



THE CHANCE CONNECTION

DEVELOPMENT OF THE DIOPTRIC LIGHTHOUSE LENS – PART I

By Toby Chance

This two-part article is an abbreviated excerpt from the book Toby has written with Peter Williams entitled: *Lighthouses – The Race to Illuminate the World*.

If you would like more information about purchasing the book, please go to: <www.amazon.com>.

The Chance Family – Glassmakers

Readers of *The Keeper's Log* have had occasional glimpses into the Chance lighthouse heritage, thanks to the painstaking research of Thomas Tag and other members of the Lens Committee. A Chance lens sits atop one of America's best known lighthouses, Heceta Head in Oregon, and recently the Ponce Inlet lighthouse museum in Florida has restored a 4th order Chance lens sourced from Australia, now on display among many other beautiful examples of maritime design engineering.

What few readers will know is how Chance Brothers became first the largest glassmaker in England (a position they lost to Pilkington's in the 1870s) and later dominated lighthouse lens manufacture for 100 years, their lenses found in close to eighty countries in every corner of the globe. As the great great grandson of Sir James Timmins Chance, who made the firm's first lens and was created a baronet by Queen Victoria for services to the seafarer in 1901, I have privileged access to the family records which document how this came about. These formed a vital source for my book, *Lighthouses: The Race to Illuminate the World*, co-authored with Peter Williams was published by New Holland in October, 2008. The book reexamines lighthouse history from the perspective of lighthouse illumination technology and explains how lighthouses became a "tool of empire" alongside the steamship, telegraph and railway.



Robert Lucas Chance, known as Lucas.

When the US Lighthouse Service began to replace their old reflector apparatus in numbers, from the 1850s, Chance Brothers of Birmingham, England, was the sole manufacturer of dioptric lenses outside France. The firm only produced their first lens in 1851, for the Great Exhibition at Crystal Palace in Hyde Park, London, so it is perhaps unsurprising that the US authorities sourced most of their lenses from France, home of the dioptric lens since Augustin Fresnel's first lens was installed in Cordouan lighthouse in 1823. It is hard to be certain how many Chance lenses found their way into US lighthouses, but they never made up more than a few per cent of the hundreds installed around the US coastline, the largest market for dioptric lenses and a prof-



James T. Chance at age 40.

itable one for the likes of Henri Lepaute and BBT. That so few Chance lenses went to the US is one of the ironies of lighthouse history, given the strong commercial ties between America and England.

The relative failure of Chance Brothers to penetrate the US market can be ascribed to the fact that in the mid 19th century Trinity House, Britain's senior lighthouse authority, was stuck in a guild mentality, insensitive to the needs of business, whereas its French counterpart did everything in its power to promote the interests of home-grown technology when new customers came knocking at the door. Chance Brothers prospered because of the determination of its partners to create a new product for its glassworks and because of

its extensive network of agents in the British Empire. By the time the firm beat the French at their own game, winning the Grand Prix for their lenses at the 1867 Paris Exhibition, French lenses were the de facto standard in the US so Chance Brothers was forced to look elsewhere to boost its output. Success eventually came, the firm becoming the world's leading supplier of 1st to 5th order lenses, turning out over 2000 apparatus between 1851 and their centenary, the longest continual manufacture of lenses from one firm.

The Chance family parallels British history as the country evolved from an isolated agrarian society into one of the Great Powers of the 19th and 20th centuries and then shed its empire after World War II as technological change and competition left it behind. Likewise, over the same period, the Chance's rose from yeoman farmers to industrialists employing thousands of workers and then to membership of the British establishment before sliding again into relative obscurity, overtaken by more aggressive and accomplished rivals. Every great industrial family is associated with a single product or service – think of Carnegie steel, Rothschild banking, Sony electronics. In 19th and most of 20th century Britain, the name Chance was synonymous with glass and it was from their mastery of the art of glass-making that the Chance family's fame and fortune were derived. Glass products of every description were made at the Chance works, from sheet glass for windows, optical glass for scientific instruments, cameras and gun sights, stained glass for churches to pressed glass for domestic tableware and – of course – glass for dioptric lighthouse lenses.

Chance Brothers: The Founding of a Dynasty

This is the state of the glass business in England at the time when Robert Lucas Chance (known as Lucas Chance) bought the British Crown Glass Company at Spon Lane in Smethwick near Birmingham in 1822:

The Spon Lane works, started in 1814, had one crown-glass furnace, situated next to the old Birmingham-Wolverhampton canal. Coal and other raw materials were transported to the works and glass was shipped to Birmingham and London via the canal. Lucas Chance was 40 years old and had more than 28 years in the glass trade under his belt. At age 14 he was already managing his father, William Chance's, trading business in Birmingham.

The family's connections with glass dated to 1788 when John Robert Lucas, Lucas Chance's mother's brother, invested the proceeds from the sale of a beer and cider business in the erection of a crown glasshouse at Nailsea, a village some eight miles (12.8km) south-west of Bristol where there were local coal pits and limestone quarries. John Robert Lucas' sister Sarah had married William Chance and William became John Robert Lucas' partner in 1790, bringing in extra capital for the building of another glass furnace as business expanded. William had entered business in 1771, at age 21, with his other brother-in-law Edward Homer, with whom he started an iron-factoring business (a merchant focusing on inland trade) in Birmingham. Profits from the business, and the sale of Canal shares that he had accumulated, enabled Chance and Homer to contribute the large sum of £10,000 to enter into partnership with Lucas.

