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TECHNOLOGICAL INNOVATIONS AND CRAFT TRADITIONS IN THE 19TH-CENTURY BELGIAN WINDOW-GLASS INDUSTRY

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Abstract

This paper explores the process of technological innovation and its relationship with old craftmanship traditions within the Belgian window-glass industry during the 19th century, before the introduction of the Fourcault process, a novel technique for making glass by drawing a ribbon of glass mechanically in a vertical direction from a bath of molten glass. The industry experienced a steady quantitative growth during the period under consideration. However, the exact nature of this growth is still not fully understood. Existing literature often puts the focus on manual production; this paper provides a more balanced view of the developments in the 19th-century glass industry, emphasizing the unique combination of the pre-industrial glass-making tradition and the never-ceasing stream of technological innovations. Within the context of innovation, special attention is directed towards international technology transfer and the exchange of knowledge.

Keywords

Glass-making, window glass, furnace technology, technology transfer, craftsmanship

Introduction

During the 19th century, Belgium was one of the most important glass-producing countries in the world alongside France, the United Kingdom and the United States of America. Various types of glassware were produced, including diverse forms of vessel glass. However, the main branch was flat-glass production, which can be divided into blown window glass and cast plate glass; this paper considers only blown window glass. The production of blown window glass grew tremendously, from 1.28 million m^2 in 1840 to 23.47 million m^2 in 1900. About 95% of the glass was exported.[1] Yet this sector is generally characterized as traditional and technologically conservative. This assumption is based on two arguments: firstly, that the use of steam power was quite limited within the industry; secondly, that the manual skills and the tacit knowledge of the workers (glass-blowers) were of paramount importance. Innovations such as the

1 The Verreries Belges glass factory, previously Verrerie Baudoux (written wrongly as 'Beaudoux'), one of the largest window-glass factories of Belgium by the late 19th/early 20th century, and one of the first to introduce tank furnaces, at Jumet near Charleroi, Belgium, photographer unknown.


Verreries Belges.
rreries Eugène Beaudoux).
lé et pillé lors des troubles du 26 mars 1886.

invention of the Biévez annealing kiln of 1867, or the introduction of the tank furnace around 1885, are seen rather as exceptional and isolated milestones (Fig. 1).[2]
The present paper examines the process of innovation in a more comprehensive way, by exploring how the Belgian window-glass industry adapted and developed new technologies while retaining manual craftmanship as a key resource. It will focus on the period from the beginning of the 19th century to the First World War, which is generally considered to have been rather deficient in innovation. The article will not address the development and introduction of the mechanical drawn-glass technique in the early 20th century.

The Emergence of a Professional Community

The development of the Belgian window-glass industry took place in a relatively small region around Charleroi. In more 'human' terms, the industry can also be defined as a community, consisting of workers, engineers, entrepreneurs and so forth. Indeed, the presence of a community that provides an 'infrastructure' of various material and immaterial resources (including skills), as well as the mobility of personnel (whether on a group or individual basis), is essential for the successful transfer and further development of knowledge and technology.[3]
Window-glass production became firmly established in this region by the 17th century, although other types of glass production had certainly existed there from at least the 15th century.[4] Interestingly, many 'glass-masters' here of the period were of foreign origin, such as was the case for the de Condé, Colnet and Desandrouin families (from Lorraine, Italy and France respectively).[5] In the first half of the 17th century, many migrant glass-blowers arrived from Southern Germany, Alsace and Lorraine, while in the next century even more glass-blowers from Southern Germany and Alsace were recruited for the production of window glass; they brought the 'secret', in other words, tacit knowledge, of this kind of production with them.[6] It was within this community of both glass-masters (entrepreneurs) and glass-blowers (workers) that the technological developments of the 19th century would take place.
In contrast to the 18th century, there was hardly any technology transfer to Belgium in the 19th century through collective immigration. At the same time, from the late 19th century onwards, Belgian glass-blowers started to emigrate to various countries. The USA, and Pittsburg in particular, attracted many Belgian glass-blowers from the 1880s onwards. Ironically, these migrant workers have played an important role in the development of the American window-glass industry that was to become Belgium's main competitor in the global market by the early 20th century.[7]
While the 19th-century mass migrations of workers contributed to the 'export' of knowledge and knowhow from Belgium, the personal itineraries of entrepreneurs and engineers contributed to the 'import' of knowledge and innovations. One particularly fascinating example is that of André-Marie Oppermann (1846–1930). He was born in then-independent Hanover, where he studied engineering at the polytechnic school.

