7. V. C. Wynne-Edwards, *Evolution Through Group Selection*, Blackwell Scientific Publications, 1986.

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From Steam to Space: Contributions of Mechanical Engineering to Canadian Development

Andrew H. Wilson, (Ed.)

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As a power systems electrical engineer interested in the history of modern engineering I found this book of commemorative essays on the development of mechanical engineering in Canada, interesting and at times fascinating. In a sense the contributions by academics and engineers gave an impression of subdued religious fervour as they help celebrate the 25th anniversary of the Canadian Society of Mechanical Engineers. But then this is what it is all about, pride in one's profession and a particular discipline and the need to publicise the contribution mechanical engineering has made by way of research, education and practice to the development of Canada as a nation. It would do no harm if we in Australia followed suit to tell what engineering has achieved for this country. Those who conceived the project and brought it to fruition obviously gave it a great deal thought and effort. They are to be congratulated.

The book is divided into two parts. The first part consists of 25 essays which are in essence historical perspectives of the impact of mechanical engineering on transportation (rail, aeronautics and automobiles), agriculture, power generation and education, set in the context of the Canadian experience over some 150 years. The second part of 10 essays is concerned with the history, organisation and activities of the Canadian Society of Mechanical Engineers. Obviously I cannot comment on all these contributions much as I would like. Hence, my intention is to concentrate on the historical aspects, as in some ways it has many parallels to that of this country.

The first essay is 'a scene setter' in that it surveys the concept of engineering through the ages and the emergence of mechanical engineering as a discipline. Like Australia, the economic development of Canada was characterised by the exploitation of primary agricultural and mining products and their export to the United Kingdom and Europe with minimum processing while importing know how from them and the United States. To this end the first series of essays are of the pioneering work of the 19th century engine foundries of eastern Canada in the production of marine steam engines for river and coastal boats, steam engines for the railways, and stationary engines for timber milling, mining and water pumping. Of significance is that Canada was a frontrunner in the building of steam vessels. As early as 1809, two years after Robert Fulton launched the first successful commercial steam boat, the vessel, the '*Accommodation*', of Canadian origin, was plying the waters of the St Lawrence River for trade. By 1834 the local industry was capable of producing marine engines of sufficient power to drive an ocean going steamer. The '*Royal William*', constructed in Quebec and towed to Montreal for the fitting of the engines, was the second ship to cross the Atlantic part way by steam.

The skills required of the foundry worker encouraged a breed of craftsman who could design and construct engines to fit a multiplicity of mechanical tasks tailored to meet the contingencies of the Canadian environment. In this it is worth reflecting that many of the early 'professionals' had no formal engineering or primary education as we would know it. Often as not they served long apprenticeships, gleaning and honing their skills at the workplace and by necessity trial and error. The owners and the managers originated from this craft class combining inventiveness with entrepreneurial flair in the context of what that they perceived as the needs of the community.

By the turn of the 19th century the beam engine of Boulton and Watt and the horizontal and oscillating stationary engines were being locally manufactured. Steam engines begat the need for boilers, condensers and pumps and a host of ancillaries, and so the foundries expanded and evolved. Although steam predominated in these early years, by the turn of the century the internal combustion engine was beginning to make its mark and again the foundries played an important part. The early Canadian experience is traced in an essay dealing with the development and manufacture of the two stroke make-and-break engine in Nova Scotia. The '*putt-putt*' engine as it was affectionately known, became the primary source of power for the Atlantic in-shore fishing boats and remained so until the 1970s. Its attraction lay in the fact that it was simple, robust and required no high degree of mechanical skills to maintain. Many a time I have ruminated as to the state of such engines when watching the local inshore fishing fleet leaving Yamba Harbour (NSW), as I rarely ever heard of one being overhauled. One story told is that they could duplicate as an anchor provided one removed the carburettor?!?

In essence, the foundry of the 19th century was the precursor of 20th century heavy industry manufacturing. This continuum is seen through essays charting the history of companies which have become synonymous with particular products; Babcock-Wilcox, boilers and condensers; Ingersoll Rand for pumps, air compressors and rock drilling equipment and Pratt and Whitney for aero engines. The insight gained engenders an appreciation of the R&D undertaken, the financial risk involved and the totality of the effort which goes into establishing a reputation.

