

Technical Transfer in the British Optical Industry

1888 - 1914:

The Case of Barr & Stroud

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Barr & Stroud

In 1888, Archibald Barr and William Stroud devised, designed, ordered components for and then assembled and calibrated an optical rangefinder for a competition organised by the British War Office. The instrument failed to impress Army experts, but an improved and modified version was judged to have performed well in sea-trials conducted by the Royal Navy during the early 1890s. The Barr & Stroud coincidence rangefinder was subsequently adopted by the Royal Navy, and by 1914 as many as nine of the instruments were carried on each British battleship and battlecruiser. Foreign navies, including those of Japan, Italy and France, also adopted the rangefinder, and a re-designed portable instrument was accepted for service with the armies of Great Britain, Austria-Hungary, France, and many lesser military powers on the eve of the First World War.⁽¹⁾

William Stroud was Professor of Physics at the Yorkshire College of Science in Leeds from 1885 to 1909, and Archibald Barr was Professor of Engineering there from 1884 until 1890, when he accepted the chair at Glasgow University. Neither man had any previous business experience, or any experience of working in the optical industry. Their original intention was simply to develop the patent for a rangefinder, the rights to which they hoped to sell to supplement their academic salaries. The Admiralty's valuation of the rights to the original patent [9520 of 1888], however, fell far short of the inventors' price of £75,000, and there appeared to be no company interested in developing an instrument for which, at that time, there was no guaranteed market.⁽²⁾ The inventors decided to set up their own private partnership, which they called Barr & Stroud's Patents, and in 1893 they opened a small workshop in Glasgow where they could continue work on the development of the rangefinder and other optical and electrical instruments.

By 1913, when the partnership became Barr & Stroud Ltd, the small company had acquired an international reputation as optical instrument-makers. Barr & Stroud was capitalised at just £200,000, had an annual turnover of £190,000 and employed a

workforce of just over 1,000 men⁽³⁾ when Carl Zeiss employed more than 2,000. Yet it maintained a significant lead in the field of optical rangefinder development and manufacture over larger and better-known competitors such as Zeiss and C P Goerz of Germany, and other established firms in Russia, France, Austria-Hungary and the United States. Barr & Stroud's achievements depended on a range of products invented, developed and manufactured in Britain without any formal technical assistance in the form of collaboration with or licensing agreements obtained from other companies specialising in the optical instrument market.

Roy and Kay Macleod have found that, between 1870 and 1914, Britain's science-based industries were afflicted 'by a neglect of technical education, resistance to cultivate applied research, and a pattern of demand and economic protection which strongly favoured continental competitors'. They state that

'...by 1900, the outlook for the optical industry seemed bleak. There were three alternative diagnoses for the malaise: first, that the economic and commercial structure of the industry militated against its success; second, that manufacturers neglected scientific men and scientific research; third, that the trade had few technically trained workmen or optical designers'.

They go on to conclude that, in 1914, 'the scarcity of capital for investment and research, the absence of a general apprenticeship scheme, no modern method of "costing", and "no policy of commercial or economic expansion", presented a gloomy picture [of the British optical industry]'.⁽⁴⁾ In these circumstances, Barr & Stroud's success appears to be remarkable. This paper seeks to show how the firm acquired and developed the technology required to dominate the international market for rangefinders and, after 1918, to produce other optical instruments, such as binoculars, gun-sights, and particularly submarine periscopes, which also proved to be highly successful. In addition, it seeks to explain how Barr & Stroud managed to retain control of vital technology, enabling the firm to remain one step ahead of its competitors.

It has long been fashionable to criticise British universities for their failure during the late nineteenth century to produce graduates able and willing to apply their talents to technical innovation and industrial enterprise. Recently, there have been attempts at re-evaluating this critical view,⁽⁵⁾ and the careers of both Barr and Stroud provide further evidence that a university education could indeed provide the stimulus for a successful career in technologically advanced industrial enterprise. Barr served an apprenticeship as a mechanical engineer while studying for a BSc at Glasgow University during the 1870s: the Department of Civil and Mechanical Engineering's famous 'sandwich courses' required students to spend just six months at the university on course work, and the other six months in local industry to acquire practical experience. He then worked for seven years as an assistant to his professor, James Thomson. Thomson was the brother of Sir William, the Professor of Natural Science at Glasgow University who was created Lord Kelvin in 1892 and was a noted inventor of scientific and electrical instruments. James Thomson and his assistant often helped Sir William with the practical work of designing the latter's inventions, and so Barr was exposed to the potentially highly-lucrative application of scientific invention to industrial enterprise.⁽⁶⁾