Shortly after graduation, he left Hanover and moved to England, where he started to work for the firm of Siemens that operated on an international scale in the United Kingdom as well as in Germany.[8] It was within the Siemens company that Oppermann developed his knowledge of glass technology. In the course of his employment with the firm, he travelled to France and Belgium in order to work on the construction of furnaces at various glass factories. In 1874 or shortly before, he settled in Charleroi.[9] Over the course of the following decades, he contributed significantly to the further improvement of glass-melting furnaces in Belgium, during which he collaborated with various Belgian glass manufacturers. Later on in his career, he travelled to Bohemia in order to construct a window-glass factory for a Belgian company there, which he managed for five years. Shortly after 1900, he was sent to the USA by the *Association des maîtres verriers* to study the latest developments in glass technology.[10] It can be stated without doubt that his legacy is vast. He held multiple invention patents related to various aspects of glass technology, ranging from melting furnaces to glass packaging.[11]

In general, the glass-producing region of Charleroi was characterized by close ties between manufacturers and other actors. For instance, the *Association des maîtres de verreries* that united most of the region's window-glass manufacturers (established as the *Comité verrier* in 1848, renamed the *Association* in 1873) met on a regular basis, providing a forum for discussion and the exchange of ideas.[12] Despite the lack of hard evidence, it is quite likely that many informal ties existed as well.

Steam Power and Electricity

The first steam engine within the window-glass industry of Belgium was introduced in 1828 at the Mariemont glass factory.[13] By 1850, roughly one third of all window-glass factories possessed at least one steam engine,[14] and by 1896, all factories were steam powered with at least one steam engine.[15] Yet such quantitative data is insufficient to judge whether an industry was 'modern' or 'backward'. It is essential to look at the way the steam engines were used in order to arrive at a more balanced assessment.

In the window-glass industry, the primary use of steam engines was to mill and mix the primary materials, as indicated in sources from the 1830s and 1840s.[16] In the second half of the 19th century, other applications started to emerge. For instance, steam engines were used to pump water or to drive ventilation equipment.[17] From the late 1880s, factories started to use steam engines to produce electricity.[18]

By the First World War, electrical power was used for many purposes. For instance, the Piges factory possessed nine electrical motors in 1916, which were used to action overhead cranes, to mill and mix primary materials, and to saw wood for the packaging. The use of steam power was not reported at this factory after this date.[19] While unfortunately no quantitative data on the use of electric power in window-glass factories exists, the aforementioned example illustrates that by 1914 at least some factories were fully electrified.

Melting Furnaces

Melting furnaces are used to melt the primary materials, such as silica (sand), flux (alkali) and stabilizer (lime) at temperatures around 1200–1400° Celsius. Traditionally, the melting took place in large pots (crucibles). In Belgium, firewood was used as the combustible until the mid-17th or early 18th century, while the English glass industry started to use coal from 1615 onwards.[20] In 1643, coal was introduced as a fuel for glass-melting furnaces in the area of present-day Belgium as well.[21] Despite this early start, the transition from wood to coal did not happen overnight. At the beginning of the 18th century, the majority of glass factories still used firewood.[22] The transition was certainly complete by the first decade of the 19th century, as attested by the requests for the establishment of factories, which almost always mention the estimated consumption of fuel and primary materials.[23]

Around 1860, the Siemens brothers invented the regenerative pot furnace in England, which enabled considerable fuel savings by using the heat of the exhaust gas for the preheating of the fuel gas and air before burning. The fuel gas was produced in the gas producers, which transformed coal into gas by partial combustion with air.[24] However, the adoption of this type of furnace in Belgium was rather slow. In 1867, the Bennert & Bivort factory started to use the regenerative furnace. They were most probably the first in Belgium to do so. However, it took them several years of experimentation to implement the regenerative furnace fully.[25] The innovative efforts of the Belgian window-glass industry in general were acknowledged internationally. According to a report from the 1873 Vienna World Fair, the use of the Siemens regenerative furnace for window-glass production was a Belgian achievement.[26]

Yet the real breakthrough came only after 1880, with the introduction of the tank furnace, in which the individual glass-melting pots were replaced by a single huge tank, making continuous production possible. Like the regenerative furnace, it was invented in England by the Siemens brothers. The first commercial tank furnace was installed at the Pilkington factory in 1872, however, a lot of technical problems still remained. For instance, the materials wore at a fast pace, such that the lifespan of the first furnaces was limited to only a few months. Moreover, the first tank furnaces were used for the production of bottle glass.[27]

The introduction of the tank furnace in Belgium can be credited to the aforementioned engineer Oppermann. Between 1874 and 1875, he conducted experiments with tank furnaces at his own expense. Subsequently, between 1876 and 1890, he worked as an engineer at the Jonet window-glass factory, where the first large tank furnace for window-glass production was installed under his supervision in 1877–1878.[28]

