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CENTRAL CANADIAN INDUSTRIAL ELECTROCHEMISTRY TO 1914:

A CASE STUDY OF ENTREPRENEURSHIP

by

Martha W. Langford

A thesis submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements
for the degree of
Master of Arts

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device - occurred at Akron, Ohio when he was 26; he subsequently formed at least two more companies in the New York-New Jersey area, where he made two contacts of importance in his subsequent life. One was his future wife, who played an important role in his later Ottawa career as a "captain of industry". She was a daughter of a Speaker of the California legislature who was living with her relatives the Swards (the nephew of Lincoln's Secretary of State, remembered for the purchase of Alaska in 1867). It took him seven years (1888-1895) to persuade her to marry him, which he finally did just before his return to Canada.

The other contact was with James Turner Morehead, and probably also occurred through the Swards; his last U.S. employer, according to Canadian Men and Women of the Time (1912 edition) was Seward and Morehead, N.Y. It was this contact which led to his subsequent fame and temporary fortune as an industrial innovator.

Major Morehead, Confederate veteran, had developed a water power at Spray, North Carolina, with a variety of milling and other enterprises which amassed enough of a fortune to make him one of the "most prominent and wealthy men in North Carolina". However, a railway promotion venture, which, though built, was a financial disaster due to a Baring Brother's failure in 1888, left him in a position where, in 1891, "he had two main assets -- a minor stream at Spray -- and an unshakable belief in the potential of the electric arc furnace."

8. Ibid.; and private communication; H. Morgan (ed.), Canadian Men and Women of the Time, (Toronto, 1898), p. 1089.

9. John Motley Morehead, "James Turner Morehead", An Address before the International Acetylene Association, Chicago, October 27, 1922.

10. Ibid.

11. Malcolm Greenhalgh, "Carbide", ms. for Union Carbide public relations publication Update, 1976.

ABSTRACT

Canada's emergence as an industrial capitalist nation between Confederation and 1914 coincided with the widespread incorporation of new science-related technologies into the process of industrial development in the Atlantic economy as a whole; the period around the turn of the century has been called a "second industrial revolution". In Canada today, the industries based on these technologies are largely foreign-owned. In order to throw some light on the historical origins of this situation, the cases of three Canadian pioneers in the introduction of such technologies have been examined: those of Thomas Willson, innovator in the production of calcium carbide and acetylene; Ernest LeSueur, inventor of an electrolytic cell for the production of caustic soda and chlorine; and William Gibbs, developer of an electric furnace method for the production of phosphorus. Hypotheses concerning factors both internal and external to Canada that might have inhibited the long-term success of entrepreneurial efforts such as theirs have been considered. The interaction between the new technologies of the period and the emerging institution of the multinational firm has been found significant.

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CHAPTER I : INTRODUCTION

A. The Problem

In 1962, W. Leontief gave a lecture at the Collège de France¹ entitled, "When Should History Be Written Backwards?" His answer to that question implies that, when seeking a causal analysis of a dynamic, unstable historical process, it may be wise to derive earlier events from those better known events that have occurred at a time closer to the present, rather than hoping to perceive a logical cause-to-effect relationship among events occurring along a chronological time scale in a dimly-known past.

The three electrochemical entrepreneurs who form the subject of this thesis were chosen "backwards"; that is, a current problem was identified, and historical figures whose careers might throw some light on the origins of that problem were then investigated.

The current problem of interest is the perceived lack of distinctively Canadian entrepreneurship in those sectors of the Canadian economy populated by large, technologically-oriented firms. The origin of many of these firms can be traced to the period of Canada's emergence as an industrial capitalist nation - roughly from Confederation to 1914; so evidence regarding Canadian technological entrepreneurship during this period may illuminate this aspect of Canada's economic development.

This first chapter sets the historical and analytical framework, within the Atlantic economy as a whole and within Canada in particular, for the investigation. The second chapter presents the case histories

1. W. Leontief, "When Should History Be Written Backwards?" Economic History Review, XVI, 1 (1963), 1-7.

of three particularly innovative technological entrepreneurs. The third examines, in the light of the case histories, two groups of hypotheses concerning internal factors and external factors which may be used to explain at least partially why these experiences of the turn of the century did not blossom into successful Canadian high-technology industries of today.