Stroud already possessed a BSc in Chemistry when he graduated from Balliol College Oxford with a double first in Maths and Natural Science. Before sitting his examinations for a DSc at London University in 1884 he visited Germany to attend lectures and laboratory demonstrations given by the famous scientists Kohlrausch and Quinke at Wurzburg and Heidelberg. He was only twenty-five years of age when he accepted the Physics chair at the Yorkshire College of Science, but had already acquired a reputation as one of the most promising scientists of his generation, and had a wide-ranging knowledge of the latest developments in science. It was Barr's idea that the two professors should turn their hands to the invention of scientific

instruments, marrying his flair for engineering design to Stroud's talents for applying theoretical scientific knowledge to invention.⁽⁷⁾

Barr's views on the importance of employing men with scientific training in enterprises such as the one he set up with Stroud were made clear in evidence he gave to the Worshipful Company of Ironmongers in 1906.

'I am convinced that one of the worst things a man who was going to devote his life to practical work could do was to spend too much time in any scholastic institution. The best training in Applied Science could only be got by a combination of scientific study in a University or College and service in a works, and the more intimately these two sides of his training were associated the better. The teacher and the research student should both be in intimate contact with the condition and requirements of the industry to which their work had reference.'⁽⁸⁾

In 1916, he wrote that

'... just as regards to chemists and other highly-trained assistants in industry, engineering employers in this country have not yet learned to take full advantage of the facilities that are available for securing men of sound scientific training. I may be permitted to say that in my own Firm we have found such men indispensable for the development of work in new lines, and we seldom - I may say never - appoint a man to a responsible job, even in the supervision of purely workshop work, who has not had a sound and extensive course of scientific training'.⁽⁹⁾

Barr recruited nearly all of Barr & Stroud's managers and scientific assistants from the ranks of his own engineering students at Glasgow University, promising young men being given the opportunity to prove their worth at the factory during the six months they had to spend each year in local workshops. Harold Jackson was the first scientific assistant taken on, and he rose to become company secretary and, in 1901, a junior partner in the firm. James French and J Martin Strang joined the firm as scientific assistants a few years later, and were eventually to acquire control of Barr & Stroud. Other engineering students who started as part-time assistants and became full-time members of staff included the first works manager, George Blair, who later joined the car manufacturers Arrol Johnston, James Blacklock Henderson, who became Professor of Applied Mechanics at the Royal Naval College in Greenwich, and John D Cormack, who succeeded Barr as Professor of Engineering at Glasgow

University in 1913. By August 1914 Barr & Stroud's Board and staff contained sixteen men with university degrees or technical college diplomas, all with a thorough grounding in the practical side of the business. Most of these men were involved in research and development work at the factory.⁽¹⁰⁾

Barr & Stroud's skilled workers were also encouraged to acquire relevant scientific knowledge. Barr sent out circulars to local headmasters and Boys Brigade captains asking them to mention the firm's name to any boys interested in becoming mechanics or instrument-makers. By 1914, 15 per cent of their employees - 150 young men - were apprentices. Youngsters who joined the firm served a rigorous five year apprenticeship, and from 1904 the apprentices were sent to local night schools to take science courses, with financial rewards offered for passing examinations, and bursaries to enable the most promising to go on to study at Glasgow University.⁽¹¹⁾ In 1917 Barr & Stroud announced they were to introduce scholarships for 14-year-old boys recommended to the firm by headmasters, to enable the boys to stay at schools where mathematics and practical physics were taught to a high standard. Glasgow School Board rejected the scheme, which required the boys to sign up for a five-year apprenticeship with Barr & Stroud on completing their education. The decision was made on the grounds that children should be given a wide education, with the prospect of going on to a Higher Grade School, rather than a course of instruction such as was favoured by German industrialists.⁽¹²⁾

Although Barr & Stroud had little difficulty in recruiting suitable managers and scientific assistants from Glasgow University, and finding and training mechanics and instrument-makers, the firm had to reach beyond Glasgow to obtain other vital workers and technology. At first, Adam Hilger & Co of London supplied most of Barr & Stroud's optical components, using optical glass manufactured by Chance Brothers of Birmingham. The quality of the products supplied by Hilger, however, was the subject of constant complaint from the Glasgow firm. Barr & Stroud

protested that Hilger's prisms were not always made to the angles specified. The quality of lenses was often poor, and Stroud noted in 1907 that Hilger & Co did 'not know one hundredth of what Zeiss know about lenses' and noted ruefully that 'Zeiss have Rudolph, Czapski, Von Rohr and others on their staff who are the recognised authorities on lenses'.⁽¹³⁾ The backwardness of the British optical industry made Barr & Stroud's efforts to match the quality of Zeiss instruments very difficult indeed.