The Baudoux window-glass factory was the second to use tank furnaces in Belgium. Before starting his own factory, Eugène Baudoux (1841–1912) had worked at the Jonet factory.[29] Together with his engineer Jean-Matthieu Pagnoul (dates unknown), Baudoux had made numerous improvements to the tank furnace's construction. The greatest challenge in adapting tank furnaces for the production of window glass, as

2 Tank furnace, late 19th or early 20th century, Belgium, photographer unknown.

opposed to the production of bottle glass, was that a much greater depth was required for the window-glass bath. The depth required depended on the heat permeability of molten glass which, in turn, depended on the purity of glass and, hence, the glass composition. For bottle-glass production ('shaded' glass with impurities), a bath depth of 30–40 cm is sufficient, but for window-glass production (clear glass), the depth required is 1.5–2 m. Baudoux and Pagnoul succeeded in resolving this problem by 1885.[30]

The final improvements to the tank furnace in Belgium were made by Émile Gobbe (1849–1915). Originally from France, he settled in Jumet near Charleroi in 1890. With Pagnoul as a partner, he established a firm that came to play an important rôle on the world market for tank furnaces. Around 1896, there were two major players on this market: Siemens in England (who did not produce glass commercially themselves except for some test production on a limited scale but supplied furnaces to Pilkington and other manufacturers) and Gobbe & Pagnoul in Belgium. Gobbe & Pagnoul were especially successful in the USA, where they delivered the majority of all tank furnaces. Gobbe & Pagnoul were a study office rather than a production company: physical construction was executed by specialized contractors, who worked under the supervision of Gobbe & Pagnoul.[31]

The introduction of tank furnaces within the Belgian glass industry proceeded at a rapid pace in the second half of the 1880s and the 1890s, when pot furnaces were almost completely replaced.[32] After the introduction of tank furnaces, the industry could not be described as 'traditional' anymore, even if the production process (glass-blowing) remained manual (Fig. 2). Apart from the furnace itself, the adjacent equip-

3 Battery of gas producers for a tank furnace, late 19th or early 20th century, Belgium, photographer unknown.

ment, such as gas producers and large steam boilers, transformed glass factories from relatively small workshops into large-scale industrial enterprises (Fig. 3).

The development of the tank furnace was not an exclusively Belgian innovation, as it was pursued at the same time in other countries as well, most notably by Siemens in collaboration with Pilkington.[33] However, after the introduction of this new technology in Belgium, further improvements were carried out by various engineers and entrepreneurs within Belgium, such as Oppermann, Baudoux, Gobbe and Pagnoul, whereby knowledge was transmitted within the community in an almost relay-race-like manner. Despite the lack of hard evidence, it can be assumed that the close geographical proximity of the aforementioned actors, who all lived and worked within a small region, and numerous professional ties contributed to the development and implementation of the new technology.

