THE CHANCE CONNECTION

Development of the Dioptric Lighthouse Lens – Part II

By Toby Chance

Chance Brothers' First Dioptric Lens

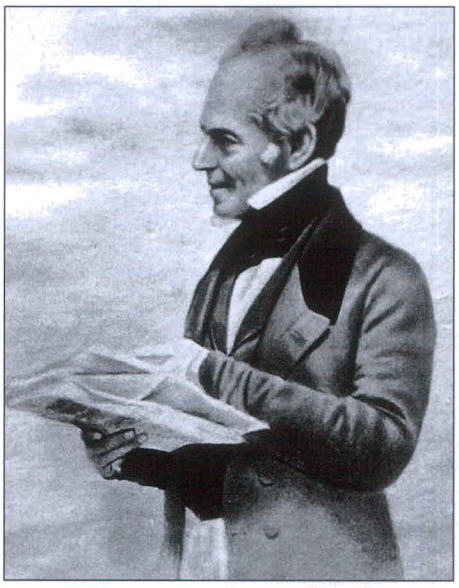
The coincidence of Lucas Chance's determination to expand the firm's glassmaking business into optical glass and lighthouse lens apparatus with his fixation on winning the contract to supply the glass for the Crystal Palace was pivotal for both Chance Brothers and lighthouse-lens manufacture in England. The glass for the Palace demonstrated Chance Brothers' position as England's foremost glassmaker, applying techniques of standardized production that marked them as one of the first manufacturers of the Second Industrial Revolution. Chance's success in making optical glass and later dioptric lens apparatus proved that Britain could match France, not only in manufacture but also in the application of science for which England's manufacturers had so often been derided.

Lucas relied on his nephew James in both endeavours, but the characters of the two Chances could not have been better contrasted than in the tasks they had set themselves. Lucas Chance's obituary in the *Birmingham Post* in February, 1865 described him as "a risk taker, fanatically driven, dictatorial, peremptory, and explosive." Lucas did not let anything get in the way of business. While James was on his honeymoon in 1845, Lucas instructed him to cut it short and hurry to Namur in Belgium to secure more glassblowers for the factory. Lucas wrote to his son Robert who, just back from holiday in Constantinople, was likewise sent off to Picardy and the Lyonnais in France: "He [James] takes up the journey *con amore*, and having read the *volumes* I have written on that subject, has his mind imbued with the importance of his mission." These traits were essential in achieving what most saw as the impossible task of producing the 900,000 square ft (83,612 square m) of glass for the Palace in less than six months.

James, on the other hand was cerebral, disciplined, precise and high-minded – he wanted to better the world. Rather than dashing between London and Birmingham to supervise the erection of the Palace, James preferred to spend time at the works, bent over a workbench, pencil and instruments in hand, producing technical drawings and instructing workmen on new engineering techniques. What Lucas and James had in common, however, was an unshakable faith in their respective visions, a determination to achieve them and the ability to motivate others to come along for the ride.

How was it, then, that Chance Brothers decided to embark upon dioptric lens manufacture? James Chance was initially reluctant to agree to Brewster's request to attempt making lenses, for Chance Brothers were successfully expanding their glassworks for the manufacture of the more lucrative plate and sheet glass, and the optical-glass business was still small by comparison. But Brewster's persistence paid off. James Chance, in his 1867 paper to the Royal Institution of Civil Engineers, obliquely acknowledged his debt to Brewster: "And here it might be remarked, that the introduction of the dioptric system into this country had a zealous advocate in Sir David Brewster, who at once recognized its unquestionable superiority over the method of metallic parabolic reflectors." Being averse to controversy James did not make any reference to the acrimonious correspondence between Brewster and Stevenson on the provenance of the polyzonal lens for lighthouses.

After Brewster's letter, James Chance dropped the subject of lighthouse lenses for four years but Bontemps, with his knowledge of the French dioptric lens manufacturers, brought up the subject again in 1949. Robert Chance, Lucas Chance's son and a partner in the firm since 1846, paid a first visit to Trinity House in London in December 1849 where he was introduced to Robert Wilkins. Wilkins had



