a device to introduce tar. Subsequently, this oven was improved by the incorporation of a tar injector such as the one constructed by Grebel. An example of this modified oven was the Echinard oven (Audra, 1911: 321-326).

In the last decade of the nineteenth century and in the first decade of the twentieth century, new methods were devised to mix coal gas with carburetted water gas. Three new methods of coal distillation were introduced to meet the challenge of electricity: 1) ovens of intermittent carbonization in vertical retorts, 2) ovens of continuous carbonization in vertical retorts, 3) ovens of inclined chambers.

2.3. Ovens of intermittent carbonization

The term intermittent carbonization includes traditional distillation ovens, e.g. Parsy, Lachomette, Hovine and Echinard ovens. The feature that was common to these ovens was that between the periods of distillation of 4, 6, 8, 12 or 24 hours there were shorter periods in which the oven stopped functioning to allow the discharge of coke and the charge of coal.

In 1885, André Coze, director of the Compagnie de Gaz de Reims, conceived the idea of fitting 6m long retorts inclined between 32° and 35° in an oven in order to facilitate the descent of coal under its own weight. This coal turned into coke during the descent. The coke was discharged into wagons, reducing man power (Grebel; Bouron, 1924: 220).

In 1905, Bueb of the Continental Gas Dessau built in Berlin ovens of vertical retorts 5m in height. These retorts had a tapered rectangular shape and rounded corners. The oven distilled coal for 10 or 12 consecutive hours. The charging and discharging were carried out mechanically so that the resultant coke was collected in a water channel in which it was submerged for a few minutes to cool without becoming moist. In some cases, the steam produced during this discharge together with that produced in a boiler was introduced into the retorts for about two hours to produce water gas (Industria Química, 1906: 251-256).

One example of ovens of intermittent carbonization was the Klönne oven, which was equipped with between 3 and 6 vertical chambers heated by flames that circulated in vertical ducts from top to bottom. This heat was recovered to increase the temperature of the secondary air and to generate steam in order to produce water gas, which was injected into the chambers after distillation. This method was known as Steaming.

In 1907, Dr. Reis in Munich constructed ovens of inclined chambers that were commercialized by the Klönne Company. These ovens resembled those built in the United States to produce coke, the residual gas being used for lighting.

The burners were located at the base of the oven at ground level. The combustion products occupied the spaces between the chambers and were conducted to the top and diverted down before introduction into the recuperator. This model was implemented in Munich, Hamburg and Leipzig because it significantly reduced labour during the night shift (Grebel; Bouron, 1924, 228).

So far we have described methods of intermittent carbonization of vertical and inclined chambers. Another type of oven had horizontal chambers and was manufactured by the Koppers and the Klönne companies. Koppers applied to gas ovens the same system that had been applied to coke ovens (Grebel, 1910: 501-507) (Grebel 1913: 129). These ovens, consisted of parallelepiped shaped chambers and occupied less space than the inclined chambers of their rivals. Between these chambers were vertical ducts in which a burner was fitted to receive the gas from the producer and the secondary air that was preheated in the recuperator. This recuperator was located under the oven and consisted of ducts that drove the combustion fumes up the chimney after the boiler was heated (Grebel, A.; Bouron, H. 1924: 166).

2.4. Ovens of continuous carbonization

To accomplish continuous carbonization, coal had to be introduced and coke extracted without interrupting the process. In the retort, one part of the coal was being distilled while the other part was not. The undistilled coal was that which had been introduced to replace the extracted coke. Continuous carbonization was carried out in vertical retorts in which coal descended at 2 cm/min.

In 1903, Harold Woodall and Arthur McDougall Duckham tested continuous carbonization, but the industrial application was not implemented until the end of 1907 owing to the difficulties of obtaining the high temperature necessary for distillation.

The Woodall Duckham oven managed to resolve four of the most difficult problems in the gas industry: 1) continuous insertion of coal in retorts, 2) regular distillation in vertical retorts so that the coal descends under this own weight, 3) removal of continuously generated coke, and 4) recovery of heat produced by the incandescent coke (Lemaire, 1912: 401-405), (Industria Química, 1906: 149-150).

This type of oven consisted of four vertical refractory retorts between 7 and 8 m high with square sections that were narrower at the top than at the bottom. These retorts were heated from top to bottom through vertical ducts where the gas from the producer came into contact with the preheated secondary air. This raised the temperature to 1300°C at the top and between 800°C to 1000°C at the bottom (Masse, 1926: 189).

In 1908, William Young, John Glover and Samuel West devised in Manchester another oven of continuous carbonization. This model had four retorts about 6 m long in square sections with rounded angles, narrower at the top than at the bottom. These retorts were also manufactured with elliptical sections.

The main feature of this oven was that it was heated by ten horizontal ducts, placed one on top of the other, that crossed the retorts transversally. The lowest duct was used to recover the heat of the coke before removal and transfer to the secondary air. The following eight ducts were used for the combustion. In these ducts, gas from the producer merged with the pre-heated secondary air. The uppermost duct was the one that collected the smoke produced by the combustion. The hot smoke was used to heat the coal at the entrance of the retort. In addition, the Glover-West system also produced water gas through the injection of steam during distillation (Grebel; Bouron, 1924: 210).

2.5. Water gas production

The Italian naturalist Felice Fontana (1730-1805) had shown that if water vapours passed over incandescent charcoal, a gas consisting mainly of hydrogen and carbon monoxide was produced. This gas came to be known as water gas, blue gas or blue water gas because of the blue flame produced during combustion. The reaction was endothermic i.e. heat is absorbed leading to a decrease in temperature which terminates the reaction. Therefore, water gas production was always accompanied by periods during which air passed through the coal in order to increase the temperature.

