ERNST ABBE (1840-1905)

THE ORIGIN OF A GREAT OPTICAL INDUSTRY

THE great optical works of Zeiss in Jena, employing round about ten thousand people, is one of the leading firms of the world in the production of fine optical apparatus. This firm owes its high scientific standard, its economic efficiency and its growth to the creative genius of Ernst Abbe. The optical works of Carl Zeiss were originally the workshop of a skilful mechanic producing the necessary equipment for the laboratories of a small provincial university. The scholar Abbe gave to the mechanic Zeiss the results of his original scientific research. This was then leading to new methods in the design of optical apparatus, especially of microscopes. Those new instruments were of extraordinary perfection, so that an enormous demand from every part of the world made possible an extremely rapid expansion of the business. When after twenty years of growth, the well-known company had developed, Abbe renounced all his rights and gave the firm of Zeiss a constitution which has enabled it to survive its creator and to continue into our own turbulent times.

Ernst Abbe was born on January 23, 1840, as the eldest child of a poor workman. It was beyond the means of his father to provide a higher education for him. The boy started in an elementary school. Later, the generosity of the employers of the father secured a scholarship at a higher school for the boy, who early showed signs of an unusual intelligence.

In 1857, Abbe began his studies in Jena, which was at that time still a small town with a population of less than seven thousand. Jena was living then in idyllic isolation from the great world; no railway touched it. The university was incredibly small. Its faculty of science consisted of three professors only, who were paid an average salary of £30 a year. Abbe studied in poverty; his father could provide very little for him. He augmented his income by giving private lessons. It is not surprising that he had to live in the cheapest quarters, and it was no unusual event for him to replace a hearty meal by a pipe of tobacco. But in spite of all hardships, the two years in Jena meant a happy time for Abbe, who there acquired a knowledge of the fundamentals of the mathematical and physical sciences.

In 1859 Abbe continued his studies in Göttingen. He left Göttingen in 1861 with a Ph.D. The next two years were spent as lecturer to a private physical association in Frankfort. Although this engagement for popularizing science was not to the taste of a personality like Abbe, it brought him social contacts which proved to be important. When, in 1863, he was admitted as an unpaid lecturer at the University of Jena, a rich merchant of Frankfort enabled him to start his academic career by a personal grant sufficient to cover all his initial expenses. During his early years Abbe was kept busy with running practical classes and with preparing and delivering lectures. This was the beginning of his activity as a university teacher, which was destined to last for thirty-five years until 1898. He became associate professor in 1870 and full professor in 1878. He refused the most tempting offers of appointments in other universities, and spent the whole of his time in Jena. During the course of time he gradually dropped his mathematical lectures, specializing more and more in physics and eventually in optics only. His last lectures were of the widest interest, and were attended by the staff of his industrial co-operators and by distinguished scholars from all over Germany. From his early years he was closely attached to the professor of physics, K. Snell, whose daughter Elise he married in 1871.

While still a young lecturer, in 1866, Abbe came in close contact with Carl Zeiss. The little workshop of Zeiss was then successfully producing simple microscopes which could well compete with other instruments of this kind. All these microscopes were made according to a practical tradition developed by empirical methods. Abbe was the first to introduce scientific methods and systematic design. He recognized that the magnification of an even ideally corrected microscope was limited. There were no prospects whatsoever of resolving optically two parts of an object separated by less than about half the wavelength of the illuminating light, that is, about 0·0003 mm. This is of the greatest importance, because it indicates clearly that the only possible way of developing the microscope was by elimination of the optical errors within the limitation of reasonable magnification. Two lines of attack were available: first, the geometrical shape and the arrangement of the refracting lenses; secondly, their physical properties, that is, their refraction and dispersion. Abbe made fundamental progress in both directions. His new results were at once applied in the optical workshops of Zeiss.