Barr & Stroud first advertised for optical workers in 1895, two years after their small assembly shop was opened in Glasgow. At first they sought only 'a respectable young man who could do edging of lenses etc and cementing and generally fitting the optical work into the instruments', and a technician was taken on the following year to start up an optical department where this work could be undertaken.⁽¹⁴⁾ It proved impossible to recruit other skilled workers to take charge of an optical grinding and polishing department, however, and Barr & Stroud had to look beyond Scotland to acquire these skills. C P Goerz offered to act as Barr & Stroud's agents in Germany, and became sole agents for the Scottish company's instruments in Germany in 1898. The agency agreement contained a clause giving Barr & Stroud the right to send a representative to Goerz's works and to study production methods there, and James French, who had recently graduated from Glasgow University, spent a year working and studying at Friedenau.⁽¹⁵⁾ He was able to learn enough in Germany to set up a new optical grinding and polishing shop when Barr & Stroud moved to a new purpose-built factory in Anniesland, Glasgow, in 1904. Due to the recession in the optical industry, which followed the Boer War, the company was able to recruit skilled men from Yorkshire and London to work in the new department. By 1906 these men were making many of the prisms required by the company, although, owing to the surge in demand for rangefinders following the Russo-Japanese War, large orders continued to be placed with Adam Hilger & Co.⁽¹⁶⁾

No-one on Barr & Stroud's technical staff had any experience in the computation of lens curves, and the skills of those relatively few Britons proficient in lens computation, as well as the formulae they so painstakingly calculated, were jealously guarded by their employers. In 1897, Hilger had offered to transfer his works to Glasgow, and his offer of some form of amalgamation between Adam Hilger & Co and Barr & Stroud gave the latter company the opportunity to acquire an established lens-making operation. Stroud, however, objected strongly to a close connection with Hilger. Apart from his low opinion of Hilger's optical work, he feared that Hilger would use a formal tie with Barr & Stroud to acquire sufficient knowledge of the business of rangefinder production to enable him eventually to set himself up in direct competition with Barr & Stroud.⁽¹⁷⁾ Having spurned Hilger's proposals, therefore, Barr & Stroud had to look elsewhere for the technical knowledge they required.

In 1912 the technical assistant, J Martin Strang, was sent to the optical works of the state-run Obhoukoff Steelworks in St Petersburg, which had been awarded the contract to clean and repair Barr & Stroud rangefinders supplied to the Imperial Russian Navy. Ostensibly, Strang visited Russia to advise on methods of dealing with a fungal growth which had appeared in the optics of many of the Russian rangefinders, but he was also told by Harold Jackson that 'any information regarding the cutting of fine lenses on glass diaphragms by means of a diamond (not etching), would be very acceptable'.⁽¹⁸⁾ Strang did better than that. Barr & Stroud enjoyed good relations with the head of Obhoukoff's optical department, Professor A Gerschun, and offered to invest in a new optical firm, which Gerschun planned to set up in St Petersburg. Barr & Stroud also agreed that Gerschun's new company would be granted agency and licensing agreements with Barr & Stroud.⁽¹⁹⁾ It is probably no coincidence that Strang spent a lot of time with Gerschun at the Obhoukoff works, was able to study methods of computing there, and returned to Glasgow with formulae for lens computation. He was put in charge of a new computing department at the Anniesland factory soon afterwards.⁽²⁰⁾ During the war the firm was finally

able to obtain training in computing and optical design in Britain, when a member of staff attended Professor Conrady's lectures at the Optical Engineering Department of the Imperial College of Science and Technology. In 1919, two female members of staff attended lectures at the Imperial College, and the computing department soon assumed a vital role in the company, particularly after 1917 when Barr & Stroud began to manufacture submarine periscopes.⁽²¹⁾

Barr & Stroud's next move in the direction of self-sufficiency in optical component manufacture was to investigate ways of setting up a glass-making department. German optical glass, particularly from Schott's works in Jena, had long been considered superior to British glass. It was generally believed, however, that the best German glass was reserved for the use of German firms, and nearly all supplies to Britain were in any case cut off after the outbreak of the First World War. The technical challenge of upgrading the quality of British optical glass was subsequently taken up with great success by Chance Brothers. Nevertheless, Barr & Stroud were unable during the early years of the war to obtain sufficient quantities of pentagonal prism blocks from the Birmingham firm, and were alarmed to find the price for optical glass increase in price by 50 per cent during the first four months of the conflict.⁽²²⁾ Although the output of rangefinders at Anniesland rose from forty per week in August 1914 to 120 by June 1916,⁽²³⁾ demand continued to exceed Barr & Stroud's production capacity, and so the firm proceeded in haste with plans to manufacture its own glass.