The most usual way of generating water gas was to use producers that made use of the coke obtained in coal gas production. These producers worked in two stages. The first stage, known as blow down, consisted in introducing an air current through the coke to produce blow gas to increase the temperature. The second stage, which was termed gasification, consisted in passing the vapour through the coke to produce water gas. In this stage, coke was transformed into gas leaving a residue of ash and slag. However, water gas was odourless and had a low calorific value. These two disadvantages were overcome by mixing other substances to provide an odour and by injecting oil or benzene to increase its calorific value. The gas thus obtained was called carburetted water gas (Masse, 1923: 227) (Bosko, 1957:186-189).

There were two kinds of water gas producers: one involved recovering the heat to increase both the air and the steam. The prototype of this producer was the Tessie of Mottay model, which was used to produce water gas without carburetting although it could also be carburetted. The German model Dellwik-Fleischer was based on this type. The other type involved the use of heat to decompose oils in order to produce carburetted water gas directly. The model used in this case was the Lowe producer, on which the Anglo-American model Humphrey and Glasgow was based. Other models were the Tully from England and the Rincker & Wolter from the Netherlands. These water gas producers were characterized by the decomposition of oil that was cast directly over the incandescent coke. This yielded a carburetted water gas with a lighting power similar to that of coal gas. There were other models that required regenerators like the Krammers & Aats from Germany, which produced complete combustion or the Strache model from Austria, which resulted in incomplete combustion (Grebel, 1920: 161-164).

Only three water gas producers were widely used: a) Dellwik-Fleischer, 2) Humphrey and Glasgow, 3) Krammers and Aats.

The Dellwik-Fleischer producer was equipped with a dual circulation of vapour. The water vapour circulated up and down and viceversa, which favoured gas production. The blow air entered from below and was driven by a fan (Masse, 1934: 238) (Deschamps, 1902: 119).

The Humphrey and Glasgow producer consisted of three elements: a gas generator, a carburettor and a booster heater. During the blow phase, the gas produced had a high content of carbon monoxide because some of the air entered the carburettor and passed through the boost heater and returned to the producer to burn the coke that had not undergone combustion. In the gasification stage, blue gas passed through the carburettor under a shower of oil (Masse, 1934: 241-243).

The Krammers & Aats producer consisted of two groups, each one constituted by a generator and a recuperator. During the blow phase, these groups operated in parallel. However, during the gasification phase they operated in series. The vapour entered the base of one generator with the result that the gas produced passed through the two

recuperators. Subsequently, the gas entered the second generator where the carbon dioxide was transformed into carbon monoxide (Masse, 1934: 240).

Water gas was first manufactured in the USA, where it accounted for two thirds of the gas consumption. However, in Europe its toxicity and its lack of smell were used as arguments by the proponents of coal gas to thwart its production. The laws governing water gas were restrictive in some European countries, allowing it to be mixed with coal gas in a proportion of less than 15% .

3. Technological change in the Spanish gas industry

The evolution of the gas industry in Spain may be divided into five periods, from its beginnings in 1842 to the 1960s, when coal gas production was replaced by cracking: 1) Early period (1842-1860), 2) Period of expansion (1861-1890), 3) Period of awareness of the need for technological change (1891-1921), 4) Period of consolidation of technological change (1921-1938), and 5) Period of autarky (1939-1960).

3.1. Early period (1842-1860).

The first gasworks was built in Barcelona on the initiative of Charles Lebon and the Gil banking family, who constituted the *Sociedad Catalana para el Alumbrado por Gas* (Catalan Company of Gas Lighting). Given the absence of primary sources, we shall use a secondary source compiled by Pascual Madoz, who in the *Diccionario Geográfico Estadístico Histórico de España* stated that this factory in April 1846 had 10 ovens, two of which were equipped with 5 cast-iron retorts and 8 ovens of only one retort made of refractory bricks. In all probability this was a time of technological change, i.e. iron retorts began to be replaced by ceramic retorts consisting of a single retort made of ceramic material (Madoz, 1846: III, 491).

Other towns that followed the example of Barcelona were Valencia (1844), Cadiz (1846), Santander (1853), Alicante (1854), Reus (1855) and Valladolid (1858), where coal gas was manufactured in directly fired ovens. The gasworks in Valencia was equipped with one oven of 3 iron retorts and another of 5 retorts. The one in Santander, which was built by Manby & Cia and sold to Lebon in 1860, had 5 D shaped horizontal retorts that were directly fired. The gasworks in Alicante had 2 blocks of 4 ovens each with 5 D shaped retorts. The gasworks in Reus had 6 ovens of 5 retorts and 2 ovens of 3 retorts which were directly fired. All these gasworks testify to the fact that the technology using directly fired ovens of 3 or 5 horizontal ceramic retorts had been adopted in Spain (García, 1984: 193), (García, 2006: 101), (Moyano, 2000: 194).

The gasworks in Figueres is noteworthy because gas was produced not from coal but from fat obtained after washing wool. It was the *Sociedad Humbert y Cia* of Barcelona that made an offer to the council of Figueres in 1858 to supply street lighting using this method on which they had the patent. The method was known as the composite waste gas system, which corresponded to a patent number 1690 granted on February 8, 1858 to a Frenchman, Alfons Humbert, and to Antonio Escubós from Barcelona. In the explanation of the procedure, the authors made it clear that the patent concerned only the production of fatty substances to replace coal but did not involve changes to the equipment used in coal gas production. This plant, which was inaugurated in 1860, supplied gas for 150 streetlights. However, the neighbours soon started to complain about the bad smell. After a change of owners (Jose Elías and Jose Roca) two years later complaints continued to be lodged on account of the poor quality and the high price of

the gas. In 1880, Ramón Capdevila bought the company and decided to build a new plant outside Figueras using the traditional system of coal gas production (Bernils, 1992: 180).