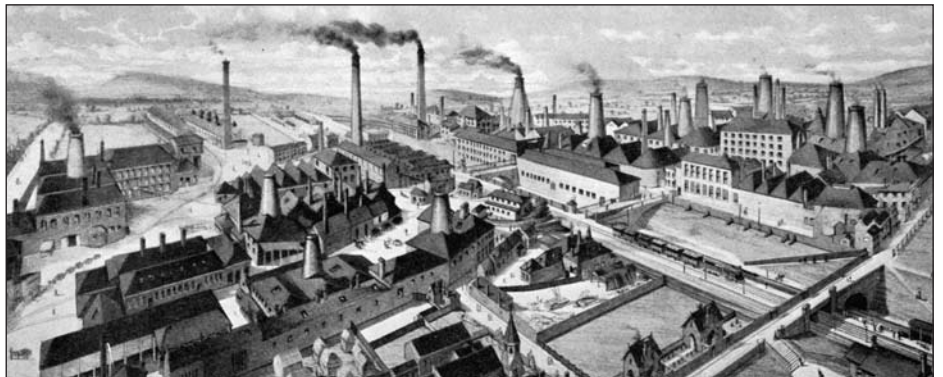
Lucas Chance was William and Sarah Chance's eldest son. He became a partner in the Nailsea business on reaching the age of 21 in 1803, and in 1810 he was given full management responsibility for the works. Continuing the family ties he married Edward Homer's daughter Louisa in 1811. He soon encountered problems with the management and went in search of new blood, reputedly finding the manager of the Dumbarton glassworks, John Hartley, in bed and, pulling him out, convinced him to come and run his works. He now had "the leading crown-glass expert in the country" to keep things in order. Lucas left Nailsea in 1815 for London, where he established himself as a glass merchant specializing in window glass and its export to North America in particular. He sold his share in the Nailsea partnership and William Chance himself retired as a partner in 1821.

Lucas Chance's energy and determination led him rapidly to expand the business and he soon opened a warehouse in Snow Hill, Birmingham, where he traded under the name "The Bristol and Dumbarton Window Glass Warehouse". For a few years, he extended his partnership to include John Dixon who owned the Dumbarton works, and this, together with Nailsea, provided the crown glass for trading. By 1822, Lucas Chance realized he needed his own source of glass, enabling him to control both the price and the quality of glass for his trading business. His entrepreneurial instincts were coming to the fore. Finding a suitable works near his Birmingham warehouse he purchased the Spon Lane glass works mentioned above for £24,000, of which £8,000 was for the freehold. Lacking his own cash resources he borrowed from members of his family, including his younger brother William, James Chance's father. Though still living in London, Lucas Chance frequently travelled to Smethwick by coach, sometimes travelling by night and returning the following night.

Lucas Chance erected a second glasshouse in 1824 and a third in 1828, in which year he also brought John Hartley to Smethwick to help manage the business after Hartley had severed his ties with Nailsea. With his elder son James, Hartley contributed the sum of £4,000 to the partnership and Lucas was ebullient. He wrote to his brother Henry, a barrister at Lincoln's Inn:

I have been so often disappointed, that I do not dare to calculate on any thing, but the probabilities are, that I shall establish on a solid basis a manufactory that will be a credit to the family, and perhaps to the neighbourhood, with an income sufficient to make all my sons glass manufacturers.

Lucas' ambitions stretched nationally and globally. He wanted to perfect the quality of his glass as Wedgwood had done with pottery. "Moreover", as Isobel Armstrong points out in



Spon Lane Glassworks in 1857.

her book *Victorian Glassworlds*, “he had two further liberal ambitions, to create and define a truly modern glass manufactory as a civic achievement, and, as a corollary, to create new technologies of the highest scientific order. This was the modern idea played out in the making of glass.”

Lucas’ emphasis on science was very unusual in British manufacturing at that time. He referred to it in his valedictory speech on leaving the glassworks in 1860. It was chiefly responsible for the succession of experts, first French and Belgian then British (notably his nephew James), that Chance Brothers brought to the firm over its 150-year existence, giving it a leadership position in glass technology, mechanical and finally electrical engineering.

Lucas’ financial situation began to deteriorate when the cost of servicing the mortgage on the property and the expansion left him in financial difficulties. This was exacerbated by the depression in the glass business in the late 1820s due to the punitive excise duties and fierce competition from the French and German manufacturers. Fortunately he was able to call on the support of his brother William, who took over the freehold of the property and contributed capital to keep the works open. William also assumed responsibility for running the factoring business in Birmingham, which traded with a third brother, George, who had relocated in New York to supply growing demand in America.

James Chance – Natural Philosopher and Businessman

James Chance, Lucas’ nephew, is perhaps the single most important character in this story, so it is worthwhile to get to know him in depth. James Chance’s education and choice of career exemplify how the cultural norms of the early 19th century came into conflict with an individual’s natural talents and the expectations of family, which, in Chance’s case, owned one of the largest industrial enterprises in Britain. Chance was one of the first English natural philosophers to apply his scientific and mathematical knowledge to a practical end. Schooled in the Hellenic tradition, which separated science from crafts and technical matters, Chance had the advantage of belonging to a family with an intellectual tradition that allowed that science could be useful. His Cambridge education gave him a sound grounding in science, while the family’s glassworks offered him a rare opportunity to apply it to the realm of business.