* * *

B. Canada in the Great Transformation

Seen against the background of Karl Polanyi's The Great Transformation,² the period from 1870 to 1914 can be considered the apex of an international nineteenth century civilization which began with the Industrial Revolution in England and was to collapse by the 1930's. It was a civilization which had managed to put a single institution - the self-regulating market - at its centre, and thus to subordinate society to economics. Ironically, the laissez-faire ideal of the free market came to require deliberate state intervention to create and preserve the conditions under which it could exist, while the collectivist, protective measures which arose to alleviate the worst effects of the market on various social groups arose in a normal, if unintended, pragmatic way.³ "Laissez-faire was planned; planning was not." The philosophy of economic liberalism was characterized by "a mystical readiness to accept the social consequences of economic improvement, whatever they might be,"⁴

2. Karl Polanyi, The Great Transformation (New York, [1944], 1957).

3. Ibid., p. 141.

4. Ibid., p. 33.

and a belief that the spread of the market system was the route to unlimited economic improvement. By the 1870's and 1880's, however, elements of a "protective countermovement" were becoming increasingly evident: the rise of nationalism and socialism, of manufacturers' associations and monopolists, agrarian interests, and trade unions.⁵

Canada in the latter half of the nineteenth century was in a sense exemplary of this dual set of forces. On one hand, she was the inheritor of the British-based tradition of economic liberalism with the faith in free enterprise and free trade that that implies; and the impressed neighbour of the country where the market economy "appeared" to be working best.⁶ On the other hand, Confederation itself was in a sense evidence of a "protective countermovement": "the standard interpretation of the entire history of the Canadian economy assigns to the state of major role in guiding and stimulating development.....the creation of a national economy in Canada and, even more clearly, of a transcontinental economy was as much as political as an economic achievement."⁷

5. Ibid., p. 144-5. To a pure believer in the ideal of economic liberalism, these were the "villains of the piece." But each of the elements acted in various ways to protect certain classes of society; e.g., where free trade put a country with a less developed manufacturing sector at a disadvantage, measures associated with economic nationalism such as a tariff would protect that sector; trade unions would set a lower limit to the degree to which employers could allow free operation of the labour market.
6. Polanyi notes, however, that the abundance in the United States of land (until the turn of the century), and of immigrant European labor, made it a different case from the "self-regulating markets" of Europe. Ibid., p.
7. H.G.J. Aitken, "Defensive Expansionism : the State and Economic Growth in Canada," in W.T. Easterbrook and M.H. Watkins, Approaches to Canadian Economic History (Toronto, 1967), p. 184.

C. Industrialization and the Rise of Science-Related Technologies

Although much of Canada's economic history up to and including the latter half of the nineteenth century has been seen as organized around the export of staples, considerable industrialization had occurred by the time of Confederation. It has been argued convincingly by Steven Langdon that, in central Canada at least, an industrial capitalist society had come into being: "By the 1870's, a large-scale, mechanized factory system, with markets extending throughout Canada, had emerged. An impersonal, self-regulating labour market had matured. And a significant class of industrial entrepreneurs had appeared as a planner in the political economy."⁸ Bertram finds that, "while 1896-1914 has been regarded as the decisive period of successful Canadian industrialization", there is ample evidence that "the last three decades of the nineteenth century was also a period of substantial growth, increasing localization of industry and increasing specialization of the production of firms",⁹ attributable to staple firms and intensive development of secondary manufacturing to central Canada.

Growth of the Canadian market economy received some help from government policies. Secondary manufacturing was encouraged not only by the Patent Law of 1872 which required manufacture in Canada within two years, and the National Policy tariff of 1879, but by various bonusing schemes¹⁰ at the federal, provincial, and especially the municipal level. Provincial

8. Steven W. Langdon, "The Political Economy of Capitalist Transformation: Central Canada 1840-1870", M.A. thesis, (Carleton University, 1972), p. 352.
9. G.W. Bertram, "Economic Growth in Canadian Industry 1870-1915: The Staple Model" in Approaches to Canadian Economic History, W.T. Easterbrook and M.H. Watkins, ed. (Toronto, 1967), p. 78.
10. See, for example, Chapter XIII "The Bonusing Craze and Secondary Industry", in Tom Maylor, The History of Canadian Business, 1867-1914, Vol. II, (Toronto, 1975), pp. 130-160.