The Humbert system recalls the method subsequently devised by Enric Hirzel in Leipzig in 1863. Hirzel invented a simple and economic method to separate fat from soapy water after washing wool (which is termed Swint) and began to distil this product (Porvenir, 1878: 139-141).

The Humbert system was also adopted in Manlleu and Vic for two 200 gas lights but was eventually replaced by coal gas manufactured in directly fired ovens. This change was due to the increased demand for gas and the cost-effectiveness of the system.

3.2. Period of expansion (1861-1890).

Humbert gas was not the only unconventional method of gas production. There were two other cases: Arbós gas and rich gas. The former was attributed to Jaume Arbós Tor (1824-1882) chemist and priest. Arbós, who had studied chemistry with José Roura in the course of chemistry applied to arts and crafts run by the Board of Commerce, took out five patents on the manufacture of gas and on a suction gas producer applied to engines between 1852 and 1867. The Arbós gas producer, which was the first of its kind in Europe, coincided with the first injection gas producer designed by Trebouillet in France.

Jaume Arbós obtained gas in a producer without retorts using charcoal and other carbonaceous substances. As these substances became incandescent, a current of air and a vapour was introduced to obtain gas. Despite a low calorific value (1350 kcal/m³) this gas was commercialised as Arbós gas in 1864. In this year, Arturo Galofré built a gasworks in Vilafranca del Penedes and the company Cia Jaures built another factory in Badalona to produce Arbós gas. This gas suffered the same fate as Humbert gas, i.e. when demand increased it was replaced by conventional systems.

Other towns opted for systems that distilled mineral oils or hydrocarbons. This was the case of Blanes in 1881. The company *Nait, Vilaseca y Cia* of Barcelona installed a Rieber and Gruner device to produce rich gas (Porvenir, 1881: 195). Like Humbert gas, this gas was a type of oil gas obtained not from fat but from the decomposition of hydrocarbon liquids and shale oils subjected to heat. This gas, which was known as rich gas because of its high calorific value, was produced in spherical vertical retorts that were only heated to a temperature of 850°C. The flame obtained was bright and the gas was cheaper than coal gas. The town of Palafrugell followed the example of Blanes in 1882 (Porvenir: 1882: 177). The *Nait, Vilaseca y Cia* company, which changed its name to *Sociedad Anónima de Alumbrado de España y Portugal*, installed in El Ferrol another gasworks equipped with a Rieber and Gruner producer similar to the one in Blanes (Martínez et.al., 2009: 119-121), (Arroyo, 2006: 12).

We call this period, the period of expansion, because the number of gasworks in Spain underwent a fourfold increase. Most of these gasworks continued to produce gas by directly fired ovens, i. g. in Cordoba, Malaga, Murcia, Premià de Mar, San Feliu de Guixols, Terrassa, Tortosa, Valls, Vilanova etc.

However, other gasworks because of the high demand took advantage of the need for retort replacement by implementing more modern systems that were much more cost-effective. This was the case of Cadiz and Barcelona. The similarity between the two cities was striking. Both towns had been pioneers in testing gas and in building the early gasworks in Spain: Barcelona in 1842 and Cadiz in 1846. At this time there were two gasworks in Barcelona and in Cadiz. The second gasworks in these towns was

deliberately created to break the monopoly of the first. Technological innovations were implemented in both towns. In Cadiz *la Sociedad Gaditana de Fabricación de Gas* charged Augustus Klönne of Dortmund in 1885 with the construction of the new factory with ovens of nine retorts (Fabregas, 1989: 10-11). In Barcelona *la Sociedad Catalana para el Alumbrado por Gas* implemented in 1890 for the first time in Spain some ovens of inclined retorts of the André Coze system at the gasworks in Barceloneta, which increased production and reduced labour costs (Falgueras, 53) (García, 1984:198).

3.3. Period of awareness of the need for technological change (1891-1921).

The fierce competition between gas and electricity led to technological change. This change consisted in an increased efficiency of the ovens and in reduced costs due to mechanization. Therefore we find only one example of another directly fired oven, i.e. the gasworks in La Garriga. The other gasworks that were built in Spain had recuperative ovens. This was the case of Mahon, Reus, San Feliu de Guixols and Vilafranca del Penedes.

The largest factories, most of which were owned by the *Compagnie Centrale d'Eclairage pour le Gaz Lebon*, opted for the Lachomette ovens. This was the case of the gasworks in Arenal and Sant Marti in Barcelona and in the district of Puntuales in Cádiz. The other factories of this Company in Valencia, Santander and Málaga also incorporated the Lachomette ovens. In Santander, in 1912, the directly fired ovens were replaced by Lachomette ovens, each one of 8 retorts, and in Málaga after WWI, 6 ovens, each one of 9 retorts. The Lachomette ovens were suitable for large gasworks (García, 1984: 163), (García, 1984: 182).

However, French technology used by the *Compagnie Lebon* was not adopted by its competitors. In Barcelona, in 1905, the *Sociedad Catalana para el Alumbrado por Gas* opted for Bueb type vertical retorts ovens obtained from the German company Didier. And in San Sebastian, where the gasworks had belonged to the City Council since 1893, the Otto ovens, which were based on coke oven technology, were preferred.

