

THE CEDARGROVE SERIES OF
DISCOURSES, MEMOIRS AND ESSAYS

#25/2013

THE HISTORY OF ENGINEERING: AN INTRODUCTION

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May 2013

Abstract

This paper was presented originally as a talk by the author to the SAGE Group of the Kiwanis Club of Ottawa on 27 June 2012. It was designed for an audience whose senior-age members included few engineers and had had no previous exposure to engineering and its history. It was not seen originally as part of the Cedargrove Series. Also, much of its content has been included in other papers in the Series. However, second thoughts about its usefulness as introductory 'stand alone' - yet substantive - material for other non-engineering groups changed this view.

The paper deals first with some definitions and some ancient history, and moves very quickly through the centuries, paying particular attention to Canada. It then has some things to say about engineering history in different regions of the world, again with special reference to Canada. The original talk was illustrated with slides, some of which have been reproduced at the end of the paper.

About the Series

Principally, the Cedargrove Series is intended to preserve the research, writing and oral presentations that the author has completed over the past half-century or so but has not yet published. It is, therefore, a modern-day variant of the privately-published books and pamphlets written by his forebears, such as his paternal grandfather and grandmother and his grandfather's brother John.

About the Author

He is a graduate in mechanical engineering and the liberal arts and has held technical, administrative, research and management positions in industry in the United Kingdom and the public service of Canada, from which he retired over 25 years ago.

He became actively interested in the history of engineering on his appointment to chair the first history committee of the Canadian Society for Mechanical Engineering in 1975 and has been active ever since in research, writing and editing historical material on behalf of that Society, the Engineering Institute of Canada and the Canadian Society for Senior Engineers. He has also served as president of CSME and EIC.

To those of you who are engineers, my apologies in advance. I may not mention your favourite piece of engineering history. But there's always the question period!

I brought my own piece of engineering history with me today. The slide rule I started with 67 years ago. But I haven't used it in over 30 years!

It seems that, these days, the study of history, generally, is being largely ignored - and the engineering part of it even more so. Not many professional historians are working in the field, and the amateurs are very few indeed.

But actually, evidence of the *Canadian* engineering part is all around us for all or most of the 24 hours of any day.

For example, as well as what you can actually see, there are the books written by the likes of Robert Legget, Norman Ball and Robert Passfield. (I have brought a sample of such books with me this morning; please feel free to browse.) There are also biographies of people like Sandford Fleming, the Shanly brothers and C.D. Howe. There are several about the building of the CPR and about Canadian aviation. There are company histories of, for example, SNC and the Montreal Engineering Company. And the *Canadian Encyclopedia* has sections on the history of engineering and technology. There are articles in magazines and in publications by engineering societies and museums. But you won't get much help from the movies. However, there are several TV channels - such as TVO, Discovery and History - that have engineering shows. But there are no such fictional shows to match the medical ones, except perhaps MacGyver - although his exploits are erroneously attributed to 'science.' And if all else fails, you can appeal to the Internet.

When I speak of *engineering* I am not speaking of science and/or technology. To me, these are bodies - storehouses, if you like - of knowledge, of information. Engineering, on the other hand, is an activity that results in the building of the likes of the Parliament Buildings here in Ottawa, or the Welland Canal, the CN Tower, and the Lion's Gate Bridge, the manufacture of automobiles, aircraft and paper, and the processes that produce food, pharmaceuticals and gasoline. Engineering has a number of sub-activities, such as design, development, construction, research, operations and education. It has a lot to do with experience, safety, and risk. It also needs customers and sources of finance, and it needs to be marketed.

The activity of engineering is a lot older than the use of its name. The earliest manifestations of it - very many thousands of years ago - were the discovery that some materials are harder than others and could be used to make tools and weapons, the discovery of fire, and the discovery that fire's heat could turn iron and lead ores into usable materials. Along the way, our forebears developed uses for wheels, levers and wedges. They learned to dig canals for irrigation and the supply of water for other purposes, to use horses, oxen, camels and other

animals to draw ploughs and to do other kinds of work for them.....and to make glass, and sails for boats.

Closer to our times - only a few thousand years ago - the Sumerians drained the marshes along the Euphrates River and the Egyptians built their pyramids. A little later, the Romans built bridges, aqueducts and water systems and the Chinese built their Great Wall. Speaking of the Romans, around the first century BC, they discovered that *pozzolana* volcanic ash made excellent concrete that could even be used under water. And in the first century AD Emperor Vespasian ordered the construction of the enormous Colosseum in Rome.

The Middle Ages lasted from the 11th to the 14th centuries AD. In Europe, at this time, living was not easy. Disease decimated populations and wars took further tolls on human life. Yet these were times during which some magnificent structures were built - principally fortresses and houses of worship. These were the days of the master builders, who were both engineers and architects, as well as the first use of the term *engineer* in association with the design and construction of fortresses and weapons of war. They also saw the development of water-driven mills, flying buttresses, large mechanical clocks and printing.