Canada has been at the forefront of the development and application of heavy water (moderator and coolant) reactors which burn natural uranium for fuel. In the 1950s it was decided to build a small demonstration unit to produce nuclear power. By 1962 this unit was producing 20 MWe of power. In 1960 work commenced on the design and construction of a 200 MWe unit which by 1966 had become fully operational. The success of the Canadian-Deuterium–Uranium (CANDU) reactors can be measured by the number of units in service in Canada and other parts of the world. By the early 1990s, 20 (including the original) reactors rated up to 938 MWe in Canada, 3 on the Indian sub-continent, 4 in Korea, one in the Argentine and one in Romania. Three essays tell of the work of research, design and application which went into the CANDU reactor. The first is set in the context of the research, design and manufacture of fuel channel tubes and the decision to use alloyed zirconium. Fast neutron irradiation causes the fuel channels to degrade in the form of corrosion, reduced ductility and tensile strength. As such, it is a major problem in maintaining the integrity and reliability of the channels and as a consequence, the efficiency of the reactor. The essay charts how eventually metallurgists and mechanical engineers combined to find a solution. The reliability of the fuel channels is taken up in the second essay which details an investigation into cracking of the pressure tube channel inserts of channels installed in two reactors of Pickering power station. Investigations of this nature make excellent

reading as they highlight forensic skills of logic and evaluation in situations which must be exceedingly trying.

The units which were commissioned in 1971 and 1972, on returning to service after routine maintenance in late 1974, were found to have water leaking from the primary heat transport system into the gas annulus. The source of the leak was a pressure tube of a particular fuel channel. Despite the tube being replaced the leakage problem persisted implying that water was leaking from other channels. The apparent crisis can be imagined, as it placed the CANDU reactor program at serious risk.

When the faulty pressure tubes were removed from their respective reactor channels a series of cracks were uncovered. The cause of the cracking was attributed to a rare phenomena called '*delayed hydrogen cracking (DHC)*'. This phenomena had its origins in the method adopted in joining dissimilar metals of the fuel channel pressure tube. The tool used to make the joint, caused the joint to extend beyond the end of the tube and as a result it created an area of high residual stress. The cracks were the end result of a combination of the high residual stress and the cooling of the tube and coolant. Knowing the cause of such a problem does not always bring solutions. In this case, the over extension of the roll joint has been corrected, but the phenomena of DHC remains. It is an interesting example of how little we know of the consequences of applying techniques when working at the edge of knowledge.

The third essay in the series concerns itself with the reliability of the CANDU reactors. A power station of any sort needs to have a high commitment to reliability and maintainability, a nuclear power station even more so considering the consequences should a major failure occur. It was of interest to read that a reactor of the 'Pickering' design has some 700 valves of various types and sizes installed. Readers who have experienced the operation of a power station would know what a problem it is to maintain pumps, valves, and seals and minimise leaks.

Of the remaining essays of the first section, there is the work of a group of mechanical engineering undergraduates in the conversion of a petrol driven car to that of a hybrid electric vehicle. This is followed by two essays on co-operation and the interface between disciplines, aeronautics and mechanical and medicine and mechanical. The work of the CANDU reactor emphasised this point. Finally, there are six essays on the history, education and training of mechanical engineers in Canada. One sees parallels with the Australian scene in respect of funding for research, university-industry co-operation and the need to impart to engineering students social science and management skills.

The second part of the book relates to the Canadian Society of Mechanical Engineers. Although specific to the peculiarities of the Canadian scene it is interesting as it tells of the development of the society, co-operation with its US counterpart, and in general of learned engineering societies in Canada as autonomous bodies within the Engineering Institute of Canada.

A review of this nature cannot do justice to all that is contained in this book. To any person interested in mechanical engineering in particular it provides a good reference to the discipline as developed in Canada. In this context I recommend it to persons interested in engineering history.

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