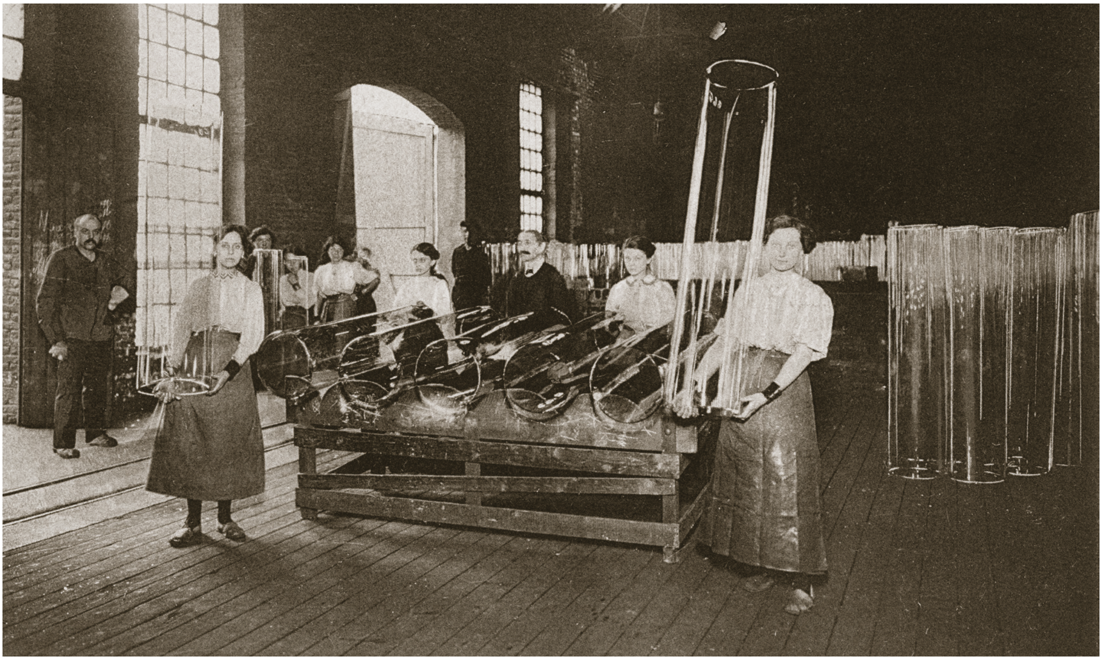
Glass-Blowing

Manual glass-blowing remained the dominant technique for the production of window glass until the early 20th century. The 'cylinder method' (also known as 'broad glass' in England), was the standard way of producing window glass in Belgium from around 1750 until the First World War. In very basic terms, it consisted of blowing a huge glass cylinder that was then cut lengthwise and flattened to achieve a sheet of flat glass.

This technique may seem quite straightforward and uncomplicated, but the production of glass required exceptional skills. Although the craft of glass-making developed

4 Glass-blowers at work, late 19th or early 20th century, Belgium, photographer unknown.

largely outside guild structures, the training remained somewhat reminiscent of the traditions found within old craft guilds. For example, there was no formal vocational training, and apprentices learned their skills on the workfloor from senior glass-blowers. The full apprenticeship could take up to seven years (Figs 4 and 5).[34]



5 Cylinders of glass, late 19th or early 20th century, Belgium, photographer unknown.

The tacit knowledge and craftsmanship of glass-blowers were of extreme importance for the industry, as is indicated by glass-blowers' wages. In 1846, glass-blowers earned the highest wages of all Belgian industrial workers. An average day's wage in the factories amounted to 2.58 Belgian francs, while in coal mines it amounted to 2.07 francs and in the linen industry to only 0.80 francs. By 1891, glass-blowers earned between 15 and 17.5 francs, while wool-weavers, for example, had to be satisfied with a day's wage of only 3 francs.[35]

Although the basic work process remained unchanged between the late 18th and early 20th centuries, small improvements were able to provide surprising efficiencies. Between 1822 and 1867, various pieces of equipment were developed that helped to support the glass-blower's cane, which allowed larger cylinders to be blown. These pieces of equipment are known as the *lanceman* (introduced in 1822–1823), the *crochet d'ouvreau* (introduced in 1845), and the *manique* (introduced in 1867). Because of these improvements, the maximum size of glass plates evolved from 49 × 38 cm in 1820 to 130 × 86.5 cm in 1870.[36] These dimensions should not be taken as absolute; they reflect rather the most common sizes of regular sheets. The increase in the size of sheet glass is an example of product improvement by means of small innovations.

Annealing Kilns

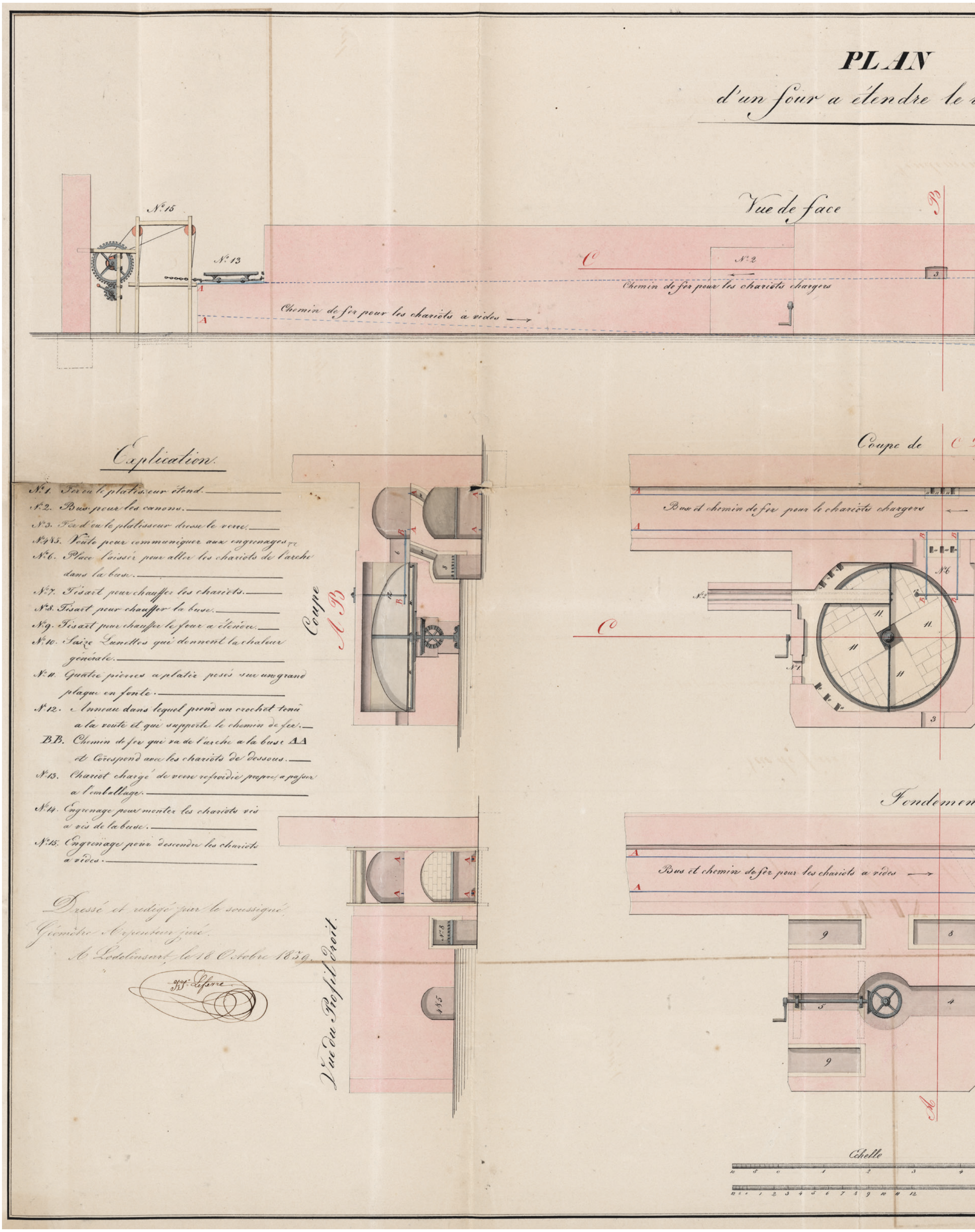
Annealing kilns are kilns in which glass cylinders are flattened and cooled down slowly. The process of flattening and annealing consists of several operations: firstly, the cylinder is warmed up; it is then cut open lengthways and flattened to achieve a rectangular sheet of glass; finally, the sheets of glass are cooled down gradually to remove any internal stress and damage. The temperature within the annealing kiln is around 600° Celsius.