James Chance’s letters and lectures during the 1840s contain clear signs of his fascination with optics, mechanics and the theories of light. But they also point to an understanding of how these could be applied to the design and manufacture of useful instruments, as well as the improvement of processes that would benefit the family firm. Chance’s fascination was understandable given that his family’s business was the manufacture of glass. The behaviour of light had for centuries absorbed great minds because it combined pure speculation about the properties of invisible matter with the need to devise and engineer very precise instruments to observe and measure this matter. James Chance delivered his lectures on light before he built his first lighthouse lens, but he had already been admitted as Chance Brothers’ third partner in 1840, when the firm was just beginning to experiment with the manufacture of optical glass, probably the most technically complex form of glass. James’ progress from school to partnership in the family business did not follow a straight path, however. It was uncertain whether the attractions of law, the church, academia or business would eventually lure him. Fortunately for lighthouse engineering, the ties of family and business proved too strong to resist.

James Timmins Chance was born in London in 1814, the eldest son and one of 11 children born to William and Phoebe Chance. Phoebe was the daughter of James Timmins, head of another prominent local family from the Midlands where the Chance’s had originated. While at Totteridge School near Mill Hill north of London James received several awards of learned books, which give a fascinating peep into his prodigious academic attainments and the challenge he faced later when deciding on what career to pursue. Clearly James’ interest in the relations between science and religion were being encouraged from an early age. As a young student at London University (now University College, London) James’ academic achievements and affection for a catholic education continued.

Perhaps most interesting of all, in view of his choice of lighthouse engineering as his driver and passion, is his award of *A System of Mechanical Philosophy* by John Robison LL.D. by the University of London in 1830, as first prize in the class of Natural Philosophy. By a twist of fate the book, published in 1822, includes notes by Sir David Brewster and was published in

the same year that Augustin Fresnel released his paper *Memoire sur un Nouveau Systeme d’Eclairage der Phares*.

James must have been aware of the controversy raging at the time about the status of science and its application to practical matters of manufacture and business. In the Regency years in England, a career that applied the physical sciences to business was still considered inferior to holy orders, the armed services or the law. James was still young and in no hurry to make a career decision yet. His shifting predilections between law, academia and business continued for the next eight years.

James received the First Certificate and Highest Prize at the London University in 1831. Between his graduation in 1832 at the tender age of eighteen and his eventual admittance as the third partner in Chance Brothers in 1840, there were some agonizing years of indecision. He first tried his hand in his father’s merchant business for a brief spell in 1831, but he soon looked elsewhere for fulfilment. On 7 July 1832 his uncle, Henry Chance, wrote to him offering advice on what course of law would be suitable were he to choose that career. As a barrister at Lincoln’s Inn, Henry knew that a career at the Bar would bring distinction to his clever nephew but never pressed him too hard to follow his example. A few weeks later while at home at Spring Grove in Birmingham, James received another letter, dated 24 July from his tutor at University College, Augustus de Morgan, congratulating him on deciding to go to Cambridge and advising Trinity College for mathematics and the chance of a fellowship. On 16 December de Morgan followed this with another letter advising James to select Mr. Higginson as his mathematics tutor in preference to Mr. Whewell (one of Brewster’s adversaries) or Mr. Peacock. “He is not as well known to the world as either of the other two but I know from experience that I received a great deal more attention from him than I should have received from the others.” In taking de Morgan’s advice, James turned down the opportunity of being tutored by one or another of Cambridge’s most celebrated mathematicians, preferring the man with more interest in his pupils than himself. It was an early sign that James opted for what he considered of genuine value rather than personal celebrity.

James commenced his studies at Trinity in 1833 on a Foundation Scholarship and set himself the highest possible targets. Though ini-

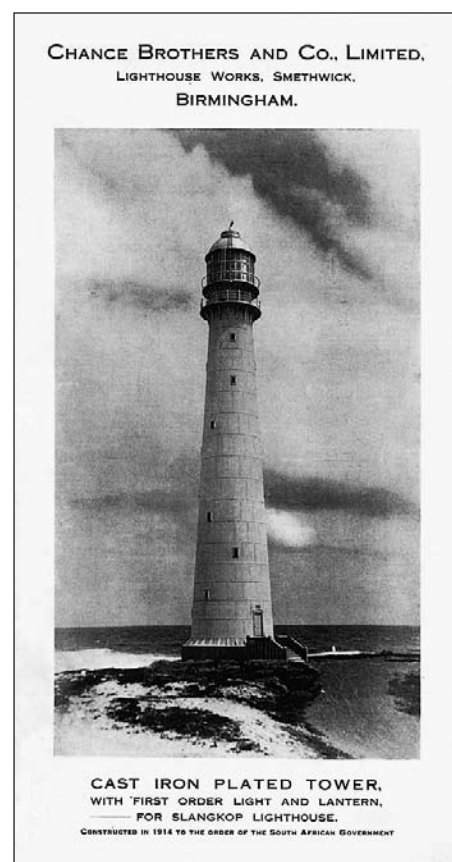
tially enrolling for the Mathematics Tripos he soon shifted to theology, with the intention of taking holy orders after graduation. His ambitious work programme led to a prolonged period of insomnia brought about through overwork and in 1836, after attaining a First-class pass in theology, he was forced to take a year off to recover his health. That was also the year he, along with his elder sister Eliza and younger sister and brother Sarah and George, went on their Grand Tour of Europe, something that many members of the leisured classes undertook to broaden their cultural education. The exhilaration of travel restored James' energy and zest for life and temporarily put him off the closeted atmosphere at Cambridge for, in November that year, he was admitted a student of Lincoln's Inn to become a barrister. This was the passing whim, however, of a restless and indecisive young man, and to the exasperation of his barrister uncle Henry and the delight of his father he soon returned to Trinity to complete the mathematics degree as he had originally intended. After graduating as seventh Wrangler in 1838 (seventh-top mathematician in his year at Cambridge), James' tutors and mentors immediately saw a glittering career for him in whatever field he chose to pursue.