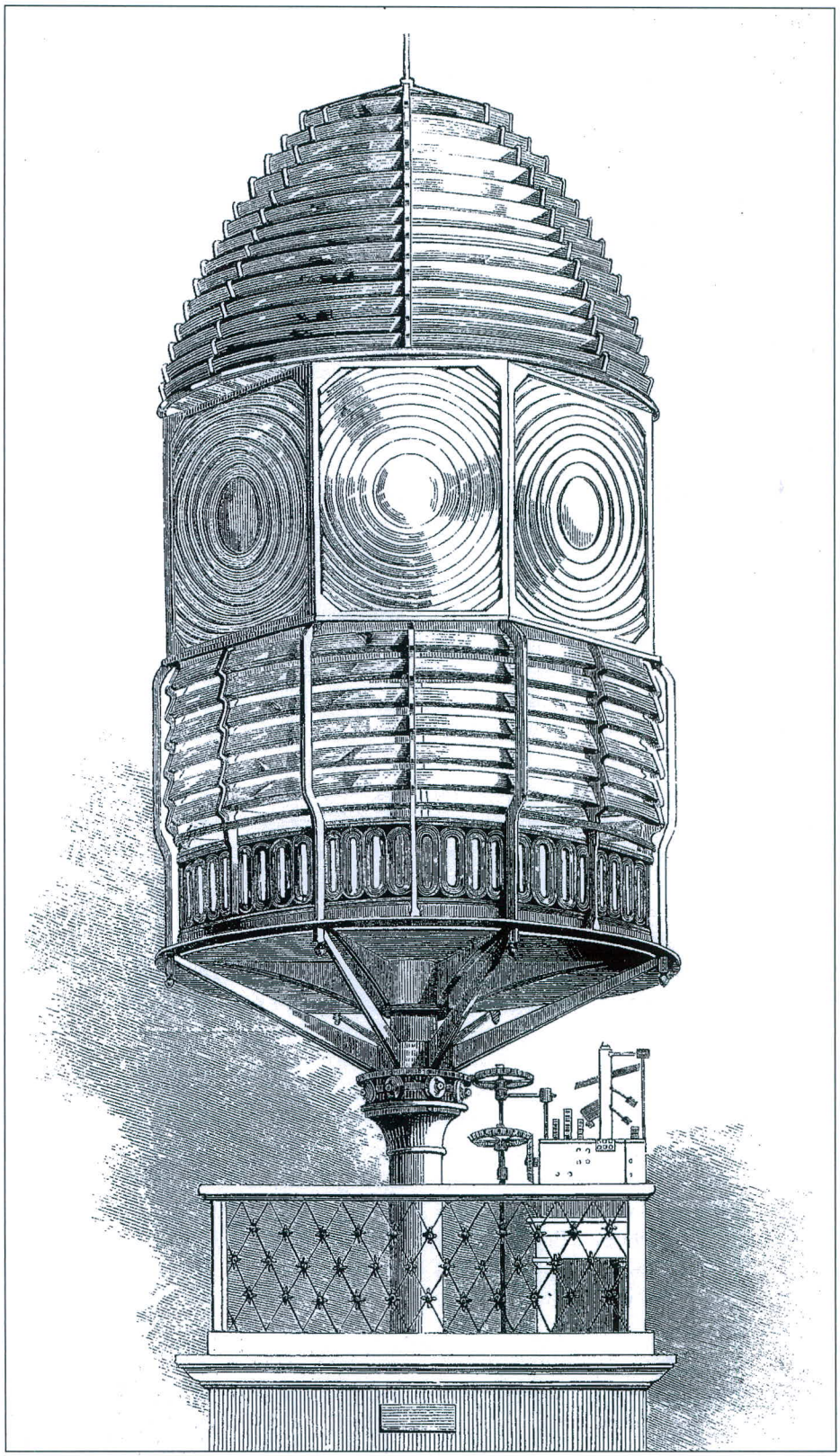
Above – James Chance.
Below – Robert Lucas Chance.
Photos courtesy of the author.

by now taken over from George Robinson in the successful business they had built up. That introduction placed together two men who were

experts in their own right, as Robert Wilkins was the monopolistic supplier for almost all of Trinity House lighthouse equipment needs, with the exception of glass, which at that time Wilkins was purchasing occasionally from Letourneau in Paris. Wilkins and Robinson had for 60 years supplied Trinity House with lighthouse equipment, including the standard Trinity House lantern, complete catoptric apparatus, and more especially the burners for which Wilkins had taken out patents and for which his firm was highly regarded. Principally a firm of metalworkers, under the direction of Robert Wilkins it made parabolic reflectors and sold them all over the world, even working with the Stevensons' early lights in Scotland.

At the Great Exhibition, Wilkins was the only British company to exhibit both a catoptric and a dioptric lens, which they built in partnership with Letourneau. They built the metalwork themselves and outsourced the lenses, first to Letourneau and later also to Chance Brothers, before assembling it with their homemade burner and shipping it off to customers. Because of their reliable supply of catoptric apparatus to Trinity House over many decades, it was natural for Trinity House to order some of their early attempts at dioptric lenses, especially as they incorporated trusted French lenses in their design. Wilkins also bought from Chance's the plate glass used to glaze the lanterns, and by the time James Chance turned his full attention to lighthouse design and construction in the mid-1850s, Chance Brothers and Wilkins had established a close business relationship.

As a result of the meeting between Robert Chance and Robert Wilkins in 1849 Lucas Chance became convinced that lighthouse equipment could be another viable product line for his glassworks. Subsequent to the meeting, Chance Brothers and Wilkins agreed to co-operate to make the new-style Fresnel dioptric lenses. Lucas ordered his French glass expert, Bontemps, to go to France to recruit a team of lens makers. Bontemps did so and on 1 January 1850 recruited M. Tabouret with two assistants M. Mangematin and M. Tabouret Jr. They arrived at Spon Lane later that month and, after setting up their workshop, they commenced building a first-order lens that was to be a centrepiece in the British exhibit in the nave of the Crystal Palace. Robert Chance was put in charge of production while James Chance took control of the mathematical and technical aspects, working closely with Tabouret.



Chance Brothers First Order Fresnel (Dioptric) Lens. Photo courtesy of the author.

James Chance was fascinated with the study of optics and the science and engineering of glass. The lure of succeeding where Cookson's had failed was too great for him to resist. He was taking up a task that the great Fresnel, whose works he undoubtedly had read as an undergraduate at Cambridge, had pioneered, and he intended not just to mimic the master but to surpass him in design and engineering excellence. James could devote most of his time to this undertaking, while the rest of the firm's business

was taken care of by Lucas, his son Robert and James' younger brother Henry. Henry had graduated from Trinity College Cambridge with a first-class honours degree in Classics, entering the business in 1850, and is another of the rare examples of a classically educated, middle-class man who eschewed the church and professions for business.