Then came the Renaissance, which might be regarded principally as an Italian phenomenon. It coincided with the disappearance in Europe of slave labour and the development of mechanical devices to replace it. Its best-known *engineering* name is perhaps Leonardo da Vinci, but there was also Brunelleschi, Palladio, Vauban and Galileo. And Georg Bauer wrote, under the pen-name of Agricola, his famous book, *De Re Metallica*. It was also the age of discovery - in particular, of North and South America - and the beginning of the transfer of technology to them from Europe.

Speaking of this transfer, it is important to remember that people who were not living in Europe or in the Near East before these times - in Asia and Africa as well as the Americas - had to develop their own engineering and engineers.....and they did so.

The next significant period in the history of engineering is the Industrial Revolution, which I prefer to divide into three and to bring it up to the present time.

The First Revolution lasted from around 1750 until 1850. It was mostly a British phenomenon, based on the increased and more efficient use of steam and the beginning of railroads. It was the time during which a lot of canals were built in Europe. The use of iron was also prominent. The first iron bridge was completed at Coalbrookdale in Shropshire, England, in 1779. Then there was the development of machine tools by Maudslay, Whitworth, Nasmyth and others. France made a special contribution to this Revolution through developments in engineering education. And John Smeaton, an Englishman, is usually credited with being the first to call himself a *civil* engineer, in contrast with a *military* one.

The Second Revolution lasted from 1850 until the end of World War II. It was around the middle of this period that the United States and Germany became the foci for it, displacing Great Britain. Its principal activities were centred on the rapid growth of railroads and shipping, and the switch from iron to steel. It gave birth to electrical and chemical engineering; also to the steam turbine, the automobile, the aeroplane and large energy-generating plants, as well as large cities with extensive transportation, sewage and water systems - and the weaponry needed to fight two World Wars. On the negative side were the various economic 'recessions' and 'depressions' - and especially the 'great' one of the 1930s.

The Third Revolution, which began after World War II ended, is still in progress. It has been driven by air and space engineering, even larger cities and their systems, electronics and new kinds of chemicals, by the computer, and now by hand-held communications devices and the Internet. It has benefitted from some significant increases in research and development, world-wide. On the other hand, it has given rise to problems associated with climate change, waste disposal and instantaneous world-encompassing communications.

The first Canadian 'engineers' were said to be the beavers, who felled trees and built dams and lodges with underwater entrances. However, in real terms, the Aboriginal peoples were the first. They dealt with fire and the use of metals, with the problems of survival in our climates, with the trapping and growing of food, with defence against both human and animal enemies, and with travel across long distances.

When the Europeans did begin to arrive in Newfoundland and Eastern Canada in the 16th and 17th centuries, they brought their own technologies with them. But they still had much to learn about survival in unfamiliar and obstacle-filled territory from experienced Aboriginals. Nevertheless, they introduced - for example - new kinds of fortifications, water-driven mills, and the skills of the mechanic and the shipwright.

The Canadian colonies almost missed participating in the First Industrial Revolution. However, changes brought about by the Treaty of Paris of 1763 and the American Revolution that followed brought more settlers to Canada, with new skills, enterprise and different imperatives in trade.

Canada was better able to participate in the Second Revolution. It had a growing number of engineers to get the work done. The country's agricultural, mining and other natural resources were developed significantly, as were public utility services associated, for example, with water and electricity supplies. Bridge-building accompanied the building of railroads, of which the Intercolonial to the east and the CPR line to the west were the most spectacular. And especially as a result of the World Wars, Canada advanced its manufacturing industries, although not to the same extent as its neighbour to the south.

The Third Revolution began when Canada had emerged as a significant participant in the world's engineering activities. On the one hand, the primary and secondary industries prospered through trade. On the other, support for the further education of war veterans in fields such as engineering, as well as the arrival of immigrant engineers, brought further increases in the country's engineering capabilities.

Since the War ended, Canada has built the first nuclear reactor outside the United States and was the third nation to send a satellite into space. The St. Lawrence Seaway was built in partnership with the United States. There have been several very large hydro-power projects, such as James Bay and Churchill Falls, as well as the development of the oil industry in Alberta. A number of spectacular buildings and bridges have been constructed, such as the CN Tower, the *Skydome* and the Confederation Bridge connecting Prince Edward Island with the mainland. And the *Canadarm* has played a vital part in the building of the International Space Station.

Let me now show you a few examples of the engineering that has been done around the world during the past 2500 years - up until the early years of the 20th century. Not included, however, will be such well-known ones as the Eiffel Tower, the Rideau, Suez and Panama canals, the Victoria, Brooklyn, Québec and Sydney Harbour bridges, the *Titanic* and the *Queens*, the pre-World War I battleships and the post-World War II nuclear plants and earth satellites.

To the Far East and South America first.....

The oldest example I want to mention is the Great Wall of China, probably the largest construction project in history. Starting with a series of small walls in the 5th century BC, the work continued for something like 1800 years. The length of the actual walls built has been reported as more than 20,000 km, including 12,000 km recently discovered.

Next comes Angkor Wat, a temple complex in Cambodia built by King Suryavarman II early in the 12th century AD as his state temple and capital city. At its centre stands a group of towers of rather extraordinary construction and decoration.