It was at this time that he filed the patent for his ingenious method of grinding and polishing glass, spending many months perfecting his designs for the machinery. This new product, which confusingly he called Patent Plate (for it was not plate glass but sheet glass) was "just the thing for coach windows, for glazing oil paintings and engravings, for ornamental mirrors and later for photographic plates." Nearly 25 years later, the *Illustrated Times* saw fit to draw readers' attention to this process, for it still formed the basis of Chance's leadership in. It seemed James' course was decided and that the pull of the family business was too much for him to resist. But back at Cambridge he had not been forgotten. On 18 September 1840, John A. Frere wrote to James at Spring Grove imploring him not to pass up the opportunity to write the fellowship exam for Trinity College, which came up a few weeks later. His heart not really in it, however; James travelled to Cambridge to sit the exam and narrowly missed out on the fellowship, several of his less-talented contemporaries winning places ahead of him.

It was the first time he had failed something so important in his life. His mathematics tutor, and the man who coached him in the months leading up to the exam, J. W. Blakesley,

wrote James a consoling letter on 15 October regretting his bad luck and blaming it on ill health and his decision to spend time on other pursuits. He hit the nail on the head. James Chance suffered from the burden that befalls men of many talents who are frequently faced with a well-nigh impossible decision – which way to go in life? He might have become anything from a bishop, a law lord to Master of a Cambridge college. First a natural philosopher, then a mathematician, a theological student, then a lawyer, then back to being a mathematician before turning his attention to design engineering and finally a half-hearted attempt at academia, James Chance ended up where destiny had perhaps intended him in the first place, ever since growing up among the machines and excitement of the family glass business in Smethwick. Had James put all his efforts into the fellowship there is little doubt he would have won it, and the history of lighthouse engineering and glass manufacture would have been very different.

James Chance stood out among the Wranglers of his day as one of the tiny fraction who went into business. Of the 300 Wranglers who graduated in the top 10 at Cambridge between



The First Order Lens at Slangkop in South Africa. Photo by the author.

1830 and 1860 only 3.3 per cent chose business as a career. A third entered the Church, nearly a half went into higher or secondary education, a fifth into the professions (mainly law) the remaining three per cent deciding on a career

in government administration. It is very surprising in the 21st century to find mathematicians eschewing their educational background for totally unrelated careers, but this was the norm in Chance's time at Cambridge.

James Chance's choice of a little-trodden career path was contrary to accepted norms. Had Chance Brothers been an unremarkable firm and James not excelled here he would have sunk into obscurity and probably lost touch with his university friends, who had almost no contact with the manufacturing classes. The intermarriage of members of prominent families was a way of helping to secure the line, with nephews and brothers-in-law being regarded as the next best thing when blood sons were in short supply. What is indisputable is that James Chance changed the course of lighthouse history by following his father and uncle into business rather than choosing a career as a barrister like his other uncle Henry, an academic (and later priest) like his friend Richard Ferguson, or a priest like his other friend Thomas Ferguson.

Georges Bontemps and Optical Glass

Chance Brother's decision to manufacture lighthouse lenses in the mid-1840s and its later industrialization of the process, came about through a number of interrelated factors. The French connection played an important role, for it was the employment first of George Bontemps and later M. Tabouret that enabled Lucas, and later James, Chance first to master the science and manufacture of optical glass and then to adapt this to the making of dioptric lenses. Another factor was James Chance's mathematical and engineering ability, which placed him and the firm in a unique position in Britain to absorb and adapt the Fresnel lens into the glass works. Yet another was the sheer scale of the Chance Brothers' enterprise, which supplied the capital and engineering resources required to enter a branch of manufacture that had defeated Cookson's and led to their acquisition by Swinburne in 1845. Bontemps' influence is felt here too, for it was his expertise in sheet glassmaking that enabled Chance to take the lead in what was the biggest money spinner for the firm in the 1840s and 1850s, especially after excise duty was abolished in 1845 and James Chance patented his new method of grinding and polishing the glass to give it the lustre and fine surface of the best-quality plate glass at a far lower cost.