Professor Barr worked at first on the design of an annealing chamber for the fine annealing of glass, and several of these chambers were made at the factory and installed there in 1915.⁽²⁴⁾ The difficulties involved in actually manufacturing glass were much greater than he had anticipated, since the Ministry of Munitions did not recognise Barr & Stroud as glassmakers and so refused to offer any financial or technical assistance to the company in this project. The company responded by

resorting to the type of 'industrial espionage' which had proved so successful in earlier attempts to acquire optical technology. According to rumours, which circulated in the industry, a member of the scientific staff 'dressed as an artisan' was sent off to work in various English potteries and to learn the secrets of manufacturing the special clay pots in which glass was melted during the production process. He returned to Glasgow with the necessary information, and the production of suitable pots began immediately.⁽²⁵⁾ Meanwhile, Barr and James French set to work designing gas-heated melting furnaces, as well as handling tools. In 1916, Barr & Stroud were producing optical crown glass of a satisfactory quality for prisms, within nine months of embarking on the project.⁽²⁶⁾

Barr & Stroud were able to recruit locally the men of scientific talent they required to undertake research and development and the various production processes at their factory. Drawing on a great pool of skilled labour in the west of Scotland, they were able to recruit and train most of the instrument-makers, tinsmiths, brassmoulders and others required. Stroud, a highly-respected theoretical scientist, and Barr, a mechanical engineer with a wealth of academic and practical experience, remained in charge of research and development work, and with a small circle of scientific assistants they continued to provide the ideas for improving existing products and devising new ones. Yet Barr & Stroud proved willing to search abroad for solutions to problems which could not be solved at the factory, as in the setting up of optical components and optical glass manufacturing. The firm showed itself equally willing to search out and 'borrow' other types of technology.

In 1896, Barr was given permission by Glasgow University to sail to the USA to visit engineering schools and report back on the design and equipment of engineering laboratories at colleges there. Barr took the opportunity to conduct some of his own research during the visit. He visited Andrew Carnegie, Thomas Edison and other industrialists, toured their works and returned to Scotland highly impressed by

American machine tools and by American business methods and factory organisation.⁽²⁷⁾ In 1898, he imported what was said to be the first American milling machine to be used in Scotland, and by 1902 Barr & Stroud's factory was equipped entirely with American machine tools.⁽²⁸⁾ The Rowan System - a form of the American premium wage system adopted by the Clydeside firm of marine engineers, D Rowan & Co in 1898 - was introduced by Barr & Stroud in 1901, and remained in operation until the 1930s, while the organisation of the factory, described in great detail in two articles in *Engineering* in 1906 and 1919, owed much to American and German ideas.⁽²⁹⁾

Nevertheless, foreign was not always considered best for factory organisation and equipment. In 1903 the works manager was sent to the USA to study the most modern American factories, when Barr & Stroud planned to build their new factory at Anniesland in Glasgow. He reported back that the Americans had little to offer in this department, and so Barr & Stroud's staff worked with the architects and consulting engineer to come up with the specifications of a suitable building. In 1903 Barr & Stroud also broke with their 'buy American' policy regarding machine tools, and purchased an engraving machine from the English manufacturer, William Taylor.⁽³⁰⁾

Barr & Stroud developed their own technical expertise at Glasgow, while always willing to borrow from others the technology most suited to their needs. Having developed a range of successful instruments and a wealth of technical expertise, the firm was also eager to prevent competitors from emulating their methods and copying their products. Barr & Stroud's efforts to retard the process of technical transfer to competitors were as energetic as those to acquire technology for themselves.