Reliance on foreign technology did not seem to be the best solution for small gas plants. One example is the case of the gasworks in Valls. In this town, there was a directly fired oven of 6 retorts. Around 1911, Pablo Yvern, son of the owner, incorporated a gas producer and a recuperator, which he designed and patented. This new system had far-reaching repercussions for similar factories in Spain (Ribé, 1995: 40).

Pablo Yvern Ballester (1879-1950?) had studied science at the University of Barcelona and Chemical Industrial Engineering at the School of Industrial Engineering. He spent the summer of 1901 in England working as an apprentice at the Gas Light & Coke Company of London and attended some classes for engineers. As soon as he finished his studies in Barcelona in 1902, he returned to England to work as an engineer for Gibbons Juniors and Gibbons Bros Ltd. These were two gas companies, the former dedicated to refractory products, and the latter to the construction and engineering of ovens. In 1907 he returned to Spain to direct the family factories (File 231, Archive FGN).

As manager of his factories, Pablo Yvern took out a patent No 51162 of 14 August 1911 on "Improvements to the heat recuperator oven fired by gas". He installed his recuperators at the factory in Valls and subsequently at other gasworks on the Mediterranean coast.

The patent concerned the construction of a heat recuperator composed of two ducts (air-gas) or three ducts (gas-air-gas) that were independent and contiguous. Each duct contained refractory components to produce a zigzag movement.

3.4. Period of consolidation of technological change (1921-1938).

In 1938, during the Civil War, the *Servei de Gas Unificat de Catalunya* (Unified Gas Service of Catalonia; SGUC) made an inventory of gasworks existing in Catalonia. There were 25 factories one of which, the one in Tortosa, was closed. Of these, only 8 that retained directly fired ovens although three of them also had recuperative ovens. Of the 12 factories that were equipped with recuperative ovens, 8 were of the Yvern type and the others used foreign technology. This bears testimony to the significance of the Yvern recuperative ovens. Thus, in line with the 1943 statistics, the ovens in Cartagena, Alicante and Denia should be included.

The Lachomette ovens continued to be used at the Lebon factories although the factories in Gracia, Arenal and San Martí had been taken over by *Catalana de Gas* in 1923.

Nevertheless, the technical innovations introduced in this period concerned ovens of continuous carbonization. After WWI, the installations in Valencia were replaced with 5 Woodall-Duckham ovens, which used coal from Asturias. This technology was not restricted to large gasworks (García, 1984:163) as shown by the decision to build a plant of continuous carbonization in Reus, which accounted for one sixth of the gas production in Valencia. Two ovens of 5 retorts of the Glover West type were purchased from the West Gas Improvements Co. Ltd., Manchester, and were inaugurated in Reus in 1935 (Moyano, 2009: 215-219).

Catalana de Gas, which owned large factories, also opted for a more innovative system for the gasworks in Barcelona and Sevilla. Vertical chamber ovens of continuous carbonization manufactured by Dr. Otto and Company, of Bochum were chosen. However, the installation of these ovens were interrupted by the civil war.

3.5. Period of autarky (1939-1960).

After the Civil War, the ovens of continuous carbonization did not live up to expectations. The West Glover ovens from Reus did not work satisfactorily. More noteworthy was the case of Barcelona, where these continuous ovens had never worked as continuous ovens but always as intermittent ovens. Consequently, in 1942, the Dr. Otto and Company, agreed to replace them, without charge, by other ovens of 5 chambers of intermittent carbonization. However, these changes were not implemented until 1947 because of WWII (File 2275, Archive FGN).

More information on the technical characteristics of gasworks in Spain became available after the Civil War owing to the statistics produced by the *Sindicato Vertical* (The Francoist Trade Union) after 1943. The first statistical data concerned the gasworks that existed in the 1930s just before the outbreak of the civil war. These statistics confirmed that, apart from Barcelona and Seville, Otto ovens of vertical chambers of intermittent carbonization had also been implemented in the gasworks in Oviedo, Bilbao and San Sebastian.

The statistics show that the gasworks in Madrid were equipped with Didier vertical retort ovens similar to the Bueb model in Barceloneta, A Coruna and Zaragoza. Moreover, the gasworks in Madrid used Koppers ovens, which were less common in Spain. These ovens were of intermittent carbonization and consisted of horizontal chambers. The exact year of the implementation of these ovens at the Puerta de Toledo factory is unknown but it is thought that they existed before the Civil War (La producción, 1996: 18).

The statistics also show that some companies opted for less common ovens such as the Parsy oven, which was adopted in Calella, Girona and Vigo or the Hovine oven, which was installed in Jerez de la Frontera.

Gas technology in Spain underwent few changes between 1943 and 1960. Nevertheless, where new ovens were installed, they were basically ovens of intermittent carbonization of vertical chambers. This was the case of Granada and Murcia but, in Malaga, ovens of continuous carbonization were preferred.

In Granada, Lachomette ovens were replaced by Collin ovens, which were similar to the coke ovens of the same name. The Murcia factory replaced its old ovens by three double ovens of vertical chambers similar to those in Granada. A Woodall-Duckham model similar to the one existing in Valencia was built in Malaga (Espín, 2001: 79), (García, 1984: 187).

In 1955 Spain had 53 gasworks, 8 of which were not in operation and 4 distributed gas from the gasworks in Barcelona. In reality, there were only 41 gasworks in operation including two new ones in Lleida and Tarragona.