Lucas Chance heard about Bontemps' developments and in 1832 Bontemps sent the first contingent of French and Belgian workers to Chance Brothers, comprising

blowers, gatherers, cutters and flatteners, who were at first employed in introducing sheet-glass manufacture at the Spon Lane works. In 1837, Bontemps and Chance reached an agreement in which Chance agreed to purchase the rights to Bontemps' manufacturing techniques for optical glass in return for five-twelfths of the profits, with five going to Chance Brothers and the rest to M. Claudet, a partner of Bontemps. The purchase price was 3,000 francs, but it would only be paid once the firm had realized that sum for itself. In 1838, using the furnace installed in Smethwick a year earlier, Lucas Chance took out the English patent for the process. Lucas and James Chance made extensive use of patents to protect their inventions. In England patent law was recognized as an important source of competitive advantage. Bontemps, however, was sceptical of patents, and wrote to Lucas on 7 August 1844 that, "A patent in general is fit only for an inventor, who has no manufactory of his own, and who wishes to sell the use of his invention." In this instance he clearly took the position of an inventor and not a manufacturer.

Lucas' proclivity for taking on new products and processes met with opposition from his brother William and nephew James. Some heated correspondence ensued when, in 1840, Lucas invited Bontemps to come to England "to perfect the optical glass" and bring some more workmen with him from France. While Lucas was in Ireland, William wrote expressing his "most decided opposition". He explained his reasons as "the vital importance to our concern, that while we are carrying on our present important operations, our attention and that of our managers should not be distracted in the slightest degree by any new operation." Just at that time Chance Brothers were engaged in what, to Lucas, was the more important job of perfecting sheet glass manufacture and he certainly did not want Bontemps to get his hands on it, for Bontemps was still competing with Chance Brothers in the production of sheet glass. Even though father and son eventually prevailed, Bontemps was later able to produce glass of sufficient quality for its fabrication into microscope slides – the first optical glass produced by Chance Brothers and an important breakthrough.

Bontemps returned to France; but in 1848 he was forced out again by the Revolution and reached agreement with Chance Brothers to "devote his exclusive services to the firm, to

superintend the Coloured and Ornamental Depts., generally to advise and assist in the optical glass business, and to carry out the manufacture of Optical Glass in accordance with Lucas Chance's patent of 1838." Bontemps was to be paid £500 a year, five-twelfths of the profits of the optical department and one tenth of those of the ornamental department. A new furnace was built which was immediately set to work on the output of "Hard Crown" and "Dense Flint" for telescopes, and "Soft Crown" and "Light Flint" for camera lenses. In 1849 Bontemps obtained orders from London opticians as well as from Austria and Germany, where he spent an extended visit in 1850. Bontemps was "happy to mention their unanimous approbation of the glass they received," and "one of the most competent, Mr. A. Ross, says that our Flint Glass is even superior to the Swiss Flint, not being altered so easily by the atmosphere. As for the British Flint plate, they confess our Light Flint is superior by far." Chance Brothers' optical glass business was now established and had a foothold on the world market, competing mainly with Germany in lenses for optical instruments and spectacles and later with France in dioptric lenses.

The contrasting fortunes of the Royal Society and Chance Brothers' optical glass endeavours shows that new technologies were developed in England mainly because of the ingenuity and determination of private enterprise rather than through sponsorship by government-funded institutions or their academic counterparts. The celebrated case of John Harrison's manufacture of the first clock to accurately calculate longitude, despite being overlooked and positively discriminated against by the same Board of Longitude that sponsored Faraday's failed efforts to produce optical glass 50 years later, is perhaps the best known example of this dynamic. Both cases illustrate the uneasy relationship between industry, government and the scientific establishment that existed in England. Professional scientists resided outside industry and it was left to men of vision such as Lucas Chance to source the expertise he needed from wherever he could find it – in this case, ironically, France – to accomplish his goal. He was fortunate in having a nephew with the skills to use the firm's glassmaking expertise in a specific industrial application. James Chance was an early case of a scientist applying his skills within a business context

and his and Chance Brothers' achievement in becoming the world's dominant manufacturer of the highly complex lighthouse lens through his scientific accomplishment is an important example that historians of science and technology in Britain have overlooked.

Brewster Visits Chance Brothers

With the British lighthouse question being far from settled to his satisfaction, in 1844 Sir David Brewster visited the Chance works and examined samples of their optical glass. He was impressed with its quality and the absence of striations, which would adversely affect the refractive qualities of the glass. James Chance later sent Brewster a few sample lenses by post. On receiving them Brewster replied, suggesting that Chance apply his knowledge of optical glass to the construction of a lighthouse lens:

January 4th 1845

My Dear Sir,

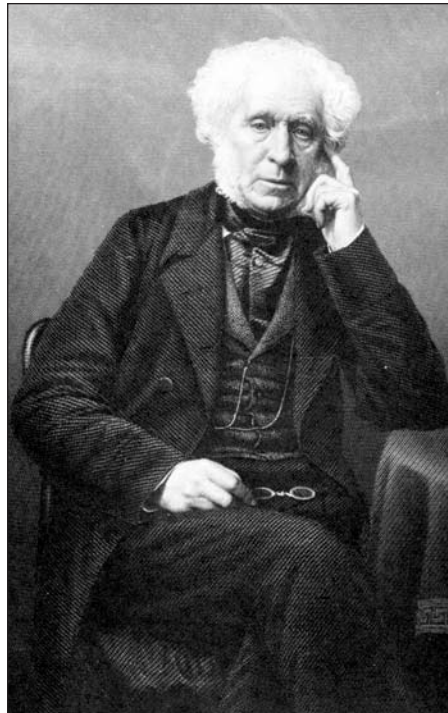
Owing to the impracticality of the Heavens at this season of the year, I received only five days ago the box of plates of ground glass which you have been so kind as to prepare and send me. They are singularly fine, and I could scarcely have considered it possible to execute such perfect surfaces.