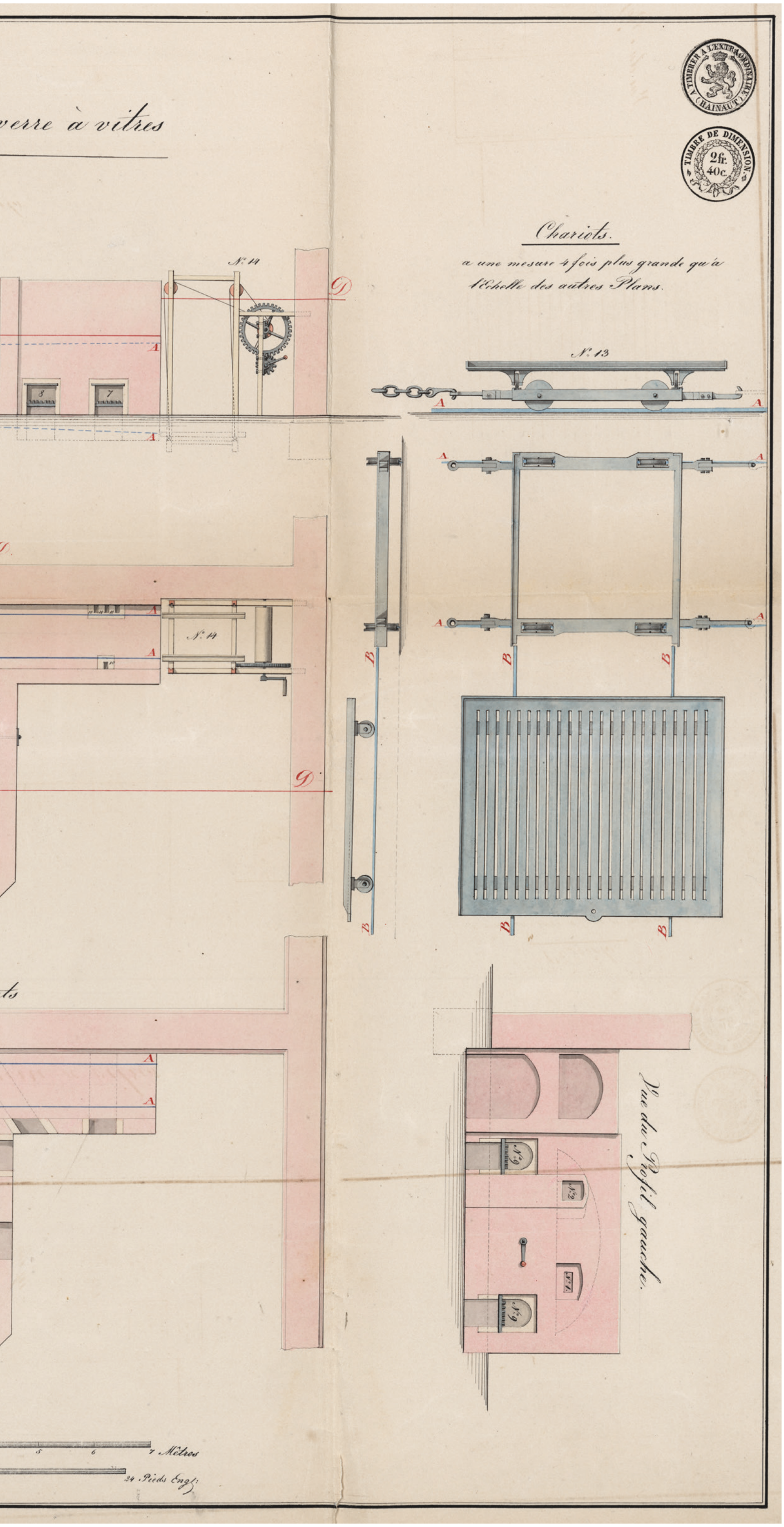
Until around 1824, primitive annealing kilns were in use. They consisted of two chambers. The glass cylinders were flattened in the first chamber, and the flattened glass sheets were placed manually in the second chamber afterwards. As soon as the second chamber was full, the whole kiln was cooled down. The process was therefore discontinuous, and in the course of production a lot of glass was broken. Moreover, fuel consumption was high, as the kilns had to be cooled down and reheated after each cycle.[37] Unlike melting furnaces, annealing kilns were wood-fired until the first decades of the 19th century, as attested by numerous requests for the establishment and expansion of factories from 1810–1835.[38]