Meanwhile, in spite of their agreement with Chance, Wilkins teamed up with Letourneau who provided a lens for Wilkins to exhibit himself. Maybe that decision was the result of Chance's rejection of Wilkins' offer to place an order with them in February for a first-order lens. The firm's reason for the refusal was that they wanted their first lens to be exhibited at the Great Exhibition. Chance Brothers enjoyed the expert advice of both Thomas and Alan Stevenson during this time. Alan Stevenson had been in regular correspondence with James Chance in the late 1840s when they exchanged ideas on dioptric lens design before Chance Brothers took the plunge by deciding to build their first lens in 1849. This began a close association between the two firms, which endured for 50 years and led to some of the great breakthroughs in performance still in evidence in lighthouses today. Each had great respect for the other as can be seen in the extent to which they co-operated to perfect lighthouse technology between 1850 and 1890. Where Chance were glass manufacturers who adapted their skills to lighthouse engineering, Stevenson were civil engineers who adopted and improved the Fresnel lens in the lighthouses they built. The Stevensons never made a Fresnel lens, they commissioned them, first from France, then Cookson's, then from Chance. They designed the lens, specified its installation and the location of the lighthouse, and often oversaw the commissioning in overseas territories. But they never supplied the whole lighthouse as Chance Brothers later did. For this reason Stevenson and Chance were principally collaborators, not competitors, as became clear during the 1860s when lighthouse technology advanced to new heights.

Early in 1851 Alan Stevenson paid a visit to Spon Lane to observe for himself the manufacturing processes. During the visit Alan gave Lucas and James much advice on lens design and also a commercial insight into the workings of Trinity House and how Chance Brothers should approach the market. They were counselled not to make lenses for stock, as Lucas wanted to do, but be prepared to supply custom-made pieces. Alan warned against, "...too many peculiarities in each case of a lighthouse to make it probable that your stock should be suitable to the wants of any customer". Yet, he said, "if the Trinity Board were to improve all their fixed lights, you might then have orders enough". Stevenson's implication that the Trinity lights left much to be desired is clear. In the same vein Thomas Stevenson commented in a letter written to James Chance in April 1851, (alluding to his own work) that lighthouse lens design was continually evolving. Stock, if any, should be confined to fixed lenses. Chance were much encouraged by these expert comments to which Thomas added, "should your glass and manufacture equal the Parisian, then there is little fear of demand."

In the year and a half between Tabouret arriving at Spon Lane in January 1850 and the opening of the Great Exhibition, Chance Brothers worked feverishly to complete their lens. They had a very finite deadline to meet, for on 1 May 1851 the Great Exhibition was due to be opened by Queen Victoria. No better place to exhibit the lens could be imagined. A new product for the firm and a new market, not just in England but throughout the rapidly expanding Empire, which was being opened up thanks to Britain's maritime supremacy. A lighthouse needed to be placed on every major headland, every entry to a port, every straight and dangerous rock that the merchant and naval fleets would pass by.

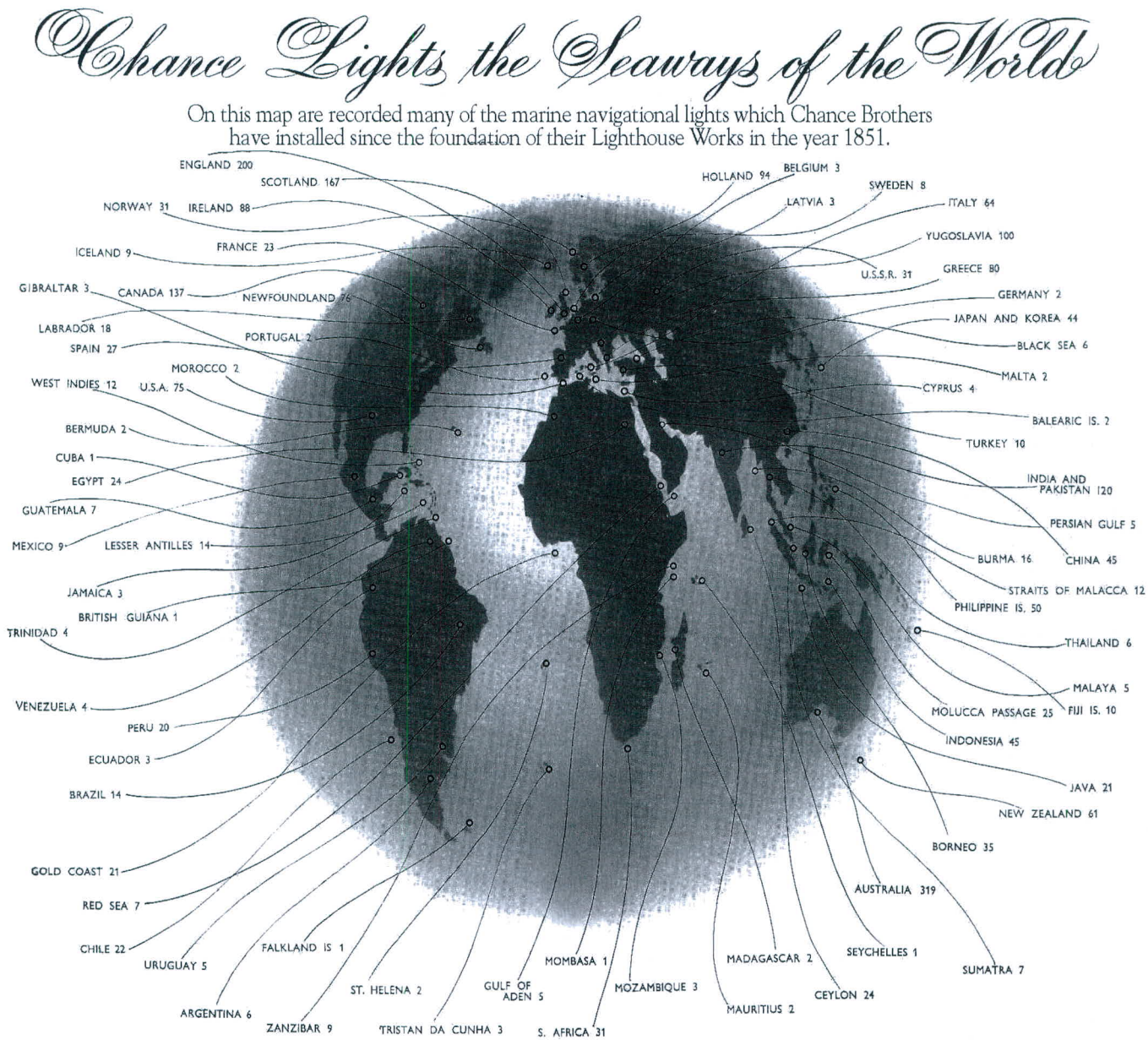
The apparatus that they eventually displayed combined Fresnel's revolving drum of eight polyzonal lenses alternating with segments of a fixed light belt. These catadioptric segments, 13 above and six below the polyzonal lenses, together with the polyzonal lenses, which completed a revolution in four minutes, produced a fixed light waxing to maximum intensity every 30 seconds. More than a prototype, the dioptric lens was far from state of the art with its distinct green tinge. The Jury admired it for its economy of design and absence of ornament, while it took the opposite view of Letourneau's lens the ornamental finish of which it considered "objectionable"! The Great Exhibition was the harbinger of things to come, both for Chance Brothers and the host of manufacturers that displayed their goods for the world to see. The Palace of Industry was just that – a cornucopia of industrial inventiveness that put Britain on a world stage and opened up hitherto unexplored markets to firms just beginning to exploit the opportunities offered by the needs of the Empire.