Between 1955 and 1960 the gasworks in Spain adopted a new technology that obtained gas from petroleum with the result that gas from coal began to be phased out. This change involved the replacement of the existing gasworks by new ones initially in Sta. Cruz de Tenerife, Sevilla, Barcelona and Madrid. This innovation marked a fundamental transformation in gas technology, which falls outside the scope of this study.

3.6. Water gas: a bold bet

In the early decades of the XX Century, water gas was developed to be mixed with coal gas. Spanish public opinion in 1874 was not favourable to water gas given the controversy and the restrictive decrees in England and France. However, this unfavourable opinion started to change at the beginning of the XX century.

When the contracts to supply gas in Barcelona had expired in 1900, the City Council considered it opportune to study the most economic and most efficient ways to produce gas. A study was accordingly undertaken by Jose Tous Biaggi, professor at the School of Industrial Engineering, who concluded that the most convenient form was to produce water gas with the Strache producer. This study also recommended the City Council to build its own factories rather than give concessions to private companies (Dictámenes, 1902).

The production of water gas mixed with coal gas was implemented in other cities. This was the case of *Compañía Popular de Gas y de Electricidad* (Popular Company of Gas and Electricity) in Gijón, where water gas was produced in a facility type Dellwitch Fleischer in order to be mixed with coal gas in a proportion of 30% (Deschamps, 1902: 102). The book entitled *Production et utilisation des gaz pauvres* and published in 1908 by L. Marchis contains an image of a Kramers and Aats water gas producer at a factory in Cádiz (Marchis, 1908-23).

Nevertheless, the production of water gas really took off in Spain in the 1930s and the Dellwitch Fleischer gas producer was the preferred model. This model was implemented at the El Arenal gasworks in Barcelona and subsequently in Sabadell. The Humphrey and Glasgow model was installed in Madrid, whereas the Kramers and Aats producer was adopted in Malaga.

An Otto-Pintsch carburetted water gas producer was installed at the gasworks in Barceloneta in 1934 to complement the Dr. Otto ovens. This producer generated 35,000 m³ of blue water gas 2,668 kcal/m³ with a gross calorific value (GCV) which was

carburetted by the injection of 55 litres of diesel to attain a value of 4,525 kcal/m³. This model consisted of a mechanical water jacket producer that was accompanied by a carburettor, a recuperator and a steam boiler to recover heat from residual gas (files 3588, 197 and 135. AFGN).

The Tully Gas Plant system was adopted in Córdoba in 1920 to produce gas using between 8 and 12% anthracite. This system, which was known as total gasification, was nothing more than a system that produced carburetted water gas. It was therefore installed at the factory in Reus in 1947 and subsequently in 1960 at the gasworks in Palma de Mallorca and A Coruña. From 1960 until the introduction of natural gas, the water gas producer became the most utilized method to obtain town gas.

4.- Conclusion

The gasworks in Spain bear testimony to the adoption of foreign technologies and also to the improvements made to these technologies.

In the early period, the most utilized technology consisted of directly-fired ovens of 3 or 5 horizontal ceramic retorts. However, at the small gasworks, gas was obtained from fatty substances, mineral oils or hydrocarbons. Humbert gas and the rich gas were examples of this technology.

In the period of expansion, the specific process adopted in small towns continued to be developed by local technicians. This was the case of Arbós gas. Nevertheless, more advanced technologies, e.g. Klönne and Coze were imported to replace ovens whose retorts had deteriorated.

In the period of awareness of the need for technological change, efficiency was increased by the implementation of recuperative ovens. Small gasworks were equipped with recuperative ovens such as the Yvern recuperative, which bears witness to the development of local technology. Large gasworks were supplied with Lachomette ovens built by the Lebon Gas Company. The largest gas plants opted for ovens of vertical retorts.

Technological change was consolidated in the fourth period (1921-1938), during which recuperative ovens, such as the Yvern, began give way to directly-fired ovens. Technological innovations arose from the introduction of continuous carbonization at large or medium sized gasworks.

Finally, the period of autarky (1939-1960) demonstrated the failure of the continuous carbonization method. In its place, the vertical retorts of intermittent carbonization were utilized. Other less diffused systems such as the Percy and the Collin were also introduced.

During the earlier decades of the XX Century, some procedures to obtain water gas were implemented. The most notable example of this was the Tully Gas Plant in Cordoba. This method was adopted after the Civil War in Reus, Palma de Mallorca and A Coruña. Nevertheless, the Otto-Pintsch water gas producer continued to be used in Barcelona after 1934 until the introduction of natural gas.

Today, the different types of technologies of gas production have become obsolete because gas companies have opted for obtaining gas from deposits. Natural gas meets some of the energy needs of modern societies and plays an important part in the energy balance of developed countries.