From approximately 1830, two measures were undertaken to modernize and improve annealing kilns. Firstly, wood was replaced by coal to increase combustion efficiency. Secondly, the annealing process was mechanized and transformed into a continuous process by introducing 'turning stones' and the 'annealing tunnel' (French: *arche à tirer*). The former serves to transport glass from one chamber to the other, and the latter is a kind of conveyor belt on which the glass is cooled gradually. The first invention patents that explicitly mention the use of coal instead of firewood were registered in 1839 and 1842.[39] The first request that mentions the use of coal for annealing kilns dates from 1836–1837.[40] The last mention of the use of firewood as annealing-kiln fuel dates from 1840.[41] All later requests explicitly mention the use of coal only.[42] It can thus be concluded that the transition to coal firing was completed just after 1840.

The origins of the turning stones and the annealing tunnel are not entirely clear. According to the literature, the turning-stones annealer was invented in France in 1826.[43] According to Georges Bontemps (1799–1883), one of the most prominent glass technologists of the 19th century, some German glass manufacturers (Bontemps did not mention any names) had claimed the invention as their own. Yet they did not file a patent and therefore could not prove that they were first. For this reason, Bontemps attributed the invention to Aimé Hütter (dates unknown) of the Rive-de-Gier glassworks, who received his patent in 1826.[44] The annealing tunnel was introduced at the Chance factory in England in 1846 (possibly in combination with turning stones, but the literature is not explicit on this matter).[45] Bontemps, however, claims to have invented it himself in 1828, but encountered technical problems, such as undesired flows of cold air in the annealing tunnel that prevented gradual cooling of glass, and had to abandon his idea of combining turning stones with the annealing tunnel. Hütter had also tried to combine the two new technologies, but had failed as well. According to Bontemps, it was François Houtart-Cossée (1802–1876) from Belgium who succeeded in developing an annealer with turning stones and an annealing tunnel.[46]

Houtart-Cossé was by no means the only one working towards solving the problem, as illustrated by the numerous invention patents related to annealing kilns registered in Belgium in the 1830s and 1840s (Fig. 6). It seems, therefore, that the annealing-tunnel


PLAN
d'un four a étendre le
Vue de face
N.º 15
N.º 13
N.º 2
Chemin de fer pour les chariots chargers
Chemin de fer pour les chariots à vides
Explication.
N.º 1. Fer ou le platisseur étend.
N.º 2. Bus pour les canons.
N.º 3. Fer d'ou le platisseur dresse le verre.
N.º 4 & 5. Voute pour communiquer aux engrenages
N.º 6. Place l'aissér pour aller les chariots de l'arche dans la buse.
N.º 7. Tisart pour chauffer les chariots.
N.º 8. Tisart pour chauffer la buse.
N.º 9. Tisart pour chauffer le four a étendre.
N.º 10. Saize Lunettes qui donnent la chaleur générale.
N.º 11. Quatre pierres a platir posés sur un grand plaque en fonte.
N.º 12. Anneau dans lequel prend un crochet tenu a la voute et qui supporte le chemin de fer.
BB. Chemin de fer qui va de l'arche a la buse AA et Corespond avec les chariots de dessous.
N.º 13. Chariot chargé de verre refroidie propre, a passer a l'emballage.
N.º 14. Engrenage pour monter les chariots vis a vis de la buse.
N.º 15. Engrenage pour descendre les chariots a vides.
Dressé et redigé par le soussigné Géomètre Arpenteur juré
A Lodelinsart, le 16 Octobre 1859.
Coupe A B
Vue du Profil droit
Coupe de
Bus et chemin de fer pour le chariots chargers
Fondemen
Bus et chemin de fer pour les chariots a vides
Échelle