Unanimity there was not, however, between the advocates of colonial expansion. Lord Palmerston, Foreign Secretary in the Russell government in power at the time, was all in favour of trade in the national interest, while the internationalists led by Richard Cobden preferred a policy of free trade for the benefit of all nations. This ideological divide ran through British society, and lighthouses – as a symbol of scientific and industrial might – sat astride the two poles. The Great Exhibition was both a nationalistic event in the Palmerston mould and an invitation to any ingenious soul with the temper and skill to foist his wares on the massed market that came by the millions. A lighthouse lens was not the sort of device that could find a place in the home of the shilling-a-day visitor to the Exhibition. It was an intricate piece of precision engineering with a price tag in the thousands of pounds sterling. For Chance Brothers there was no certainty that the lens would not be its first and last foray into this arcane branch of glass technology.

The 1850s – a Time of Trial

By 1840 Michael Faraday and the Trinity Board were engaged in an elaborate comparison of refractive apparatus of English and French manufacture, but nothing much came of it until 10 years later when Faraday began visiting the Chance lighthouse works. After the excitement of the Great Exhibition cooled, work at Spon Lane returned to normal. Tabouret supplied samples of his glass to Trinity House for inspection but none were accepted, even after Tabouret used a tracing for a holophotal quadrant prism sent to him by Alan Stevenson, and Sir David Brewster had paid several visits to the works. In 1852 the Board of Trade ordered Trinity House to use "glass of English manufacture in dioptric apparatus" and in that year sent Chance Brothers a French lens for comparison with its own. In 1853 Faraday reported favourably on a specimen of Messrs. Chance's glass, but their submission of a lens to Trinity House in February 1853 was judged to be unacceptable.

The Chance management then stopped lighthouse glassmaking, saying "that all the present operations with the lighthouse department be suspended at the earliest possible



Ultimately, Chance Brothers became a dominant supplier of lighthouse lenses and equipment throughout the world, mainly in the expanding British Empire.

period in consequence of the signal failure on the part of M. Tabouret to produce any lighthouse to the satisfaction of the Trinity Board." Tabouret's agreement was cancelled; he left Spon Lane on 16 April 1853. From 1852 until 1854 the time was spent mastering and gaining experience in lighthouse work under the management of M. Mangematin and M. Masselin, Bontemps' cousin, who had come to assist in the optical works in 1850. In February 1854, Chance reported to Trinity House that they had succeeded with a section of dioptric glass and permission was given to fix it at Faraday's house. Faraday reported it equal to the French apparatus set up in his experimental room.

Michael Faraday's role in Chance Brothers' rise to prominence in lighthouse design and engineering was crucial. As scientific advisor to Trinity House he had a special responsibility to inspect and approve all lights commissioned from French and British manufacturers. On 14 March 1854 Faraday reported to Trinity House:

Having this day examined one division of a catadioptric apparatus constructed by Mr. Chance, of Birmingham, and compared it with one of the French construction, which the Corporation possess, mounted in the comparative frame, I am of the opinion that, in the colour of the glass, the working of the various pieces, and the fitting of the whole together, the former is equal to the latter; and, from the effect of the light upon the screen, I believe that one would not be distinguishable from the other when seen at sea.

Faraday had given Chance the thumbs up and compared their workmanship with the best. Mr. Herbert, Secretary to the Trinity Board, wrote to Chance Brothers saying that many of the Elder Brethren present with Faraday at the tests concurred with his finding: "The observations made by many of the Elder Brethren, who were present on the occasion, induce them to concur with Dr. Faraday in the opinion which he expressed." In May 1854, Chance were promised Trinity House's first order of a dioptric lens.