The greatest protection for the Barr & Stroud rangefinder came from patents. Barr was an expert in drawing up patents, and to him belongs the lion's share of the credit for protecting Barr & Stroud's products from duplication by others. The two

professors' original rangefinder patent of 1888 covered a number of innovations, but the most important claim was one which covered the moveable measuring prism associated with the translucent or transparent scale - previously patented coincidence rangefinders contained measuring prisms which merely displaced the image with reference to a scale.⁽³¹⁾ The patent was quickly registered by the patent agents, J Clark Jefferson and later Bartholomew & Liddle, in the industrial nations of the world, preventing leading optical firms from copying the idea.

The original Barr & Stroud patent was registered in Germany in the nick of time. In Jena, Ernst Abbe and Professor Czapski of Zeiss were already at work on a coincidence rangefinder, which worked on similar principles to the Barr & Stroud. They abandoned their work when the Barr & Stroud patent was registered, and turned instead to develop a new rangefinder based on the stereoscopic system devised by Hector de Grouilliers. Zeiss's disappointment at being pipped at the post by Barr & Stroud in the development of coincidence rangefinders was eased later, when leading members of the German company met Barr. Barr told them that, because he and Stroud had to devote a great deal of time to assembling and calibrating rangefinders after the publication of their first patent, they were unable to complete work on another invention, prismatic binoculars. Zeiss were able to patent their own almost-identical binoculars, and therefore protect themselves from Barr & Stroud's competition until after the end of the century.⁽³²⁾

Barr & Stroud's original rangefinder patent expired during the early 1900s, allowing competitors to begin manufacturing coincidence rangefinders along similar lines. Barr & Stroud, however, introduced and patented improvements in design, which enabled them to protect the markets won since 1888. The most important improvements were the introduction of an eyepiece prism combination which allowed the eyepiece to be set at an angle to the plane of the rangefinder, and the provision of fold-away handles. These innovations permitted greater ease-of-use - the inclined

eyepiece reduced neck strain, while the handles were particularly convenient on portable instruments designed to be used in the field. Neither, however, marked any great scientific achievement, and the German firms of Zeiss, Goerz and A & R Hahn were understandably concerned that they could not use such simple 'user-friendly' features in their own rangefinders. In 1911, Zeiss and Goerz (the latter having amalgamated with Hahn) appealed against the patents to the German Imperial Patent Court. Barr & Stroud lost the case, but promptly appealed and in 1912 the Imperial High Court found in their favour.⁽³³⁾

The strength of Barr & Stroud's patents, and the firm's willingness to defend them against the might of Germany's optical industry, undoubtedly retarded technical transfer in the field of rangefinder manufacture. Zeiss, unable to develop a coincidence rangefinder while Barr & Stroud's original patent remained in force, committed themselves to the stereoscopic rangefinder for naval use. Barr & Stroud were able to convince most of their customers prior to the First World War that stereoscopy was an inferior method of measuring distances in battle situations, and Zeiss won few steady customers other than the Imperial German Navy.⁽³⁴⁾ Stereoscopic rangefinders found little more favour with military experts, while the coincidence rangefinders developed by Zeiss and Goerz for army use suffered from design faults, due to the relatively late start made by the Germans and from the absence of features such as inclined eye-pieces and handles introduced and patented by Barr & Stroud. Barr & Stroud found patent protection a highly effective means of limiting the spread of technology introduced and developed in Glasgow.

Patent protection alone was not enough to defend Barr & Stroud from the efforts of their competitors to acquire the skills, methods and processes which proved so successful in Glasgow to Barr & Stroud. In Russia, it was impossible to patent an invention which was deemed to be of use to the armed forces. Other countries were increasingly willing during the early twentieth century to follow the German example,

and refuse to adopt foreign-made products for the army or navy. To achieve sales, Barr & Stroud were forced by these circumstances either to set up foreign subsidiaries or to grant licensing agreements with foreign firms, allowing Barr & Stroud's inventions to be manufactured in the country in which orders were being sought.

By 1914, Barr & Stroud had a small assembly shop in Paris, operated by a wholly-owned subsidiary. The agreement with Gerschun would allow his new Russian company, with Barr & Stroud a major shareholder, to manufacture the Glasgow firm's rangefinder under license, and a similar arrangement was concluded with two companies in Austria-Hungary.⁽³⁵⁾ In the USA where, Bausch & Lomb were manufacturing stereoscopic naval rangefinders under a licensing agreement with Zeiss, Barr & Stroud entered into a licensing agreement with Keuffel & Esser, whereby the latter manufactured some mechanical parts for the Barr & Stroud rangefinder under licence and assembled the instruments for sale under an agency deal.⁽³⁶⁾ Of all the 'superpowers', only Germany and Japan had no companies with formal arrangements to manufacture Barr & Stroud rangefinders. Zeiss and Goerz attempted in 1911-12 to negotiate an agreement to pool or exchange rangefinder patents, but would not enter into a ten year arrangement such as was sought by Barr & Stroud. The Scottish company believed the Germans sought only to obtain access to Barr & Stroud's coincidence rangefinder patents, rather than a mutually beneficial exchange, and broke off negotiations.⁽³⁷⁾ Barr & Stroud's fears regarding Japan were more complex.