I cannot recall that I mentioned to you that the Messrs. Cooksons at Newcastle had not succeeded in executing to the satisfaction of Mr. Alan Stevenson, the engineer for Scottish Lighthouses, the Polyzonal lenses ordered and that he was obliged (or preferred) to have them executed in France.

I cannot doubt from what I saw of your works that you could overcome the difficulties which have been insurmountable by them, and that the process of manufacturing lenses would be both an interesting and profitable addition to your Establishment.

*I am, my Dear Sir
Most truly yours
David Brewster
St. Leonards College
St. Andrews*

Brewster makes plain his admiration for the quality of the glass lenses Chance had sent him. After 14 years Cookson's had given up trying to make optical-quality glass for lighthouses. Where else was he to turn to eliminate British dependency on French suppliers? He was obsessed with the idea that a British



Sir David Brewster

firm should take up the task of making dioptric lenses and Chance Brothers had shown they could do it, technically at least. In his 1862 paper on the history of dioptric lenses, he concludes with a glowing salute to the firm. "He had frequently visited" he wrote, referring to himself in the third person:

...the great glass works of the Messrs. Chance at Smethwick, and was acquainted with their admirable methods of making the finest flint glass, and various articles of which glass was the material. He therefore put himself in communication with these gentlemen, and finding that they were willing to incur any expense in preparing for the most extensive manufacture of the Dioptric apparatus, he proposed that means should be taken to induce the Government to carry into effect the conversion of the Reflecting into the Dioptric system. Sir D. Brewster, therefore, met Mr. Chance in London, for the purpose of taking the advice of one of the most eminent scientific counsel. The opinion of that gentleman did not encourage the parties to prosecute their plan. He concurred with them in regarding the contemplated reform as one of the highest importance; but he thought that, considering the state of the finances, and the indifference with which all questions of science were viewed by public men, there was little probability of gaining the object they had at heart. The Messrs. Chance, however, were not discouraged by this opinion. They provided the means of manufacturing the Dioptric apparatus,

and they sent to the Great Exhibition of 1851, a specimen of a revolving light of the first order, which met with the highest approbation. Since that time they have devoted themselves to the same work, and we are confident that the time is not distant when their Dioptric Lights will be in general demand from every part of the world.

It is tantalizing to speculate who was the "eminent scientific counsel" to whom Brewster referred. It was probably Michael Faraday, but we cannot be certain. Brewster returns to his favourite gripe about the lowly position of science in the minds of public men and applauds Chance Brothers for taking on the task in the face of official disinterest. The "Mr. Chance" Brewster mentioned was Lucas Chance, James Chance's uncle, the founder of Chance Brothers and the driver behind the firm's move into lighthouse lens manufacture. Lucas saw a potential gap in the market for glass, and optical glass for lighthouses carried a price premium that attracted him. He instinctively knew he would succeed where Cookson's had failed. It was only later that Lucas Chance persuaded his nephew James to dedicate his considerable mathematical and technical skills to taking control of lens manufacture at the firm.

The subtext of Brewster's 1845 letter and 1862 paper is that glass manufacture, and glass lens manufacture in particular, is extremely difficult. Glass has properties – its chemical composition, optical quality and workability – that were little understood at that time and only a handful of firms – all of them in France – had tried to make glass of satisfactory quality suitable for dioptric lenses. Chance Brothers was the only manufacturer in Great Britain to succeed.

Optical glass is the most difficult of all glass types to make, being cast in specially fabricated moulds rather than blown; which was how ordinary table or window glass was made. The most important characteristic is homogeneity, meaning the glass must have the same composition throughout its mass, otherwise the light rays that pass through it will not have the same refractive behaviour as predicted in optical theory. Chance Brothers was the sole British manufacturer of optical-quality glass from 1838, when Lucas Chance introduced it, until the start of the First World War, when supplies from Germany ceased completely and government pressure encouraged a few other firms to come to market. From a sideline product it suddenly became