In February 1855, Trinity House lent

Above – Manora Point Lighthouse in Pakistan, one of the few lighthouses with a Hyperadial lens. At right is the Hyperadial lens installed in Manora Point. Both photos courtesy of the author.

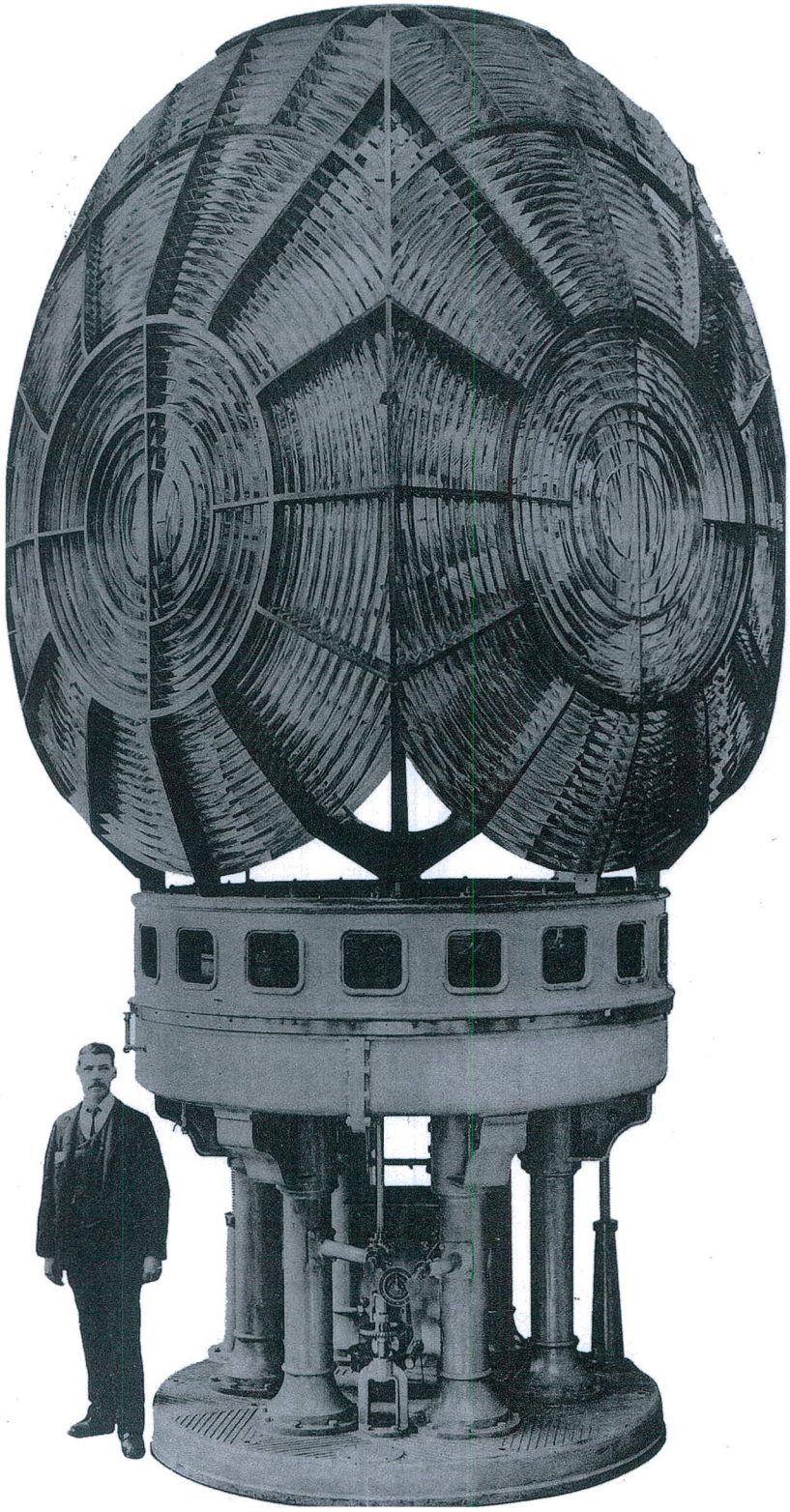
Chance a French sixth-order apparatus. In March it declined to lend them a publication on American lights, "but will give them every facility for making notes from it." This was at a time when America was in the process of equipping its entire lighthouse infrastructure with dioptric lenses, so this refusal to loan the book denied the firm a competitive position versus the French, who ended up supplying nearly all the lenses fitted to American lighthouses over the next 60 years. So much for government support for British industry! The comparison with the French authority's attitude could not be clearer.

Finally, in September 1854, Trinity House invited Chance Brothers to tender for the catadioptric apparatus for Bardsey Island off the north-west tip of Wales. In October, Faraday travelled to Smethwick to inspect the works. The firm was refused a copy of his report but were again informed that their glass was equal to the French. In December Chance renewed their request for a copy of the report and were once more refused, this time being reminded that dioptric apparatus was not in practical operation in England and Wales! Even in the face of Trinity House's obstructive attitude the firm pressed on, and in April 1856 their tender for the Bardsey apparatus was accepted. Soon afterwards a tender was invited from them for an apparatus for Lundy Island, which the Trinity Board recommended should be supplied by the French, ignoring Chance's declaration that it could undertake the manufacture – and ignoring the Board of Trade's 1852 instruction to use English manufacturers. In May the Trinity Board gave way, determining that the competition may include English glass and Chance's tender for the Lundy light was accepted.