6 Drawing from an annealing kiln from an invention patent by L. de Dorlodot (invention patent no. 1428, 19 November 1839).

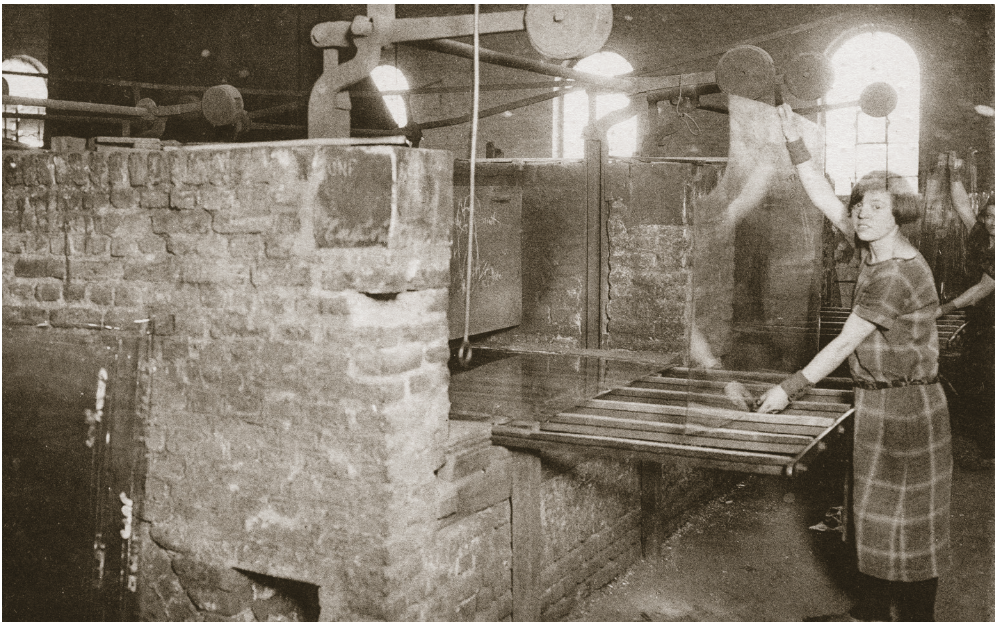
7 Placing glass cylinders into the annealing kiln, late 19th or early 20th century, Belgium, photographer unknown.

principle was introduced in Belgium earlier than in England, or at least simultaneously.[47] Plans of factories from the 1840s indicate the rate of introduction of these new annealing kilns. They show us elongated annealing kilns. The elongated form is typical for an annealing tunnel and points to the adaptation of the new technology.[48]

The next major improvement to the annealing kiln was made in 1867 by Désiré Biévez (dates unknown), an engineer at the Mariemont glass factory.[49] Due to a sophisticated system of 'moving stones' that transported glass through the annealing tunnel, this annealing kiln allowed the annealing time to be reduced drastically, from 7–8 hours to only 25–30 minutes. The system of 'moving stones' combined the functions of the turning stones and conveyor belt of the older types of annealing kilns, thus facilitating the transport of glass within the kiln (Figs 7 and 8). This annealing kiln replaced all other types.[50] In 1872, it was adapted to the use of gas as fuel instead of coal by the Belgian glass manufacturer Casimir Lambert (1827–1896).[51]

Conclusion

The Belgian window-glass industry in the 19th century is characterized by numerous innovations. The argument often made that the Belgian glass industry was backward, because steam power was used there only to a limited extent, seems inappropriate. In fact, mechanical energy through steam power had little use in this industry. Due to the specific character of the industry, the effective usage of thermal energy was much more important. Most inventions were therefore directed towards developing annealing kilns and melting furnaces.



