Remarkable Engineers

Engineering transformed the world completely between the seventeenth and twenty-first centuries. *Remarkable Engineers* tells the stories of 51 of the key pioneers in this transformation, from the designers and builders of the world's railways, bridges and aeroplanes, to the founders of the modern electronics and communications revolutions. The focus throughout is on their varied life stories, and engineering and scientific detail is kept to a minimum. Engineer profiles are organized chronologically, inviting readers with an interest in engineering to follow the path by which these remarkable engineers utterly changed our lives.

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From Riquet to Shannon

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Preface

This work is intended for those who would like to read something, but not too much, about the life stories of some of the most remarkable engineers born since the Renaissance. There are five or six profiles in each of nine chapters, making 51 engineers altogether. The emphasis is mainly on their varied life stories, not so much on the details of their achievements. Although I knew none of them personally – most of them died long before I was born – I know something of their works. In France I have sailed along Riquet's Grand Canal de Languedoc, been impressed by the fortifications of Vauban and ascended the Eiffel tower. In England, I have seen mighty beam engines at work, and in museums. I have ridden on the footplates of steam engines, and I have frequently used Brunel's Great Western Railway. In the United States, I have walked across Roebling's Brooklyn Bridge and have inspected the Wrights' biplane in the Smithsonian National Air and Space Museum. In the Second World War, I had first-hand experience of the V-1 flying bomb and the V-2 ballistic missile. In Russia, I have flown in one of Tupolev's aircraft. My house is full of electrical appliances, as is the car I drive. I write this book on a laptop computer, the descendant of Babbage's analytical engine, which was to be powered by steam. Nowadays we live in a world dependent on the work of generations of engineers.

Prologue

Most people know what an engineer is without being able to produce a definition. We say that someone has engineered the solution to a problem, and the dictionary allows this by defining an engineer as someone who contrives, designs or invents, with the same root as genius, a word whose meaning has varied much over the years. This covers not only traditional types of engineering, building bridges or railways, for example, or cars or aeroplanes, but also modern types, such as software engineering. Engineering overlaps with science, on the one hand, and with technology, on the other. There are many specialities: civil (as opposed to military) engineering, mechanical, electrical, medical, sanitary, computer, etc., are in common use. Feibleman (1961) has attempted to distinguish between these, but the distinctions matter little for my purposes. I give several examples of people who might be classified as applied physicists, others who might be regarded as electrical technologists, but they are still engineers. Although I have written about some of these engineers before (James, 2004; 2009a; b), the profiles here are not the same.

The profiles that follow are arranged chronologically by date of birth, so that when read in sequence they convey in human terms something of the way in which engineering developed. In writing this book, I had in mind the reader who, like myself, is interested in engineering but is not necessarily familiar with the history of the subject. To avoid being too discursive, I have focused in this book on certain themes. At first the emphasis is on civil engineering, the building of fortifications, canals, bridges, tunnels and so on. Then comes the development of the steam engine and the railway age. Electrical engineering became increasingly important, leading to the development of radio and television. The automobile dates from the early twentieth century, as does aviation. Finally, there is information technology and space research. Even so, certain forms of engineering had to be left out if this book was to be of a reasonable length. Some profiles are much shorter than others, mainly due to the lack of suitable biographical material.

Although I begin with two examples from the seventeenth century, most of my remarkable engineers date from the eighteenth, nineteenth and twentieth. It is hard to identify engineers, however remarkable, before the time of the Renaissance. We know the names of the architects of some of the outstanding buildings of the Middle Ages, but not much else. Bridges, fortifications, docks and canals were built, major drainage schemes were

successfully completed, but we know little about the people who were responsible. Polymaths like Leonardo da Vinci and Michelangelo Buonarroti attracted the attention of biographers but these were exceptional. From the time of the Renaissance, more information is available, particularly for architects. Architecture used to be regarded as part of engineering, or vice versa, but engineering as a profession is a later development. In France, for example, the two professions of architect and engineer, which had previously been quite close, began to separate in the eighteenth century.

In pre-Revolutionary France, the centralized state controlled entry into the profession. The Corps Royal du Génie in 1817 was responsible for fortifications while the similar Corps des Ponts et Chaussées, which was responsible for the maintenance of highways, included several architects among its members. To ensure a good supply of civil engineers, the Ecole des Ponts et Chaussées was founded in 1747, while the Ecole de l'Artillerie et du Génie in Mézières, founded the following year, trained military engineers. These rival corps were often in competition with each other in the eighteenth century, especially over the desire of engineers belonging to the Ponts et Chaussées to work on canals and on the planning of docks, which traditionally had been the prerogative of those in the Génie. Entry to these military organizations was more or less restricted to members of the nobility. After the revolution, the Ecole Polytechnique was founded, to which entrance was not so restricted. Other countries followed suit, for example, the German Technische Hochschulen and the British polytechnics were modelled on the Ecole Polytechnique.

Until the eighteenth century, Britain was a backward country in engineering, compared with, say, France or the Netherlands. The Industrial Revolution reversed the situation. Britain led the way with the invention of the steam engine and the construction of railways. Having been trained on the job, in a business context, the British engineers were more empirical and more alert to questions of profit than were the French, while the French engineers attained a deeper mastery than their British counterparts of questions having to do with the rational exposition of technical knowledge. Telford and Rennie learned French in order to read treatises that had not been translated into English. France exported expert engineers like Marc Brunel and Charles Vignoles, some of whom settled in Britain. Over a dozen British engineers are profiled in this book but it would be easy to find as many more with equal claim.