Japan's highly-successful campaign to acquire Western technology during the late nineteenth and early twentieth centuries has been described in many recent studies. Barr & Stroud first began to supply rangefinders and range and order transmission systems to the Imperial Japanese Navy during the mid-1890s, and completed instruments were all inspected at the factory, prior to despatch, by Japanese gunnery experts. From 1902 pairs of Japanese workmen were allowed to work at the factory,

ostensibly to learn about the different stages of rangefinder manufacture, to enable them to repair and adjust instruments purchased by the Japanese Navy. Their eagerness to learn, and the speed with which they acquired the skills of their teachers in the workshops, earned them a great deal of respect and, quite quickly, became a cause for concern.

In January 1907, the company secretary, Harold Jackson, wrote to Barr that the firm's Japanese agents, Messrs Takata, had informed him that their government was unwilling to give any guarantee of orders, but would welcome the setting-up of a Barr & Stroud subsidiary in Japan - at Barr & Stroud's expense. Further negotiations seem to have taken place, because, in May that year, Barr met Professor Czapski of Zeiss, and they discussed the situation regarding Japan. Barr's report of the conversation is illuminating:

Mr Stuart asked Professor [Czapski] if the Japs were to offer you an order on condition that you taught them how the whole thing was done, would you accept it? Certainly not said Professor [Czapski]. They have been at the same game with Z[eiss]. All he would promise would be that they could when the instruments were finished take them to pieces if they liked and also he would teach them to adjust them. Professor [Czapski] also said that if opticians would combine and refine said conditions it would be well, because the Japs are so clever in picking up what they can see. This from London and Jena just when we have had the same experience is *very* interesting. I am very glad we have decided to stick to our old offer.⁽³⁸⁾

This conversation arose at a time when Japan was ordering more naval rangefinders from Barr & Stroud than any other nation, and the firm had to be careful not to alienate the customer while protecting the product from Japanese imitation. In 1914, Japanese representation of the factory was upgraded when the first Japanese inspector took up residence there. The resident inspector was given free access to all parts of the factory where instruments for Japan were manufactured. However, Barr & Stroud were able to exclude him from a building in which the most advanced naval rangefinders were manufactured for the Royal Navy, by referring to Admiralty instructions which forbade foreigners from visiting areas in which vital war work was

undertaken.⁽³⁹⁾ Barr & Stroud continued to use the cloak of national security considerations to continue to conceal their most advanced work in rangefinder development during the 1920s, and the Japanese remained valued customers throughout the postwar decade. It would be interesting to discover, however, if inspectors such as Mr Yamada played any part in the growth of the Japanese optical industry after their return to their homeland.

Barr & Stroud used one other means of protecting their inventions, to great effect. In 1913, with a European war becoming ever more likely, the War Office contacted Barr & Stroud's lawyers, Cowan, Clapperton & Barclay, to insist that the company hand over the rights to some of the most important patents for infantry rangefinders.⁽⁴⁰⁾ Barr & Stroud had every right to feel aggrieved at this demand. Not only had the War Office rejected the firm's original rangefinder in 1889, but when further trials were held in 1907 it had rejected the Barr & Stroud instruments on the grounds of cost, and the Army had adopted the cheaper and inferior Marindin rangefinder instead. Barr & Stroud had been forced to develop their infantry rangefinders without the backing of the War Office, and if the French Army had not adopted Barr & Stroud instruments in 1909, the firm would almost certainly have been forced to abandon the product and leave the market to Zeiss and Goerz. Only in 1911 did the War Office heed the Army's complaints regarding the Marindin rangefinder, and authorise the adoption of Barr & Stroud instruments.