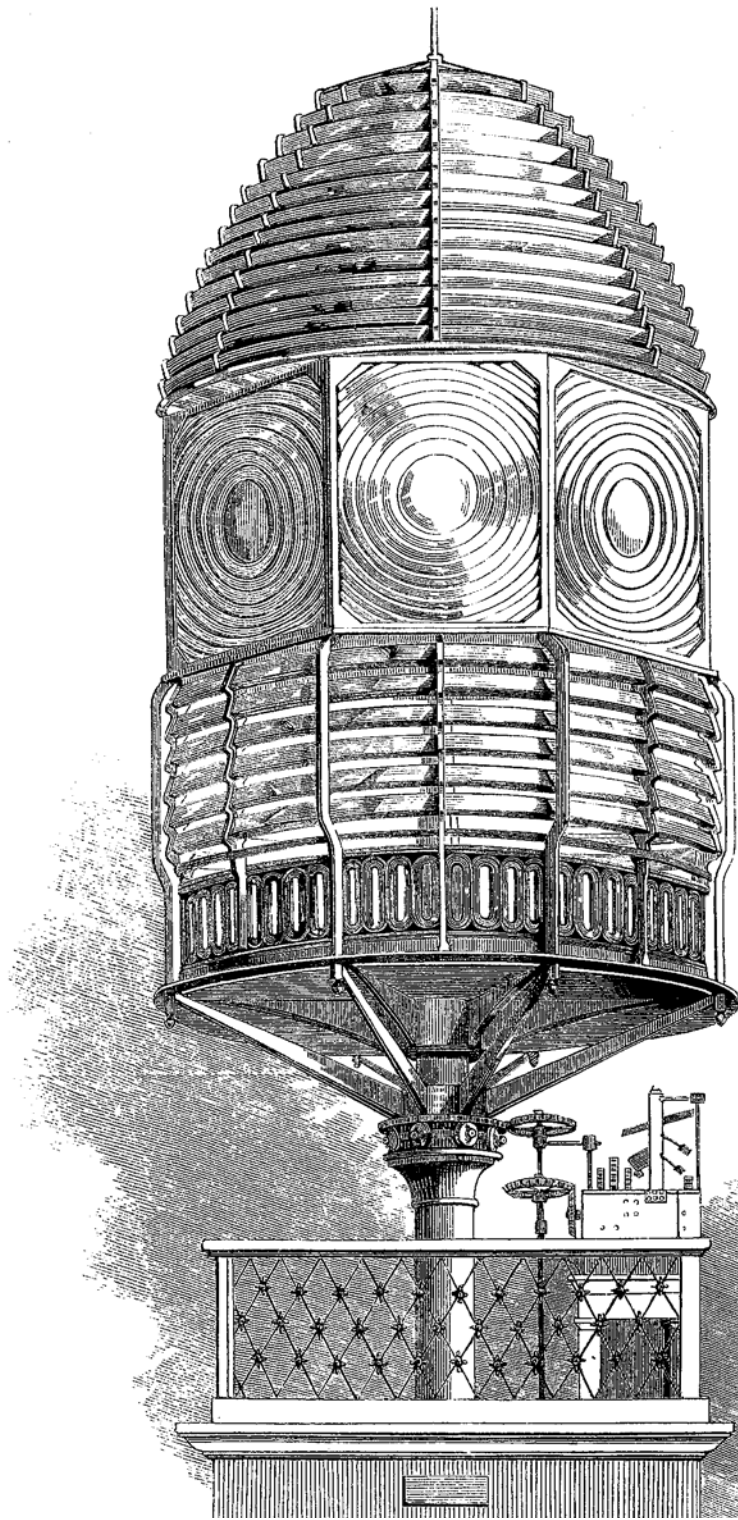
critical to the nation for use in gun sights, field glasses, cameras and other military applications. Output of optical glass at Chance Brothers alone rose from 2,600lbs (1179kg) in the first half of 1914 to 92,000lbs (41732kg) in the second half of 1918, an incredible near-40-fold increase.

The Crystal Palace

Just at the time that Bontemps had perfected Chance Brother's processes for manufacturing optical glass, the biggest commercial opportunity in the firm's history presented itself. This was the contract to glaze the Crystal Palace, which housed the Great Exhibition of 1851. The Exhibition was a chance not just to make a lot of money by supplying the glass, but also to exhibit the firm's vast array of glass products to the biggest trade and consumer market yet assembled in one place. The exhibition was also the stage for the firm to display their first dioptric lighthouse apparatus.

Two contemporary images illustrated these two facets of Chance Brothers' presence at the Great Exhibition. H. C. Selous' painting of the Royal opening on 1 May, now housed in the Victoria and Albert Museum, depicts in detail the faces of all the important personalities that had a role in the Exhibition. Leaning against one of the steel columns on the first floor and hardly visible among the assembled visitors is Lucas Chance, his quizzical expression suggesting an aloofness from the grand proceedings. He looks down upon the royal group – Queen Victoria and her young family standing next to the proud Albert – all facing the members of the Royal Commission who basked in the glory of the occasion. The other image, a striking colour lithograph of the western, British nave of the Crystal Palace, forms part of *Dickinson's Comprehensive Pictures of the Great Exhibition*, published in 1854. It shows the lighthouse lens in the left foreground, adjoining the fountain and iron gazebo, all of which rose upwards towards the lattice of glass and steel that formed the roof of this immense structure. A girl is dressed in a crimson jacket and white bonnet, head tipped up and looking directly at the lens, as if transfixed by its mesmerizing collection of glass prisms.