The new microscopes were far better than anything on the market, and thus the business of Zeiss's workshop expanded rapidly. Soon after (in 1876), the sale of the three thousandth microscope was celebrated, and in the same year a contract was concluded making Abbe an equal partner in the business. The glass sorts which were commercially available and which Zeiss used as a raw material were very much alike. Abbe tried to interest leading glass manufacturers in the production of new glass sorts with different optical characteristics. The small quantities of glass consumed in the microscope industries, however, did not guarantee a reward for these expensive experiments. In an interesting lecture during the London international exhibition in 1876, Abbe tried to interest scientific societies in his problem, but he was unsuccessful.

Abbe's appeal, however, was taken up by a young glass manufacturer, O. Schott, who was able to see beyond the immediate small practical prospects towards the great scientific and technical importance of the problem. Schott's father owned a small factory producing plate-glass in eastern Germany. Abbe persuaded Schott to move to Jena and to start a glass technical laboratory with him. New glass sorts—especially borate and phosphate glasses—were developed there, opening up new prospects for the optical industry. From this laboratory arose the famous Jena glass-works. In 1884 these glass works were started with twelve employees; the Ministry of Finance of the State of Prussia secured a subvention for the first two years. In the years which followed, the Zeiss works took up the manufacture of all kinds of optical gear, including, besides microscopes and telescopes, fine photographic objectives, prism-telescopes, telecomparators and periscopes, which are all produced in relatively large quantities. Of more specialist interest is a large number of types of other apparatus which were originally designed by Abbe, for example, spectrometers, refractometers, spherometers, apertometers and many more.

In the meantime, the firm of Zeiss expanded year by year. In 1899, a thousand workers were employed. At the time of Abbe's death in 1905, the number of 1,500 employees was passed. Before the War of 1914–18, six thousand employees were engaged in the works. Owing to the heavy demands for optical gear for war purposes, this number increased temporarily to nearly ten thousand, but it dropped to a half this number immediately after the War. Since then, the number of employees has gradually increased again, and to-day it has probably passed the former peak-level.

Of Abbe's scientific papers his discussion on image production in microscopes is still of great interest. At the age of twenty-eight, he formulated his famous sine law. A few years later, in a fundamental theory, he demonstrated the connexion of the projection of optical images with the diffraction of light waves. According to his theory, the aperture of the microscopic objective has to be large enough to collect an essential part of the diffraction pattern.

It is remarkable how quickly Abbe's discoveries became known in England. He was in the closest contact with English men of science—Crisp, Mayall, Wenham, Lettsom and Stephenson. A correspondence of more than a thousand letters with these English friends is preserved. All of them showed the greatest affection and admiration for Abbe. Stephenson wrote of him:

> "Objectives and their laws lay hid in night,
> God said: 'Let Abbe be, and all was light.'"

Abbe had worked for fifteen years managing and directing the great optical firm when, in 1891, he gave it its well-known constitution. He renounced all his property rights, making himself an employee of the great organization. The fact that one of the statutes of the constitution limits the maximum salaries in this firm to ten times the amount of the minimum wage paid, shows that the remuneration of the directors cannot be excessive. The Zeiss Institution is registered as the legal owner of the company, no shares being issued. Care and custody of the Institution is entrusted to the Ministry of Education of the country. The undertaking, however, is not subject to the control of the Government administrator, but solely to the provisions of the charter, and the function of the official administrator is to see that these provisions are carried out. The works are controlled by a board of three or four directors who have to be elected by the Minister of Education from the scientific staff and from the technical and administrative employees of the company. All the earned income is received and distributed by the Zeiss Institution. In these circumstances, the employees enjoy extraordinary benefits and their health and social welfare are first considerations.

Abbe was a true Christian, though he was not a member of any official church, and, declaring himself a dissenter, he even avoided any contact with organized religion. In opposition to many relatives and to his father-in-law, he refused the religious ceremony for his marriage and the christening of his two daughters. Politically, Abbe may be called a liberal; he joined in his later years a liberal democratic party. He disliked any extreme nationalism; he was known even to be in opposition to the policy of Bismarck. Any racial prejudice of 'blood and soil' was quite alien

to his mind. His closest co-operator and friend, S. Czapski, whom he chose as his successor in leading the great organization, was of purely Jewish descent.