Barr & Stroud were determined not to surrender their patent rights to the infantry rangefinders cheaply. If the patents were offered to the Crown then the War Office could put contracts out to tender, permitting other firms to acquire technical knowledge which Barr & Stroud had acquired and developed without state assistance. Consequently, Barr & Stroud set a high price on their products: for rangefinders of base lengths up to 80cms, they asked for £150,000 plus a 2 per cent royalty on the selling price of every instrument. In 1914 the offer was revised to £30,000 plus a

royalty of 2 per cent for each of the three patents the War Office required. The War Office considered the price excessive, and dropped the matter.⁽⁴¹⁾ Barr & Stroud profited from the knowledge that, to protect their instruments from predatory government departments, an aggressive stand on the price of their inventions was sufficient to ward off bureaucrats. This policy proved effective on several occasions between 1914 and 1945.

Mari Williams' research on the British precision instrument industry suggests that Barr & Stroud was in many ways a typical British company. In other companies, 'instrument design was usually in the hands of a very few individuals who either owned the firm or were closely associated with the owners', and this was certainly the case at Barr & Stroud. 'The pattern of a small number of technically literate designers and owners, together with workshop personnel engaged in a combination of on-the-job training and positive classes', she adds, 'was also apparent in Britain around the turn of the century',⁽⁴²⁾ and Barr & Stroud certainly conformed to this general description. If Barr & Stroud were in many ways a typical firm, how then did they overcome the obstacles to success identified by Roy and Kay McLeod?

Barr & Stroud were not afflicted by the general neglect of technical education and applied research. Where technical expertise was lacking, the firm introduced its own training courses or 'borrowed' the expertise elsewhere. They certainly did not neglect scientific men and research, and were able to raise the capital for investment and research quite easily after the business became successful in the late 1890s, largely by re-investing profits and borrowing modestly from the bank. The company's records reveal that even the smallest job was costed with care, and, unlike the Cambridge Scientific Instruments Co,⁽⁴³⁾ the firm was seldom tempted to reduce profit margins during hard times. Commercial policy and economic expansion were firmly in the hands of the directors, who jealously guarded the firm's rights and aggressively promoted their instruments in any country where they detected a possible market.⁽⁴⁴⁾

Barr & Stroud's success may well be attributed to the fact that, unlike so many British scientific instrument-makers, the company was controlled by innovative engineers and scientists who also developed keen entrepreneurial skills. The enterprise was directed by men with the energy to seek out and adopt the technology they required, and who possessed the business acumen not only to tailor their product to the market but also to use all the means at their disposal to protect their inventions from imitation. Many other British science-based companies possessed scientists and technical expertise of an equal or superior standard to Barr & Stroud, but were far less successful commercially. Perhaps the perceived failures of the British industry owed more to a lack of business expertise than to failings in technical ability.

Footnotes

- 1) For the history of the development of the coincidence rangefinder, see Michael Moss and Iain Russell, *Range and Vision: The First Hundred Years of Barr & Stroud* (Mainstream Publishing, Edinburgh, 1988).
- 2) Letters from Director of Navy Contracts to Barr & Stroud, 10 June 1892 and 10 January 1893. Barr & Stroud to Cowan, Clapperton & Barclay, 20 November 1913. All letters cited here are preserved in the Barr & Stroud Archive.
- 3) Barr & Stroud Private Ledgers, Nos.3 and 4. *Engineering* 1 August 1919, p.133.
- 4) Roy and Kay McLeod, 'War and economic development: government and the optical industry in Britain, 1914-18' in J M Winter (ed), *War and Economic Development* (Cambridge University Press, Cambridge, 1975).
- 5) See, for example, Robert Fox's review in *The Times Higher Educational Supplement*, 9 February 1990, of Crosbie Smith and M Norton Wise, *Energy and Empire: a biographical study of Lord Kelvin* (Cambridge University Press, Cambridge, 1989).
- 6) For an outline of Barr's academic career, see C A Oakley, *A History of a Faculty* (University of Glasgow, 1973) and the obituary by J W French in *Proceedings of the Royal Philosophical Society of Glasgow*, LX 1931-2, p.78.
- 7) Stroud described his academic career in *Apologia Pro Vita Mea*, a booklet published privately in 1935. He also wrote of the early days of his collaboration with Barr in *Early Reminiscences of the Barr & Stroud Rangefinder* (c.1937).
- 8) Barr to Worshipful Company of Ironmongers, 17 April 1906.
- 9) Barr to Frank Heath, 18 December 1916.
- 10) Barr to H S Hele Shaw, 24 August 1915. He referred to two Doctors of Science, ten Bachelors of Science, and four men with good qualifications from universities and colleges, augmented by seven other scientists taken on for the duration of the war.
- 11) Charles More, *Skill and the English Working Class 1870-1916* (Croom Helm, London, 1980), p.24. *Engineering*, CIII, 1917, p.583
- 12) *Glasgow Herald*, 23 March 1917, p.7.
- 13) Stroud to Barr, 24 January 1907.
- 14) Barr & Stroud to Adam Hilger & Co, 11 December 1895. EBB (Eric Brash), *Random Reflections* (unpublished ms, 1975).
- 15) Barr to C P Goerz, 4 March 1898. J Martin Strang, *Barr and Stroud Ltd: A History* (unpublished ms, 1969), p.56.
- 16) Brash, *op.cit.*, *Engineering*, 4 May 1906.