In November the Bardsey apparatus was fitted and in June 1856 the Lundy apparatus was tested at Blackwall. The substance of Faraday's report, but not the report itself, was sent to Chance, and in July the Lundy apparatus was fitted on site. At last the firm's capabilities were accepted and it constructed the apparatus for the Whitby, Cani Rocks and Vancouver Island lighthouses among others. During the next three years seven fixed lenses were made, all of the smaller sizes, mainly for Wilkins, who supplied them to Irish lighthouses, though a small fifth order is known to have gone to the Levant. This progress encouraged Chance Brothers to exhibit a first-order lens at the Paris Exhibition of 1855, where it had to compete with exhibits by Lepaute and by Sautter et Cie, Letourneau's successors. The Chance lens won a First Class medal of honour, which the Jury awarded in consideration of their efforts to introduce the manufacture into England. The influence of Sir David Brewster was apparent. As a Jury member he had a special satisfaction in seeing his dream of 50 years finally accomplished by a British firm. He reported, "In the quality of the glass, either in reference to colour or to freedom from straie, and in the fitting up of the various parts, this apparatus seemed to be very little, if at all, inferior to its rivals."

Thus emboldened, the firm set about the serious manufacture of lighthouse lenses. A sales brochure issued at the time advertised fixed, revolving and flashing, all of the six Fresnel orders, as well as Stevenson's holophotal system, dioptric apparatus for lightships and a patented dioptric signal lantern. Between 1851 and 1861, when the Royal Commission on Lighthouses, Buoys and Beacons reported, Chance Brothers manufactured approximately 60 lighthouse lenses, which were supplied to Trinity House and several other countries beyond its authority. The table which follows on the next page indicates how far afield these orders came from.

This list reveals some interesting information, notably the preponderance of large lights that were destined for headlands which required the maximum illuminating power possible. Most of these destinations had never had a lighthouse installed before and were



either important ports or guarded channels and rivers crucial to opening them up to trade or preserving their importance as the volume of trade increased.

What is also evident from the list is the number of lights supplied to Australia, the country ordering more Chance Brothers (more than 300) lights than any other in the period from 1858 to the 1960s. The Macquarie light in Sydney, supplied in 1883, was at the time considered to be the most powerful in the world and the first in Australia to be supplied with electric light. North of Australia were Ceylon, India, the Red Sea and the territories of south-east Asia, all of which were British colonies where colonial agents, through the Board of Trade, were actively promoting the interests of their merchants and overseas trade. But orders were not confined to the Colonies, the natural domain of British companies. Russia and Spain also featured prominently. It was the light destined for Odessa that Michael Faraday inspected in 1860 and which drew his favourable comment during his tour of the Chance works for the Royal Commission. The acceleration in lighthouse construction at this time was mirrored by increasing activity in other parts of the world at the hands of French manufacturers. The French were supplying scores of lighthouses to the United States as it finally realized its network of lights was hopelessly outdated and proceeded to replace nearly all its old catoptric apparatus with dioptric lenses.

In 1859 a Spanish government engineer, Lucio del Valle, inspected the Chance lighthouse works before placing an order for three lighthouses for the entrance to the River Ebro. Messrs. Stevenson supported the company's proposals for this work with letters and certificates. De Valle stated that these: *...gave assurance in a most formal manner that Messrs. Chance apparatus are made of good quality, that the curvatures of the lenses and prisms are correct, that the polish is perfect, that they give a great light, and, in fine unite all the qualities necessary for them to be considered apparatus of complete finish, equal in everything to the lights produced from the French works.*

He further added in his report of 20 January 1860:

At the time of the Universal Exhibition of 1855 I had already occasion to observe at the Palais de l'Industrie an apparatus constructed at the extensive glass-works which these gentlemen possess at Spon Lane, near Birmingham, and since that time they have devoted themselves with ardour to the establishment of the new workshops which the manufacture of the lights required, in order that they might compete with the French constructors and destroy their monopoly.

Hi-tech in France and Britain – the Case of the Dioptric Lens

The development and perfection of the dioptric lens at Chance Brothers' during the 1850s should be set against the radically new but relatively clear-cut process followed by Fresnel 30 years earlier. This provides an interesting historical postscript to how government, science and business

