THE ROYAL BANK LETTER

Published by The Royal Bank of Canada

VOL. 67, NO. 5
SEPT. / OCT. 1986

In Praise of Engineering

The world we live in has largely been created by engineers, who have delivered blessings to mankind since the dawn of history. Here we examine their role — and note that it is now more crucial to human survival than ever before . . .

☐ We in the developed countries live in the realm of the engineer. From the moment we turn on the water in the morning until we turn off the lights at night, we are surrounded by engineered structures, systems, products and processes. They help to feed, shelter, clothe, transport, comfort and entertain us, and allow us to communicate invisibly with one another. No matter what we do for a living, much of our own work is done with things made by engineers.

Yet most of us who are not concerned in our jobs with the nuts and bolts of technology seldom give more than a passing thought to how critical the engineering profession is to our existence. This is because the marvels of engineering have come to be routine. They are as much a part of our daily environment as the mountains around a Nepalese Sherpa. They have ceased to inspire the awe they deserve except when, as in an avalanche, something goes wrong with disastrous results.

The engineer himself (or, increasingly these days, *her*self) has faded into the landscape along with his all-pervasive output. We know the names of the sculptors and architects whose works grace our big cities — the Henry Moores and the I.M. Peis — but who knows who actually erected the buildings and bridges, who cut the streets and installed the pipes and wires that make a city run? In any list of historical persons, engineers rank far below monarchs, politicians and generals. The reason for this is simple: engineers normally solve problems instead of creating them, and a problem solved is a problem out of mind.

The lack of recognition of the engineer in relation to his significance is hardly a recent phenomenon. History does record the name of the man who built the Great Pyramid — Khufu-onekh — but it is less commonly known than that of Cheops, the Egyptian king for whom that incredible feat of engineering was carried out. While the poets and philosophers of antiquity are enshrined in immortality, the builders of the seven wonders of the world are forgotten. We have all heard of Homer and Plato, but who was in charge of constructing the Acropolis? Virgil and Cicero are still quoted, but who engineered the Coliseum?

In particular, the engineer has always lived in the shadow of the scientist. The latter traditionally has received the credit for advancing the cause of mankind with discoveries that might never have done any good for anybody without the added value of innovative engineering skill. The difference between the two callings is that the scientist seeks new knowledge and the engineer seeks ways to apply knowledge for practical purposes. Neither could function without the other. "There are science and the application of science, bound together as the fruit of the tree that bears it," as Louis Pasteur said.

In fact, the scientist and the engineer have often been one and the same person. Galileo not only unlocked the secrets of the sky, he built the first high-powered telescope. Marconi was a trained physicist, but his fame rests in taking Heinrich Hertz's equations and applying them to wireless communication with an antenna and radio sets he built himself.

But what, in the first place, *is* an engineer? It is difficult to summarize the work of hundreds of thousands of men and women in a vast range of technical specialities in a single sentence. The *Encyclopaedia Britannica*, however, came very close when it defined engineering as "the professional art of applying science to the optimum conversion of resources to benefit mankind."

The *Britannica* points out, incidentally, that it is no accident that engineers live by the exercise of ingenuity. The words engineer and ingenious have the same Latin root, *ingenerare*, meaning "to create."

Though engineers had been at work since before history was ever written down, no name existed for their occupation until the Middle Ages, when the term "enginer" was used to describe the man who fashioned "engines of war" such as swinging battering rams and catapults. Military engineers had never confined their skills exclusively to warfare, however. The paved roads that radiated from Rome throughout Europe and the Middle East were the work of engineering officers in the Roman legions. In peaceful times they also turned their minds to the construction of the massive stone aqueducts that arouse wonder to this day.

What engineers are meant to do: Take ideas and make them work

In medieval times a clear distinction grew up between the military and the civil engineers who constructed the great cathedrals of Europe. The craft was becoming more sophisticated; the cathedral builders employed such devices as groining, pointed arches and flying buttresses to deal with lateral thrust and stress. Engineering was also becoming diversified. Hydraulics engineers had long worked in mines and mills, and chemical processing systems were in operation. The advent of clockwork brought the mechanical engineer onto the scene.