5.- Bibliographie

- AUDRA, R. (1911) « L'usine à gaz du Landy (Seine) de la Société du Gaz de Paris » *Le Génie Civil*, vol. LIX, núm. 15, p. 301-305, núm. 16, p. 321-326.
- ARROYO, Mercedes (2006), *El gas en Ferrol (1883-1898). Condiciones técnicas, iniciativas económicas e intereses sociales*. Barcelona: Universitat de Barcelona, Col. Geo Crítica Textos de Apoyo nº 16 [ISBN: 84-689-6500-6] Versión electrónica en Colección Geo Crítica Textos Electrónicos <http://www.ub.es/geocrit/texap-4.htm> [En línea].
- ARROYO, Mercedes (1996). *La industria del gas en Barcelona (1841-1933). Innovación Tecnológica, articulación del territorio y conflicto de intereses*. Barcelona: Ediciones del Serbal, 1996.
- BANCELIN, E.; MAGNIER, M. D. (1899) *Nouveau manuel complet de l'éclairage et du chauffage au gaz ou traité élémentaire et pratique destiné aux ingénieurs, aux directeurs et aux contremaîtres s'usines a gaz d'éclairage suivi de l'aide-mémoire de l'ingénieur gazier*. Paris: Encyclopédie-Roret. L. Mulo, libraire-éditeur, vol. II.
- BERNILS i MACH, Joseph "Historia del gas a Figueres". *Annals de l'Institut d'Estudis Empordanesos*. 1992, vol. 25, 177-205.
- BERTRAN, H. (1909) « Gazogènes pour fours à cornues à gaz » *Le Génie Civil*, vol. LV, núm. 11, p. 213-215.
- BORIAS, Edmond (c.1890) *Traité théorique et pratique de la fabrication du gaz et de ses divers emplois à l'usage des ingénieurs, directeurs et constructeurs d'usines à gaz*. Paris: Librairie Polytechnique Baudry et Cie.
- BOSKO, Charles (1957) *Physique, chimie et mécanique du gaz de ville*. Genève, 3ª ed.
- CLEGG, SAMUEL (1860) *Traité Pratique de la fabrication et de la distribution du gaz d'éclairage et de chauffage*. París: Librairie Scientifique, Industrielle et Agricole.
- DAMOUR, Emilio; CARNOT, Jean; RENGADE, Étienne (1912) *Les sources de l'énergie calorifique*. París et Liège: Librairie Polythechique, Ch. Béranger, editeur.
- DARCEL, M. (1978) *Mémoire sur l'éclairage des villes*. París: Dunod.
- DESCHAMPS, Jules (1902) *Gazogènes*. París: Dunod éditeur.
- Dictámenes técnico y de la ponencia nombrada para el estudio del servicio de alumbrado de esta ciudad*. Barcelona: Tipografia L'Avenç, 1902.
- Die Firma Dr. C. Otto & Comp./ Werk Bendorf. Eine Chronik der Firma zum 100 jährigen Bestehen, 2003. <http://www.bendorf-geschichte.de/bdf-0132.htm>. [visitada el 29-07-2010].
- ESPÍN ESTRELA, Antonio; CORDEIRO, Manuel R. (2001) *Introducción a la història del alumbrado: del aceite a la incandescencia*. Granada: Imprenta Santa Rita.
- Euskomedia fundazioa. Fàbrica municipal de gas de San Sebastian. Archivo Auñamendi. http://www.euskomedia.org/galeria/A_19745 [visitada el 27-07-2010].
- FALGUERAS, J. *Una industria centenaria*. Ejemplar mecanografiado. Archivo Fundación Gas Natural.
- FABREGAS, Pedro-A (1989) Gas Cadiz 1845-1969. *Cuaderno de Historia*. Nº 1. Programa de investigación histórica del Grupo Catalana de Gas.
- GARCÍA DE LA FUENTE, Dionisio (1984) *La Compañía Española de Gas S.A. – CEGAS- "Mas de cien años de empresa"* Valencia: CEGAS.

- GARCÍA DE LA FUENTE, Dionisio (2006) *Una historia del gas en Alicante*. Madrid: LID Editorial Empresarial/ Fundación Gas Natural.
- Génie Civil, 1906 : “Nouveau four à cornues verticales de l’usine à gaz de Dessau (Prusse)”. *Le Génie Civil*, vol. XLIX, núm.. 6, p. 92.
- GREBEL, A. (1909) « Gazogènes à combustion horizontale pour fours à cornues d’usines à gaz, système Parsy » *Le Génie Civil*, vol. LIV, núm. 25, p. 412-414.
- GREBEL, A. (1910) «L’évolution des fours à gaz d’éclairage. Fours à chambres horizontales» *Le Génie Civil*, vol. LVI, núm. 25, p. 479-482, núm. 26, p. 501-507.
- GREBEL, A. (1913) « L’emploi du gaz des fours a coke comme gaz de ville » *Le Génie Civil*, vol. LXIV, núm. 7, p. 127-132, núm. 8, p. 153-156, núm. 9, p. 173-176, núm. 10, p. 195-197.
- GREBEL, A. (1920) « Quelques précisions sur le gaz à l’eau » *Journal des usines à gaz*, núm. 10, maig, p. 145-148, núm. 11, juny, p.161- 164, núm. 12, juny, p. 177-183.
- GREBEL, A.; BOURON, H. (1924) *Gaz & Cokes. Manuel de la fabrication & de l’utilisation des gaz de distillation & des autres gaz industriels, des cokes & des sous-produits de la houille*. Paris: Dunod.
- GREBEL, A.; VERDIER, ??.(1911) “L’industrie du goudron de houille”. *La Technique Moderne*, vol. III, núm. 1 gener, p. 27-31, núm. 2 febrer, p. 85-87, núm. 3 març, p. 155-158, núm. 4 abril, p. 227-228, núm. 6 juny, p. 357-360.
- Industria Química, 1906: “Perfeccionamientos á las retortas verticales para la destilación completa de la hulla”. *La Industria Química*. Any III, núm. 55, 1º juny 1906, 149-150.
- Industria Química, 1906: “Perfeccionamientos á las retortas verticales para la destilación completa de la hulla”. *La Industria Química*. Any III, núm. 55, 1º juny 1906, 149-150.
- Industria Química, 1909: “Fabricación de gas. Métodos modernos de destilación de la hulla”. *La Industria Química*. Any VI, núm. 130, 16 juliol 1909, 183-185.
- Instalación de gas de agua de cok Pintsch*. Berlin: Julius Pintsch Aktiengesellschaft.
- Journal, 1890: “Fabrication du gaz. Fours à gazogène et récupérateur, système de Lachomette, en construction à l’usine à gaz de Perrache”. *Journal des usines à gaz*, nº15, 5 de Agosto de 1890, 236-237.
- KRAFFT, Bernard (1911) « Les fours a gaz à chambres horizontales de l’usine d’Elbeuf (Seine-Inférieure) » *Le Génie Civil*, vol. LIX, núm. 3, p. 45-48.
- La producción de gas en Madrid. 150 años de historia*. Madrid: Gas Natural, 1996.
- LEBON, Lebon & Cie. *Un Centenaire, 1847-1947*, París, Lebon, 1947.
- LEBON Eugenio y Compañía (1902) *Breves observaciones a los Dictámenes técnico y de la Ponencia emitidos para el estudio del servicio de Alumbrado público en Barcelona*. Barcelona: Tipografía La Académica de Serra hermanos y Russell.
- LEMAIRE, E. (1912) « Cornues verticales a distillation continue système Woodall et Duckham. Usine à gaz de Lausanne » *Le Génie Civil*, vol. LX, núm. 21, p. 401-405.
- MADOZ, Pascual (1846) *Diccionario Geográfico Estadístico Histórico de España y sus posesiones de Ultramar*. Madrid: Establecimiento literario tipográfico de P. Madoz y L. Sagasti, Vol III.
- MARCHIS, L. (1908) *Production et utilisation des gaz pauvres*. París: Dunod, H et Pinat, E, éditeurs.