Date	Destination	Type
First Order		
1856	Rathlin Island, Antrim, Ireland	Fixed
	Rathlin Island, Antrim, Ireland	Fixed, intermittent
Bardsey Island, North Wales		Fixed
	Inisheer, Galway Bay, Ireland	Fixed
1857	Lundy Island, Bristol Channel, England	Revolving
1858	Whitby North, England	Fixed
	Whitby South, England	Fixed
	Whalsey Skerries, Shetland Isles, Scotland	Revolving
	Cape Schanck, Victoria, Australia	Fixed and revolving
1860	Gabo Island, Victoria, Australia	Fixed
	Fontana Cape, Odessa, Russia	Fixed
	Tory Island, Donegal, Ireland	Fixed
	Zarafana Point, Red Sea	Fixed
	Usruffe Reef, Red Sea	Revolving
	Cape Fanar, Black Sea	Revolving
	Rockabill, Irish Sea	Revolving
1861	Smalls Rock, Milford Haven, Wales	Fixed
	St. Abb's Head, Berwick, England	Revolving
	Cape Chesonese, Black Sea	Revolving
1862	Ile aux Fouquets, Mauritius	Fixed
	Black Rock, Mayo, Ireland	Revolving
	Hanois Rocks, Guernsey, Channel Islands	Revolving
Second Order		
1857	Rhu Val, Islay, Scotland	Fixed
1858	Pencarrow, New Zealand	Fixed
	Sescar, the Baltic Sea	Fixed and revolving
1859	Cani Rocks, North Africa	Fixed
	Race Rocks, Vancouver, Canada	Revolving
1860	Banca, Sumatra	Fixed
	Cumbrae, Clyde, Scotland	Fixed
	Daedalus Reef, Red Sea	Fixed
	Foul Point, Ceylon	Revolving
1861	Buda, Ebro River, Spain	Revolving
1862	Shortland's Bluff, Victoria, Australia	Fixed
	Edam Island, Java	Fixed
Third Order		
1858	Dungarvan	Fixed
	North Pier, Sunderland, England	Fixed
1861	Bana, Ebro River, Spain	Fixed
	McAuthur's Head, Hebrides, Scotland (azimuthal condensing)	Fixed
Fourth Order		
1858	Maryport, Cumberland, England	Fixed
	Warrnambool, Victoria, Australia	Fixed
	Portland Bay, Victoria, Australia	Fixed
	Port Albert, Victoria, Australia	Fixed and revolving
Port Fairy, Victoria, Australia		Fixed and revolving
1859	Warrnambool (No 2), Victoria, Australia	Fixed
	Esquimault, Vancouver, Canada	Fixed
	Spitbank, Cork Harbour, Ireland	Fixed
	Elephant Island, Ceylon	Fixed
	Corran and Phladda, Hebrides (2) (azimuthal condensing)	Fixed
1860	Banca, Sumatra	Fixed
	Trincomalee, Ceylon	Fixed
	River Clyde, Scotland	Fixed
1861	St Lawrence Gulf and River (3), Canada	Fixed
	Nelson, New Zealand	Fixed
	Port of Spain, Trinidad	Fixed
1862	India, stations not known (2)	
	Station not known, shown with the electric light in the 1862 London Exhibition	Revolving
	Holburn Head, Caithness, Scotland	Revolving

interacted in France as compared to Britain during the mid-19th century. Fresnel's invention of the dioptric lens was one of the first examples of the application of science to the development of hi-technology products. The Fresnel lens was a highly sophisticated piece of engineering, requiring advanced science and technology for its invention, design and manufacture. Fresnel's work was part of a conscious programme initiated by the French Lighthouse Commission, itself under direct government control, and not a random invention by a maverick scientist.

François Arago, the Astronomer Royal and a member of the Commission, realized the science of optics would provide the answer to the problem of devising a new illumination technology to replace existing deficient systems. The intentional co-operation of government, institutionalized science and technology, found in the glassworks of men such as François Soleil and the great firm St Gobain, enabled France to convert Fresnel's original concept into a complete working apparatus in little more than three years. In today's language this would be termed the "time to market" of an idea, and even today three years is an incredibly short time for completely new technologies to move from concept to product. A new car, for instance, can take five years from drawing board to dealership floor, and this is working with known technologies within the car paradigm. All Fresnel had was reference to the early use of lenses on the British and US coastlines, none of which were satisfactory. Viewed in this way, the Fresnel lens was a remarkable achievement and showed what the French scientific-industrial nexus was capable of, both in inventing a new paradigm and effecting it as a workable product.

The contrast with Britain was striking. There, the conditions did not exist for government, science and industry to work together. The three pieces to the puzzle – which had a felicitous relationship in France – either did not exist or were too far apart to be assembled into a finished product. The closest Britain came to it was the Royal Institution's commissioning of Faraday to make optical glass in the late 1820s but even then there did not seem to be any notion of what the glass was going to be made into. Furthermore, Faraday

The table at left illustrates the wide range of lenses supplied by Chance Brothers in less than ten years.

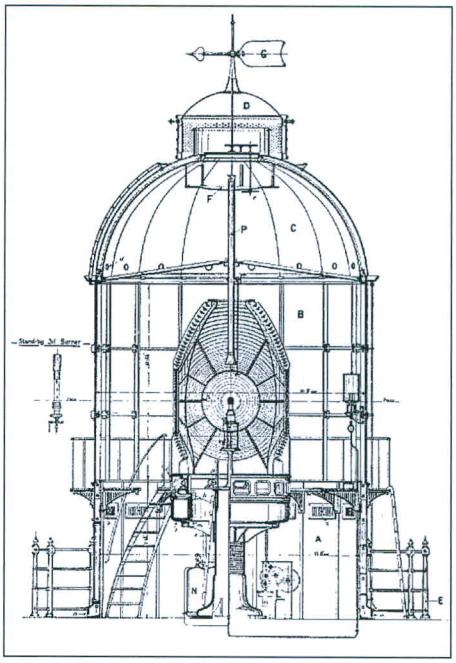
was not a trained optical scientist so did not have the theoretical knowledge required to specify the glass he was trying to make. What needed to happen in Britain was for the Elder Brethren at Trinity House to sit down and ask themselves: who in Britain understands the science of optics whom we can employ to design us a better system of illumination? Two names would immediately have come to mind – Brewster and Young, the leading optical scientists of the day. But the question did not occur to them, even when Brewster began to bombard them as early as 1823 with correspondence about the need to adopt lenses in lighthouses.

Another ingredient in the mix was also missing – a firm capable of making the glass. Gilbert, enlisted by Brewster to make his first lens for trials by Trinity House and the Northern Lighthouses Board, and Cookson, employed by Alan Stevenson but who later abandoned making lenses, both failed, and it was left to Chance Brothers to fill the void 30 years after Soleil built the first Fresnel lens.