Chance Brothers' role in the manufacture of the Crystal Palace was fundamental. Joseph Paxton deservedly takes main honours as designer and driver of the Palace construc-



Chance Brothers First Order Fresnel Lens exhibited at the Crystal Palace in 1851.

tion project. Fox and Henderson also feature prominently, as providers of the iron frame and as main contractors. But the Exhibition jurors themselves knew well the part played by Chance Brothers when they wrote:

The name of Chance occurs so frequently in the preceding observations, and is so honourably con-

nected with every branch of the manufacture, that we cannot but regret that, according to the regulations laid down by the Commissioners, their firm is precluded from entering into competition for the Medals by the fact of one of the partners having consented to act as a Member of our Jury. But though Mr. R. L. Chance is thus disqualified by his own



Crystal Palace showing Chance Brothers First Order lens on display. All glass for the entire building was supplied by Chance Brothers.

act, he has entitled himself still more to the consideration of the Jury by the valuable assistance which his practical experience and intimate knowledge of the details of the subjects committed to our investigations have enabled us to afford. When we witness the magnitude and variety of the operations undertaken by this firm, the merit of their works, the liberality, intelligence and spirit of the enterprise which they have manifested at great cost and risk in experiments tried for the purpose of introducing into this country branches of manufacture almost exclusively practiced by continental enterprises, – when we consider the advantage of inducing men so eminent in their occupation as M. Bontemps and M. Tabouret to settle in this country and superintend our works, – we feel that we should not act with justice by Messrs. Chance, or do our duty by the Commissioners and the public, if we did not call their attention, in a special manner, to the merits of the firm.

A series of fortunate circumstances led to Chance Brothers being awarded the contract. The firm was the only glass manufacturer in England with the capacity to produce the quan-

tity and quality of glass Paxton's design required and at the right price. France still possessed the largest source of glassblowers and Lucas Chance was forced to bring them over the Channel in large numbers to help with the enormous task of making the Crystal Palace glass without interfering with the factory's standard output. Joseph Paxton's design drew on his experience as the Duke of Devonshire's gardener at Chatsworth, where, between 1836 and 1841, he had built the Great Conservatory with 55,988 square ft (5201 square m) of sheet glass supplied by Chance Brothers.

On 29 June 1850 Paxton drew up an agreement between himself, Fox and Henderson and Lucas Chance. Fox and Henderson were to be the main contractors, with Chance supplying the glass. Chance had priced his bid only marginally below Hartley's of Sunderland (John Hartley was Lucas Chance's first partner in 1828 but in 1836 they had parted ways). Hartley proposed plate glass panes of 62in by 21in (157cm by 53cm), compared to Chance's sheet glass panes of 49in by 10in (124cm by 25cm), but Chance's were 50 per cent thinner and their lesser overall weight was considered more important than the reduced framing that the Hartley panes would have required.

Henry Cole – originator of the idea of the Great Exhibition and a Paxton enthusiast – came to Birmingham to secure the bid for the Fox–Henderson–Chance consortium, which was submitted to the Royal Commission. Opposition from no less an institution as *The Times* continued to dog Cole's mission, the paper dismissing Paxton's design as late as 15 July 1850 as a "monstrous greenhouse". But by mid-October Paxton was able to write to the Duke of Devonshire that "The glass palace is going very well, it begins to have the most imposing appearance, everyone who sees it appears to be delighted and astonished." *Punch*, which christened the building the "Crystal Palace" on 2nd November, turned its initial scepticism to fulsome if somewhat chiding praise. London was by now "100 per cent glass-conscious" and *Punch* even suggested, tongue in cheek, that the whole of London be put under a glass cover: "We shall be disappointed if the next generation of London children are not brought up like cucumbers under glass."

In his centenary book published in 1951, *Palace of Industry*, C. R. Fray noted that the Crystal Palace was one of the first examples of standardized production, with girders, columns, gutters and sash bars all being interchangeable.

This made it much easier to build the huge structure, for once the parts had been delivered to the Park they just needed to be assembled in situ like a huge Meccano kit. Charles Dickens, in *Household Words* in February 1851, remarked on the revolution in glass manufacturing that made the Crystal Palace more than a sketch on a piece of blotting paper. "The manufacture of plate glass adds another to the thousand and one instances of the advantages of unrestricted and unfettered trade." Dickens was referring to the tariffs on glass that were finally lifted in 1945:

The Excise incubi clogged the operations of the workmen, and prevented every sort of improvement in the manufacture. . . Nor could plate glass ever have been used for transparent flooring, or for door panels, or for a thousand other purposes to which it is now advantageously and economically applied.

The records of the Great Exhibition praised the glass exhibit, and particularly the plate glass and lighthouse optic:

The glass section was small, but the standard high. The industry had only come to life since the removal of the excise duty in 1845; Chance Brothers, the contractors of the glass for the Crystal Palace, were the only large makers, and they relied for much of their work on foreign labour.

By the time of the Great Exhibition, the firm was ready to show off the fruits of three years work on optical glass under Bontemps, including a 9in (22.8cm) achromatic lens (which, through the combination of flint and crown glass, produced a clear white light) and a 29in (73.6cm) disc of flint glass, 2.5in (6.3cm) thick weighing 200lbs (91kg). The Exhibition Jury awarded the latter a Council Medal (how it managed to do this with Lucas Chance being a member of the Jury is not recorded). The lens and disc were shown again at the 1855 Paris Exhibition where they aroused the admiration of Sir David Brewster. In his report to the Exhibition Commission, Brewster tried to persuade the British government to buy them and "construct the greatest achromatic telescope that was ever contemplated by the most sanguine astronomer." His recommendation was rejected, and the lens and the disc were bought by the French government for £1000 each. It was another five years before the British authorities, and Trinity House in particular, were sensitive to the need to promote British excellence in optical-glass manufacture. Brewster's frustrated admonitions of Britain's incapacity to apply its scientific endeavours for the benefit of manufacturing are once again evident.