- MARTÍNEZ, Alberte (coord); MIRÁS ARAUJO, Jesús; LINDOSO TATO, Elvira (2009) *La industria del gas en Galicia: del alumbrado por gas al siglo XXI, 1850-2005*. Barcelona: LID, Fundación Gas Natural.
- MASSE, René; BARIL, Auguste (1923) *Distillation de la houille*. París: Masson & Cie., Gauthier Villars & Cie.
- MOYANO JIMÉNEZ, Florentí (2009) *Un model d'empresa energètica local: "Gas Reusense" (1854-1969). Memòria de la indústria del gas a reus. La producció de gas a partir de la destil·lació de hulla, la implantació elèctrica a la ciutat i els derivats de petroli*. Tesis doctoral dirigida per Pere Anguers i Nolla. Tarragona: Universitat Rovira i Virgili.
- PECKSTON, Thomas S. (1819) *The theory and practice of gas-lighting*. London: Underwood, Ogle, Duncan &c.
- PERCY, J. (1864) *Traité complet de Métallurgie*. París et Liege: Librairie Polytechnique de Noblet et Baudry, editeurs. Vol. 1.
- Porvenir, 1878: A.A. "Elaboración de gas para el alumbrado sistema Hirzel". *El Porvenir de la industria*, núm. 163, Año IV, 26-04-1878, 139-141; núm 163, 3-05-1878, 145-146
- Porvenir, 1882: "Alumbrado por Gas-Rico de Palafrugell", *El Porvenir de la industria*, núm. 373, Año VIII, 5-05-1882, 176-177
- Porvenir, 1881: "Gas a Blanes", *El Porvenir de la industria*, núm. 327, Año VII, 17-06-1881, 195.
- SAEZ GARCÍA, Juan Antonio. "Infraestructuras de servicios urbanos". Geografía e historia de Donostia-San Sebastián. <http://www.ingeba.org/liburua/donostia/54ssinfr/543urb/543ssur.htm> [visitada el 27-07-2010]
- RIBÉ LLENAS, Ernest, GASCON ALTÈS, Vicenç (1995) *Història del gas canalitzat a Valls : des de 1854 fins a l'actualitat*. Tarragona: Gas Tarraconense.
- SCHILLING, Eugène (1895) *Traité sur la production et l'exploitation de la lumière au gaz de houille*. Paris, Moniteur de l'industrie du gaz et de l'électricité.
- SCHILLING, N.H. (1868) *Traité d'éclairage par le gaz*. París, Eugène Lacroix, éditeur.
- SCHILLING, N.H. (1879) *Traité d'éclairage par le gaz de houille*. París: Eugène Lacroix, 10^a ed.
- Sindicato Vertical de agua, gas y electricidad. (1943). *Datos Estadísticos Tecnicos de las Fábricas de gas españolas, 1930 – 1943*. Madrid: Delegación Nacional de Sindicatos.
- Sindicato Vertical de agua, gas y electricidad (1947). *Datos Estadísticos Tecnicos de las Fábricas de gas españolas, 1930 – 1947*. Madrid: Delegación Nacional de Sindicatos.
- Sindicato Vertical de agua, gas y electricidad (1950). *Datos Estadísticos Tecnicos de las Fábricas de gas españolas, 1930 – 1950*. Madrid: Delegación Nacional de Sindicatos.
- Sindicato Vertical de agua, gas y electricidad (1955). *Datos Estadísticos Tecnicos de las Fábricas de gas españolas, 1950-1955*. Madrid: Delegación Nacional de Sindicatos.
- Sindicato Nacional de agua, gas y electricidad (1960) *Datos Estadísticos Tecnicos de la Industria del gas. Producción, distribución y consumo*. Madrid: Servicio de estadística.
- SOLÀ i SALA, Josep (1979) "De les romàntiques faroles als cremadors funcionals. La Història del Gas", *Ausona*, 26-9, 6-10 y 13-10.
- VERDÚ, Javier (1874) "Gas de Agua". *Gaceta de los caminos de hierro*, Año XIX, nº 9, 1-03-1874, 136-137 y nº 10, 8-03-1874, 151-153.