It was this type of engineer, with his gears and shafts and metal screws, who set off the Industrial Revolution. John Kay's fly shuttle and James Hargreaves' spinning jenny took workers out of their cottages and into factories. The man most closely associated with this epochal development, James Watt, was an engineer in spirit and practice. Watt did not invent the steam engine — Thomas Savery and Thomas Newcomen are variously credited with that — but he improved on the invention enormously by redesigning it and making additions to it. Watt made the steam engine an efficient source of power for industry. He did what engineers are meant to do — take ideas and make them work.

Watt was a typical old-time engineer in another respect; he was self-educated, having spent only one year training as an instrument-maker. So were his contemporaries who built the canals, railways, highways, foundries and machine tools that transformed Britain from a small agrarian nation into a wealthy world power.

The engineer of that era ordinarily served an apprenticeship under an experienced practitioner, then went on to tackle the problems of nature with little more than a T-square and his own skill, knowledge, common sense and intuition. The celebrated 18th century English canal builder James Brindley never used models or drawings. As recounted by C.C. Furnas and Joe McCarthy in their 1966 Life Science Library book *The Engineer*, "Once, when asked what the arches of a proposed canal aqueduct would look like, he sent to the market for a cheese, sliced it in halves, placed the two semicircular portions on a table with their round sides up and laid a ruler across their tops to represent the trough of the canal."

Though the first school of road and bridge construction was formed in France as early as 1747, the age of rule-of-thumb engineering did not really end until electricity was put to its first major practical use in the telegraph in the mid-19th century. The common sense approach that had governed the building of things and the formulation of processes in earlier times could not be applied to electrical reactions because electricity did not follow common sense rules.

Discoveries in dynamics, chemistry, metallurgy and other fields also complicated engineering. No longer was it sufficient to go about with a handbook containing formulas based on the known data about a subject. In a world becoming ever more aware of the complexities of nature, the handbook had to give way to the textbook. Schools of engineering had to be founded, and standards of competence set by professional societies.

From the beginning, Canada was an engineer's country

The colonies that would make up the future Canada entered early into engineering education. In 1854 our first engineering school was opened in what is now the University of New Brunswick. It was the start of an educational movement that would swell to the point where today one in every hundred working Canadians is a graduate engineer. Still, for a long time to come, most of our engineering skills had to be imported from other countries.

The founding of the New Brunswick school was by way of an acknowledgement that this vast, rugged, undeveloped land was an engineer's country. Little economic progress could be made without public works such as roads, harbour improvements and canals. The great difficulty in maintaining a distinct political presence north of the United States border was a lack of communication among the pockets of settlement in British North America. The railways which were just then being built promised a solution to the problem.

Canada must be the only nation on earth to have a reference to an engineering work in its constitution. A commitment to complete the Intercolonial Railway linking the Maritimes with the central provinces was a key provision of the British North America Act. Another railway, the Canadian Pacific, was needed to bring British Columbia into Confederation and bind the nation together. Building the CPR across the barriers of the Canadian Shield and the western mountains presented one of the mightiest engineering challenges ever undertaken. Its completion 101 years ago opened the door to the settlement of the Canadian West.

The new Dominion burst with engineering activity of every known kind in the years that followed. Canada's great sprawls of rock were turned from a hobble into a spur to development through the skills of mining engineers. Their colleagues in the pulp and paper industry did the same with our forests. Hydro-electric engineers helped to give Canadians a priceless legacy of cheap, reliable energy.

Given the central role engineers have played in the building of our nation, it is fitting that one of them, Sir Sanford Fleming, should rank high among our national heroes. As a frontier surveyor and railway builder, he personified the energy and ingenuity of the engineer in Canada's formative years. And Fleming represented another tradition among his Canadian colleagues. He was an internationalist whose best-known achievement was to establish a system of standard time around the world.