In the early days of the Republic, the United States was primarily an agricultural country, but after the Civil War it began to surpass Britain in

certain industries, and enjoyed a golden age of invention. In the 40 years or so before 1914, the advance in technology slowed down in Britain while it speeded up in America and in Germany. There was a technological lag in both the old industries and in the new but other factors were also important (see Habakkuk (1962), for example).

In Britain, and to some extent in the United States, it was left to the budding engineer to find his own way of entering the profession, usually by serving some kind of apprenticeship. This survival of the medieval guild system was the well-recognized means for the training of mechanical engineers, especially. A young man, very rarely a woman, would seek a master, who would probably test him in some way. He would sign articles, a set of rules, and for a period of years would learn a trade, being paid little or nothing. Usually, a good master might have several apprentices at a time. Traditionally, when an apprentice had served his time he stood a treat for the others. He might then travel around, picking up work wherever he could. Eventually, he would settle down and practise his trade in one place. Those who could afford it might pay a premium for their training, usually in a leading firm. However, engineers were also trained in military schools: in Britain there was the Woolwich Academy and in the United States, West Point, but this was less important than in France.

I have chosen subjects from a wide range of countries, namely Croatia, France, Germany, Hungary, Ireland, Italy, Russia, Scotland, Sweden, the Ukraine and the United States. Many of them migrated from the country of their birth to another country where they spent the major part of their career. Thus, Watt, Rennie and Baird moved to England from Scotland, the senior Brunel from France, Marconi from Italy, Gabor from Hungary; Roebling moved to the United States from Germany, Ericsson from Sweden, Bell from Scotland, Tesla from Croatia, Zworykin from Russia and von Braun from Germany. Oriental countries are not represented, mainly due to the lack of suitable biographical material. I have no doubt that there were remarkable Chinese, Indian and Japanese engineers, for example. In the case of China, we are fortunate to be able to consult the multi-volume *History of Science and Civilisation in China*, written by Joseph Needham (1954–2004) and his associates, but not much is on record about the individuals who were responsible for the advances in technology, which in many cases later spread to the West.

Women were excluded from the professions until relatively recently: engineering was no exception, rather an extreme case. As a result, it was difficult to find suitable subjects to profile. The problem is both the

shortage of women engineers and the lack of sufficient biographical information about those we know of. In the end, I chose the British electrical engineer Hertha Ayrton (1854–1923) and the American electrical engineer Edith Clarke (1883–1958), but there were certainly others. Mechanical engineering does not seem an obvious vocation for a woman, and yet Victoria Drummond (1897–1980) made a successful career as a marine engineer, vividly described in her biography (Drummond, 1994). In nineteenth-century America, we find the sanitary engineer Ellen Swallow Richards (1842–1911) and the industrial production engineer Lillian Gilbreth (1878–1972). There were many cases where the wife contributed to the husband's work. Even where she worked independently, as did the wives of William Ayrton and Lee de Forrest, there was a tendency to attribute what she achieved to her husband. There is not the same shortage of women inventors – windscreen wipers, laser printers and bullet-proof vests were all invented by women – but few of them would be described as engineers.

A special issue of the tenth volume of the journal *History and Technology* describes the situation as it was in a number of different countries. Sally Hacker (1990), in *Doing it the Hard Way*, is mainly concerned with the situation in America at the end of the twentieth century. She maintains that the need for mathematical knowledge is an important factor, but this seems doubtful. Some knowledge has always been required but until fairly recently this could be learnt at school. Today, engineering mathematics is a highly technical subject but specialists are available for consultation. Moreover, many studies have shown that, broadly speaking, women are just as good at mathematics as men. However, Hacker is surely right when she says that engineering, like other professions, has a strong male tradition, which is not easily overcome. She quotes research that shows that in present-day America engineering contains the smallest proportion of females of all the major professions, and projects a heavily masculine image, which is hostile to women. Women are not easily accepted as colleagues by men in the workforce.

The position of black people in the United States was anomalous, to put it mildly. By the 1790s, there were nearly 700,000 Africans in the country. Some had been born free, others had earned their freedom fighting in the revolutionary war, and still others had bought freedom for themselves and their families. But 90 per cent were still held captive. In his youth, Thomas Jefferson stated, '[blacks] are much inferior, as I think one could scarcely be found capable of tracing and comprehending the investigations of Euclid,' although he changed his opinion later. In New Orleans, freemen

were not permitted to send their children to the public schools and had to get permission to walk in the streets of the city. The State of Louisiana required both free and enslaved African-Americans to carry passes; the United States Supreme Court decided that blacks had no civic rights. Before the Civil War, a slave was not a person, just personal property of his or her master, and could not receive a patent for any discovery or invention. Nevertheless, slaves invented devices to make their work more efficient: for example, Eli Whitney's famous cotton gin was a development of such devices made by slaves for cleaning cotton.

One of the problems in the selection of subjects is that engineers seldom work alone. The Wright brothers seem inseparable, and so they share a profile. Several engineers, for example Rennie, Stephenson, Brunel and Sperry, had sons who carried on their work. There was usually a team of assistants, some of whom performed important tasks. Nowadays, there is almost always a firm to provide essential services. Another problem is that the person who is usually given the credit is not an engineer. The Suez Canal, for example, is surely one of the great engineering feats of the nineteenth or any century. Ferdinand de Lesseps is given the credit for it but he was a professional diplomat and businessman, not at all an engineer, as his subsequent failure in the case of the Panama Canal makes all too clear. In my first profile, which follows, the situation is not so clear-cut. Riquet was responsible for the Grand Canal de Languedoc, financed it and planned the route, but it was the Italian-trained engineer who constructed it, and others were involved as well.