8 Taking flattened glass out of the annealing kiln, late 19th or early 20th century, Belgium, photographer unknown.

The developments made in this field present us with instances of technological creativity. The basic principles may have been ‘borrowed’, such as had been the case for the principles of the regenerative and tank furnaces invented in England (Siemens), or of turning stones and turning stones / annealing tunnel in France (Bontemps and Hütter), but developments in Belgium made them suitable for productive use through improvements made in Belgium. Unlike the picture found in the existing literature, which presents inventions such as the Biévez annealing kiln or tank furnace as isolated and singular, albeit important facts, the present paper shows that improvements were made over longer periods of time. Long waves of innovative activity are a much better representation of technological development than a few isolated milestones. In other words, the process of technological innovation evolved as a result of the contributions of many actors (inventors and entrepreneurs), all of whom lived and worked within the Charleroi region as part of the glass-making community.

The following table sets out these waves of innovative activity.

Piece of equipment or Production step	Period	Kind of innovation
Melting furnace	1643 – before 1800	Adaptation to coal
Annealing kiln	c.1830 – c.1870	Adaptation to coal, development of ‘turning stones’ and ‘annealing tunnel’, adaptation to gas
Melting furnace	c.1870 – c.1890	Adaptation to gas, tank instead of pots

As for skills and craftsmanship, they remained of paramount importance for the window-glass industry until the expansion of mechanical production after the First World War. The long-established community of highly skilled glass-workers was one of the most important advantages of the Belgian window-glass industry. All in all, the Belgian 19th-century window-glass industry was a truly hybrid one, in which traditional craft skills went hand in hand with a never ceasing stream of technological creativity and innovation.

1 Douxchamps 1951, 512; Engen 1989, 194; Chambon 1955, 198.
2 Delaet 1986, 113–30.
3 Hilaire-Pérez/Verna 2006.
4 Poty/Delaet 1986, 20–29.
5 Close 1928.
6 Caen 2009, 129, 230, 239–40; Poty/Delaet 1986, 20–42.
7 Poty/Delaet 1986, 76–78.
8 On the development of furnaces by Siemens brothers, see Cable 2013.
9 Journal de Charleroi 1874.
10 Revue belge des industries verrières 1930.
11 For example: AGR-2, brevets, nos. 52563 (1880), 61792 (1883), and 69954 (1885).
12 Darquennes/Gobbe 2003, 369–78; Darquennes/Gobbe 2006, 166–67.
13 Stanier 1870.
14 Poty/Delaet 1986, 72; Journal de Charleroi 1852.
15 Office du travail, 1900–1902, vol. XV, cadre XIII, 30–31.
16 For example: AGR-Mines, no. 776, dossier 1671, and no. 778, dossier 582.
17 AvCh, Etablissements, DA, BT 22, dossier no. 698, and Etablissements JU, BT 110, dossier no. 3379.
18 AvCh, Etablissements, JU, BT 110, dossier no. 3379.
19 MdV, Verrerie des Piges.
20 Chopinet 2019.
21 Lefèbvre 1938, 22; Cable 2020.
22 D’Hainaut 1980.
23 AGR-Mines, no. 776, dossier 712; no. 778, dossier Verrerie Delobel.
24 Chopinet 2012, 2019; Cable 1999–2000; Fabrication et travail 1907, 52–54.
25 Drèze 1913, 446; MdV, Verreries Charleroi 8914/161/57 and 8914/161/59, ‘Les verreries Bennert & Bivort’.
26 De Luynes 1875, 28.
27 Chopinet 2012, 2019; Cable 1999–2000; Krupa/Heawood 2002.
28 Revue belge des industries verrières 1930; Chambon 1969, 42–44; Drèze 1913, 450; Journal de Charleroi 1920.
29 Chambon 1969, 44.
30 Damour 1896, 138–39; Linet 1888.
31 Damour 1896, 138–39; Chambon 1969, 46.
32 Engen 1989, 197.
33 Cable 1999–2000.
34 Poty/Delaet 1986, 125–54; Delaet 1986, 125–26.
35 Olyslager 1947, 145–46.
36 Lefèbvre 1938, 52–54; Engen 1989, 195.
37 Poty/Delaet 1986, 47–49; Drèze 1913, 450–53.
38 For example, AGR-Mines, no. 776, dossier 712; no. 778, dossier Verrerie Delobel; no. 777, dossier 1669.
39 AGR-2, brevets, brevet AC 1408; brevet AC 2148.

40 AGR-Mines, no. 778, dossier 2859.
41 AGR-Mines, no. 777, dossier 2899.
42 For example: AGR-Mines, no. 777, dossier 1722.
43 Poty/Delaet 1986, 47–49; Drèze 1913, 450–53.
44 Bontemps 1868, 286.
45 Poty/Delaet 1986, 49.
46 Bontemps 1868, 286–88.
47 AGR-2, brevets, brevet AC 878, AC 1133, AC 1408, AC 1428.
48 AGR-Mines, cartes et plans, AK3648, AK3641.
49 Poty/Delaet 1986, 49; Engen 1989, 195.
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