Even before Fleming rose to fame, Canadian engineers had their eyes trained outward. In the 1850s and '60s they took part in such historic projects as laying the transatlantic telegraph cable between Newfoundland and Ireland and drilling the first railroad tunnel in the United States. The new science of petroleum engineering had its cradle in Southern Ontario at about the same time. (In those days before the internal combustion engine, the oil was refined for use in kerosene lamps.) As early as 1874, Canadian petroleum engineers were exporting their expertise to the Dutch East Indies. From then until the outbreak of World War I, they were to be found in the far corners of Europe, Africa, South America, the Middle East and Australia, drilling and building refineries and pipelines to meet the growing thirst for oil in the age of the automobile.

In the meantime, the Canadian with the slide rule and the high laced boots became part of the scenery at mining and utility construction sites in Latin America and the Caribbean. It has been said of the British Empire that trade followed the flag. In Canada's case, exporters often followed the engineer.

'Helping to make life better for people in other countries'

Today as never before Canadian engineers are spreading their skills around the world, not only in their traditional fields of leadership in hydroelectricity, telecommunications and pulp and paper, but in every aspect of engineering activity from metallurgy to medicine. In recent years, Canadian firms have worked on projects and studies in more than 100 countries — and trade has continued to follow the engineer.

Camille A. Dagenais, Chairman of the Board of the globe-ranging SNC Group of Montreal, has conservatively estimated the export spin-offs from overseas engineering activity at $700 million annually, in addition to the $300 million a year which engineering companies earn directly from foreign projects. Among a "small sampling" of items bought from Canadian suppliers he lists piping, handtools, telephone poles and textbooks, along with turbines, generators, crushers, cranes and mobile housing. An uncountable number of jobs at home are dependent on the jobs Canadian engineers do abroad.

"Other rewards of working abroad, though less utilitarian, are perhaps more important in the long run to individuals and groups," writes Mr. Dagenais. "Best of all, perhaps, is that you have helped make life better for people in other parts of the world. Today, with widespread drought and the threat of famine looming in so many countries, the contribution of Canadian engineers is more vital than ever."

The guiding interest must be concern for the fate of man

When the World Federation of Engineering Organizations gathers in Montreal from May 17 to 22 next year, the vital contribution which the profession can make to dealing with the desperate problems of the world will be a prime topic of discussion. The conference will mark the founding of the Canadian Society of Civil Engineers (later the Engineering Institute of Canada) in 1887, and it will doubtless be remarked how much the profession has changed in those hundred years. Engineers now work in large teams, drawing on the immense capacity of computers to aid them in their efforts. They have branched out into a range of specialities and sub-specialities that would be utterly bewildering to a member of their profession a century ago.

But though the approaches, techniques and tools have changed, the basic function of engineers is constant. They are the members of society who are ultimately responsible in detail for getting things done. Not only must they get things done, but get them done in the most economic manner possible. Consider that *Britannica* definition again: ". . . the optimum conversion of the resources of nature to benefit mankind."

The depletion of natural resources worldwide has lent this phrase a keen new meaning. We humans can no longer afford to waste the dwindling supply of resources at our command. Nor can we afford more damage to the natural environment. The waves and clouds of pollution around us are evidence of the folly of the theory of development at any price.

In the global village of communication created by the engineer, the social consequences of development weigh heavily on the public conscience. The harm done to minorities in the pursuit of an elusive material progress can no longer be overlooked. A new human dimension has thus been added to the engineer's professional obligations. Albert Einstein anticipated this back in the 1930s when he told an audience of students at the California Institute of Technology that "concern for man himself and his fate must always form the chief interest of your professional endeavours. . . in order that the creations of your minds shall be a blessing and not a curse to mankind."

The fate of man now more than ever hangs in the balance, and engineers will play a crucial part in determining whether that fate will be blessed or cursed by the application of technology. Enormous problems still haunt the world, and many of those problems have been man-made. But if anyone can do something to solve them, it is the engineer, who has been working "to make life better for people" since the dawn of history. It is a huge responsibility to be placed on a profession — but then, engineers have always managed to do the things that need to be done.

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ISSN 0229-0243