In nearby Bhutan there is the so-called Tiger's Nest, a monastery located high on the side of a precipitous cliff about 900 metres above the Paro Valley. It is reached by animal transport and a stairway. The original monastery was a cave, in use since the 8th century AD. The present temple complex was built around the cave in the 1690s.

Then there is Machu Picchu, one of many Inca sites in the Andes mountains, inland from the present Peruvian capital of Lima, and 8,000 feet above sea level. It is thought to have been built in the middle of the 15th century and to have flourished for another century. It was rediscovered in 1911 by Hiram Bingham, an American.

In Central and North America during the years between 1500 and 1750, the engineering achievements included a number of fortresses.....

One is El Moro, one of two that have stood guard over the entrance to the harbour of San Juan, Puerto Rico, for several hundred years. It was built by the Spanish to protect their various interests in the Caribbean area. Construction began in the late 1500s and continued for 200 years. It has six levels that include tunnels, dungeons, barracks, turrets and towers.

Another is Canadian. The French were ordered by King Louis XIV to build a well-fortified town at Louisbourg on Cape Breton Island to defend *their* military and Atlantic fishing interests. It was hardly completed in 1745 when it was besieged and captured by an army from New England. Given back to the French in the peace negotiations that followed, it was besieged again in 1758, by the British this time, and demolished. However, the area around the fortress remained 'in business'. Interestingly, the second most important man at Louisbourg - after the governor - was the engineer. Partial reconstruction was begun by the Government of Canada in the 1960s.

I mentioned earlier that the first cast iron bridge was erected at Coalbrookdale in Shropshire, England. It was completed in 1779 and has a span of 30 meters over the River Severn. Many of the castings were made in the Darby Foundries nearby. The bridge is still in operation but has been closed to vehicular traffic for some time.

Back to Canada and two canals and a waterworks.....

The first is the Welland Canal, known as "Mr. Merritt's Ditch" after its promoter. The first 'iteration' of it was completed in 1829, but nothing remains. There have been three others. It was originally built as Canada's answer to "Clinton's Big Ditch" - otherwise known as the Erie Canal that linked Lake Erie with the Hudson River and New York.

The second is the Trent-Severn Canal. Construction began in 1833 and finished in 1920. It is almost 400 km long. Its lift-lock at Peterborough is well known. Less well known is the other one at Kirkfield. It also has a marine railway.

The waterworks is at Hamilton. It was designed by one of Canada's best-known 19th century engineers - Thomas Coltrin Keefer. It was built in the late 1850s to help get rid of the recurring scourge of cholera in that city. The water was taken from Lake Ontario and pumped into a reservoir above the city. The pumping engines were designed and built by John Gartshore, to James Watt's original design, at his foundry at Ancaster. The plant operated from 1869 until 1928. It is now a museum.

To Europe once again.....

.....to London's Hyde Park and the Crystal Palace. In addition to its novelty and considerable size - it covered 19 acres - it was conceived and designed by the Duke of Devonshire's head gardener, not an engineer, who had already built a large greenhouse for His Grace. The Palace was completed in less than a year as the centrepiece for the Great Exhibition of 1851 and intended to demonstrate Britain's pre-eminence in engineering. Among its components were 300,000 panes of glass and 4,500 tons of cast iron.

The Isle of Man lies in the middle of the Irish Sea, roughly equidistant from Scotland, England, Ireland and Wales. It is known world-wide for its three-legged badge and for the motorcycle races that it hosts annually. It is less well-known for the metal mining industry it once had. But it has preserved from its mining days one of the world's most spectacular pumping engines - the Lady Isabella, also known as the Laxey Wheel. Built in the 1850s, the diameter of the gravity-fed backshot water wheel that drives the pumping mechanism is over 70 feet and its width six feet. When working, the wheel turned at between two and four revolutions per minute and generated up to 200 horsepower. Attached to the wheel was a crank with a ten-foot stroke that was attached to a series of movable rods that slid along a viaduct and connected at the mine end to a vertical pumping shaft that drew the water from the mine. The wheel operated until the late 1920s. Some years later it was restored and opened as a tourist attraction.

The original railway bridge over Scotland's River Tay was completed in 1877, but part of it was blown down two years later in a violent storm, with considerable loss of life. As the photograph shows, a second bridge was built right beside the first.

Not far from the Tay Bridge is the spectacular Forth Bridge. It was completed in 1890, after seven years of construction. It has so far survived all the storms thrown at it. It, too, was built too early to accommodate vehicular as well as rail traffic.

And in London, the Tower Bridge across the Thames River was completed in 1894. Technically, it is a double-leaf bascule bridge. Should you wish to see a single-leaf bascule, there is one at Smith Falls, over the Rideau Canal.

To Canada again and two bridges.....

The first is nearby, at Pakenham, over our Mississippi River. It is reputed to be the only five-arch stone bridge in North America. It was built in 1901.

The second is the Lethbridge Viaduct in Southern Alberta. Spanning the Oldman River, and replacing the much longer rail line that crossed the river valley at ground level, this bridge was opened in 1909. A century later it was recognized as being of national significance by the