Later in life, Abbe suffered from insomnia, which he tried to overcome by an excessive use of drugs. In the end his nervous system showed all the signs of exhaustion and at the early age of sixty-three he had to retire. Two years later, in 1905, he died from pneumonia.

It will be widely agreed that the firm of Carl Zeiss occupies the first place among the optical firms of the world. This distinction is merited on the ground of the size of the firm and the variety of its products, coupled with the general excellence of its work. Its reputation for many years has been so high as to have given rise to a superstition that any Zeiss instrument is better than a corresponding instrument made by any other firm. In passing, it should be said that this superstition has many adherents in Great Britain, though it is unquestionably and inevitably false. Just as other firms have imitated Zeiss instruments, so a number of the finest Zeiss products are more or less copies of designs introduced by other manufacturers; indeed, the firm makes a special point of knowing exactly what its rivals are producing, and to this end makes a practice of purchasing on the open market a sample of all new designs of optical instruments. But the fact that the lead in particular instruments changes at times from one maker to another in no way detracts from the many valuable contributions made by Zeiss to the progress of optical science.

The foundations of the firm's greatness were laid by Abbe. Its reputation in the first place was built on the notable improvements he introduced in the microscope. It is interesting to note that from the beginning he followed the plan, which has since proved so valuable to the firm, of publishing papers in scientific journals.

Abbe's theory of image formation in the microscope has been of great assistance to large numbers of microscopists, though many physicists find Rayleigh's treatment of the subject more fundamental and convincing. Among the new glasses produced in an endeavour to secure better microscopic images were some which led to greatly improved photographic lenses—the anastigmats—Zeiss being one of a number of firms to bring out new designs at about the same time.

Although these new instruments were calculated trigonometrically on lines laid down by Abbe, whose aim was to use computers with limited mathematical knowledge, the problems involved were considered in a general way in a treatise planned by S. Czapski. This and a number of later volumes, notably those due to M. von Rohr, are among the best modern works on optics and have added to the prestige of the firm.

The prosperity of Zeiss to-day is in no small measure due to the form of control set up by Abbe—there are no shareholders and no family claims, so that it has always been possible to secure the finest machine equipment as well as to advertise effectively, and to select able men for responsible posts. The great size of the business, which in part was brought about by the large continuous demand for military instruments for the German Army, has enabled research and development to be carried out on a scale impossible in much smaller businesses. By way of illustration, the firm studied the problems that would be presented if maps were to be prepared from photographs. The outcome was the construction of a series of instruments, used to-day in several countries, for mapping from aerial photographs. Some of these instruments are of extreme complexity; despite their great interest and the ingenuity shown in their construction, they have found less favour in Great Britain than in other countries. As another example, possibly built largely for their advertising value, the Zeiss planetaria may be mentioned.

In recent years the firm of Zeiss has built a number of beautifully designed and made instruments of great value to engineers in setting up difficult work accurately, and in other ways. A number of laboratory instruments has also been marketed, but some of these show a tendency which ought to be discouraged. Instead of measurements being recorded on scales which can be defined apart from the instrument, readings are obtained which must be compared with others made on the same type of instrument. Apparently conversion to values obtained in other ways can only be made if the Zeiss apparatus is purchased to experiment with. This course appears to have been adopted deliberately: it tends to create a closed market for instruments in fields where one or two leading investigations have been carried out with Zeiss apparatus. The remedy is clearly in the hands of scientific workers.

This note must not close without reference to the equipment made for ophthalmic opticians and to the firm's spectacle lenses. Apart from such special products as contact lenses and cataract lenses, the Punktal series of lenses is designed to give the best possible vision over a large field with the most varied kinds of visual correction. This is a service of great humanitarian value. The moderate price of these lenses, which are highly finished, shows that the firm can manufacture a wide variety of aspherical surfaces with good accuracy by mass-production methods.