In France, the Lighthouse Commission started with a market (or more accurately a government) requirement – lighthouse illumination – and proceeded directly to a concept solution, a design, a manufacturing process, a test bed and finally a working product. This process has been followed ever since in the development of hi-technology products. Needs are established in the market place, these are communicated to research laboratories in universities who devise new fundamental technologies based on scientific principles and experiment, to which business then buys the rights before turning out the finished product.

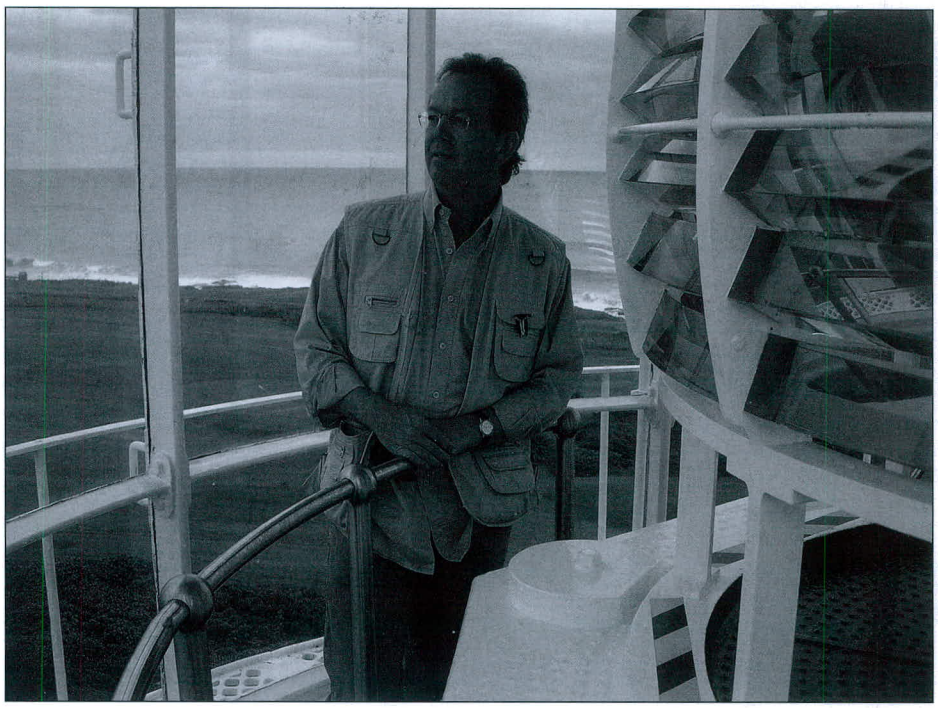
The reason Britain struggled to come up with a working competitor to the Fresnel lens is that it had no equivalent institutionalized process. Instead there were scientists, government bodies and businessmen all working independently and speaking different languages. When Britain did eventually produce a competitor it occurred only because the firm in question, Chance Brothers, had both the industrial muscle to finance the research and the requisite brains in James Chance to perfect the technology. The firm had to lobby the British government endlessly and deal with its obstructive attitude to and hoarding of vital technical information. It also had to call upon the skills of Frenchmen such as Bontemps first to teach them how to make optical glass, and then Tabouret to make the first lens. Lucas Chance was a brilliant businessman and knew he had to employ the best brains in the business. He was not shy to poach from his competitors and he was lucky to have, in his nephew James, a man with the capabilities to take the technology and run with it.

Hi-tech as described in France took several decades to mature in Britain and is still today a source of controversy. State-funded research and development is often scorned by reactionary commentators as wasteful and bureaucratic and not "the British way". The British way they refer to is the domain of the talented amateur, who, through toil and sweat, produces inspired solutions to new problems and is almost always an outsider. James Chance was one such man, though after 1860 he finally shed the amateur label and became the quintessential professional, elected an Associate of the Institution of Civil Engineers in 1867 when he was at the height of his technical inventiveness. In his paper on "Dioptric Apparatus for Lighthouses" presented in that year he stated very clearly his admiration for the French way, and one suspects that he would have found it far more appealing than the frustrations of being a scientist-turned-entrepreneur working to convince a sceptical government of the value of his work. It was the formation of the Royal Commission on Lighthouses in 1858 that changed Chance's life and finally provided the direction he craved. For the first time the British lighthouse system was scrutinised in an avowedly scientific fashion, and in James Chance the Commission found a man ready and waiting to offer his unique skills in the service of lighthouse science.



A typical lantern room with lens and all necessary equipment. Chance Brothers often supplied complete lighthouse lanterns and lenses.

Toby Chance in the lantern room of East London Lighthouse in South Africa. Photo courtesy of the author.



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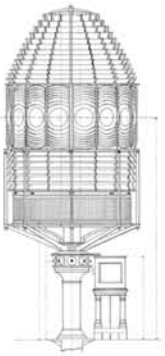

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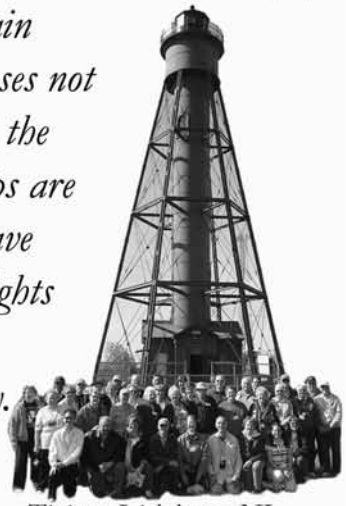

Tinicum Lighthouse, NJ

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