X. P. (1909) «XXXVI Congrès de la Société technique du Gaz (Lyon, 22-25 juin)» *Le Génie Civil*, vol. LV, núm. 11, p. 208-210.

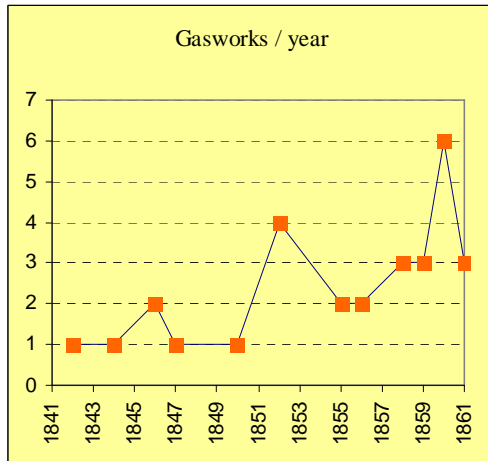


Table 1 Annual installation of Gasworks in Spain between 1841-1861

Estimated gasworks existing in 1861		
Town	year	Company of gas production and distribution
Barcelona - Barceloneta	1842	Charles Lebon - Sociedad Catalana para el Alumbrado por gas
Valencia	1844	Charles Lebon - Sociedad Valenciana para el alumbrado de Valencia
Cadiz	1846	Charles Lebon
Madrid	1846	Sociedad Madrileña para el Alumbrado de Gas en Madrid
Bilbao	1847	Compañía Lionesa del alumbrado
Sevilla	1850	Juan Pedro Lacave (en nombre de York & Co. de Londres)
Gràcia	1852	Ramon Salvadó
Sabadell	1852	Prats, Benessat y Cia
Santander- Molnedo	1852	Manby Wilson & Cia
Málaga	1852	Louis Gosse
Reus	1855	Gas Reusense
Matarò	1855	Clavell y Cia
Igualada	1856	Altadill y Cia
Sant Andreu de Palomar	1856	Agustín Rosa y Cia
Tarragona	1858	Sociedad Tarraconense para el alumbrado por gas
Valladolid	1858	Compañía general de crédito en España
Oviedo	1858	Gonzalez, Alegre y Polo
Manresa	1859	Mariano Torrents y Cia
Girona	1859	Barrau, Balarí y Cia
Palma de Mallorca	1859	Sociedad de Alumbrado por Gas
Terrassa	1860	Juan Vallès y Cia
Figueres	1860	Sociedad Cda de gas de residuos compuestos
Manlleu	1860	Alfonso Humbert, M.Petit i F.Benessat

Vigo	1860	Sociedad de Alumbrado y Calefacción de la Coruña y Vigo
La Coruña	1860	Sociedad de Alumbrado y Calefacción de la Coruña y Vigo
Jerez de la Frontera	1860	Compañía General de Crédito en España
Cartagena	1861	Compañía General de Crédito en España
Alicante	1861	Compañía General de Crédito en España
Pamplona	1861	Compañía General de Crédito en España

(Table 2 elaborated by the authors)

Small gasworks (1901-1933) Less than 250.000 m³
Arbós, Calella, Figueres, la Garriga, Granollers, Girona, Hospitalet de Llobregat, Igualada Manlleu, Palafrugell, Sallent, Tortosa, San Feliu de Guíxols, Sitges, Valls, Vic, Vilafranca del Penedès, el Vendrell
Alcoy, Castellon, Denia, Vinaroz, Xàtiva
Chipiona, Jaen, Puerto Real, Puerto de Santa Maria
Felanitx, Inca, Lluçmajor Maó, Sóller
Santiago de Compostela,
Ciudad Real
Logroño
La Unión (Murcia)

Medium-sized gasworks (1901-1933) Between 250.000 and 1 million m³
Arenys de Mar, Badalona, Manresa, Mataró, Premià de Mar, Reus Sabadell, Tarragona, Terrassa, Vilanova i la Geltrú
Granada, Jerez de la Frontera, San Fernando, Sanlúcar de Barrameda
La Coruña, Pontevedra, Vigo
Burgos, Valladolid
Gijón, Oviedo
Cartagena, Murcia
Alicante

Large gasworks (1901-1933) More than 1 million m³
Almeria, Cádiz (E. Lebón y Cia), Cádiz (Coop. Gaditana), Córdoba, Huelva Màlaga, Sevilla
Barcelona (Barceloneta), Barcelona (Arenal)
Palma de Mallorca (La Económica), Palma de Mallorca (Alumbrado por gas)
Santander
Valencia
Zaragoza
Madrid
Santa Cruz de Tenerife

(Table 3 elaborated by the authors)

Volume of production (m ³)	Gasworks
More than 50.000.000	Barcelona y Madrid
About 25.000.000	Valencia,
About 10.000.000	San Sebastián y Sevilla,
Between 1.000.000 and 9.000.000	Alicante, Bilbao, Cádiz, Cordoba, Gijón, Granada, La Coruña, Malaga, Manresa, Mataró, Murcia, Oviedo, Palma de Mallorca, Reus, Santander, Santa Cruz de Tenerife y Zaragoza
Between 100.000 and 1.000.000	Cartagena, Figueres, Girona, Igualada, Mahón, Manlleu, San Feliu de Guixols, San Fernando, Sitges, Soller, Tortosa, Valladolid, Valls, Vendrell, Vic, Vigo, Vilafranca del Penedes y Vilanova i la Geltrú.
Between 0 and 100.000	I' Arbós

(Table 3 elaborated by the authors)