- 17) Stroud to Barr, 27 January 1897. Stroud also wrote 'I don't wish to run down H, but you must remember that he is a Teuton and a Hebrew, I won't say quite a G _____ J _____'.
- 18) Barr & Stroud to Strang, 26 February 1912.
- 19) Barr & Stroud to Professor Gerschun, 6 November 1913.
- 20) Strang to Barr & Stroud, 15 April 1913. Strang, *op.cit.*, p.59.
- 21) Brash, *op.cit.* Strang, *op.cit.* Barr & Stroud to the Directors of the Optical Engineering Department, Imperial College of Science and Technology, 8 October 1919.
- 22) Barr & Stroud to Adam Hilger & Co, 13 November 1914, and to Maurice Loir, 17 December 1914.
- 23) Barr & Stroud to Maurice Loir, 23 June 1916.
- 24) Strang, *op.cit.*, p.101.
- 25) R S Whipple in *The Daily News*, 19 January 1922.
- 26) Strang, *op.cit.*, pp.101-5. *Engineering*, 29 August 1919, p.264.
- 27) Barr to Jackson, 21 April and 8 May 1896.
- 28) J W French, obituary, *op.cit.*
- 29) *Engineering*, 4 May 1906 and 1 August 1919.
- 30) Barr & Stroud to William Taylor, 3 June 1903.
- 31) Strang, *op.cit.*, p.8. See also p.19 for an evaluation of the importance of Patent No.13507 of 1893.
- 32) Barr to Lord Kelvin, 24 October 1892. Barr to Jackson, 9 May 1907. Alexander Gleichen in *The Theory of Modern Optical Instruments*, HMSO London 1921, p. 203, notes that Zeiss were the first to develop the 'inverted lower field' system for coincidence rangefinders, but Barr & Stroud succeeded in patenting it first (1462 of 1903).
- 33) A file of letters and memoranda concerning the legal action proceedings in Germany, 1912-13 is preserved in the Barr & Stroud Archive. See Moss and Russell, *op.cit.*, pp.60-3.
- 34) There is evidence to suggest that the Russians were about to adopt the Zeiss naval rangefinder on the eve of the First World War, and after 1908 the US Navy favoured a stereoscopic rangefinder made by Bausch & Lomb under a Zeiss licence.
- 35) Gerschun's company was called The Russian Society for Optical and Mechanical Industry. The French subsidiary, in Saint-Cyr, Paris, was Societe Barr et Stroud, and the Austro-Hungarian companies were Barr und Stroud GmbH and Barr es Stroud es Tarsa.
- 36) Barr & Stroud to Baird, Smith, Barclay and Muirhead, WS, 1 February 1945.

- 37) Moss and Russell, *op.cit.*, pp.60-3.
- 38) Barr to Jackson, 9 May 1907.
- 39) Strang, *op.cit.*, p.138. Barr & Stroud to Secretary of the Admiralty, 19 March 1913.
- 40) Barr & Stroud to Cowan, Clapperton & Barclay, 20 October 1913.
- 41) Barr & Stroud to Cowan, Clapperton & Barclay, 18 December 1913 and 13 and 14 February 1914.
- 42) Mari Williams, 'Training for Specialists: The Instruments Industries in Britain and France, 1890-1925' in R Fox and A Guiginni (eds), *Education and Industrial Performance in Modern Europe* (Cambridge University Press, Cambridge, forthcoming)
- 43) See M J G Cattermole and A F Wolfe, *Horace Darwin's Shop: A History of the Cambridge Scientific Instruments Company, 1878-1968* (Adam Hilger, Bristol, 1987). Barr & Stroud Balances, 1906-12 reveals that the firm added 100 per cent on net wages and 20 per cent on materials for oncost.
- 44) Archibald Barr and Harold Jackson emerge from the firm's correspondence as the dominating directors on business policy prior to 1914.