governments developed their own "national policies"; Nelles, for example shows how between 1891 and 1911 "Ontario came to regard itself as a self-contained industrial empire."¹¹

With a situation as of 1873 of a physical expansion from 33,000 to 3 million square miles characterized by "a serious lack of communication"¹² it was that railroads and other infrastructure that demanded first priority. The "filling out of a gangling frame" is the theme of Waite's history of the period from 1874 to 1896.¹³ Speaking of the post-1896 period, Brown and Cook say, "'Modern industry' grew out of the demands of a booming agricultural economy for more extensive transport and communications facilities, for new railroads, new and improved roads, bigger lakes grain carriers, refrigerated ocean steamers, and the machines and tools needed to produce them."¹⁴ Industrialization, encouraged by the National Policy, then, moved toward a massive integration of the national economy as the completion of transcontinental railroads and immigration to the Prairies facilitated the rise of the wheat economy. Fowke shows the importance of the Prairies as an "investment frontier" for the rest of Canada, principally Ontario and Quebec, as the capital equipment needed for farms, marketing centres, and transportation routes was supplied from the late nineteenth century onwards.¹⁵

11. H.V. Nelles, The Politics of Development: Forests, Mines and Hydroelectric Power in Ontario 1890-1939, Ph.D. Thesis (University of Toronto, 1970), p. 9
12. W.L. Morton; The Critical Years: The Union of British North America 1857-1873 (Toronto 1964), p. 263-4.
13. P.B. Waite, Canada 1874-1896: Arduous Destiny, (Toronto 1971), p. 280-1.
14. Brown, R.C. and Cook, R., Canada 1896-1921: A Nation Transformed, (Toronto 1974), p. 83-4.
15. V.C. Fowke, The National Policy and the Wheat Economy, (Toronto, 1957), pp. 71-72.

In addition to the internal dynamics of development based on the creation of a national market, external relationships not only remained extremely important, but also developed in new ways after Confederation. British portfolio investment, particularly in commercial infrastructure such as railroads, remained essential. American direct investment increased rapidly, particularly from 1908-1913.¹⁶ Some of this investment was in new staples, whose importance was increasing as a result of technological change; for example, pulpwood for paper, and minerals such as copper, nickel, and asbestos. An increasing part of this investment was in manufacturing firms. Marshall, Southard and Taylor record¹⁷ 79 such firms in 1900, and 285 established between 1901 and 1914. For present purposes, this increase in foreign direct investment can perhaps best be seen as triggered by a change in industrial structure which was occurring both within and among all the countries of the North Atlantic economy in the years before 1914. McManus says of the international case: "The essence of [foreign direct investment] is not foreign investment, which is an international transfer of capital, but the international extension of managerial control over certain activities."¹⁸ In many ways, this phenomenon is a logical outgrowth of interregional extension of managerial control within any one country.

16. G.M. Maier, "Economic Development and the Transfer Mechanism: Canada 1895-1913," Canadian Journal of Economics and Political Science, XIX, (Feb. 1953), 10.
17. H. Marshall et al., Canadian-American Industry, (Toronto[1936]1976), p. 21. The figures are low because they do not include firms which withdrew or were sold to Canadians subsequently.
18. John McManus, "The Theory of the International Firm", in G. Paquet, (ed.), The Multinational Firm and the Nation State, (Don Mills, 1972), p. 66.

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This process within Canada is given a detailed account by Naylor in his chapter on "The Rise of Big Business" before 1914.¹⁹ Extensive attempts at cartelization were taking place by the 1880's; use of the joint-stock company spread rapidly in the 1890's.²⁰ After that time, industrial mergers occurred fairly frequently, concentrated particularly in the years 1909-1912, when "important moves were made toward concentration of control in the heavy industries such as cement, asbestos, coal, and iron and steel, as well as in textiles, milling, pulp and paper, and others"²¹ - 58 in all. This movement was met with relative equanimity by the federal government; "freedom of enterprise" included "freedom to combine".²² The dominant motives for these consolidations seem to have been price control and promoters' profits.²³

The extension of managerial control on an international basis occurred, not surprisingly, among U.S. and European firms to a larger extent than among Canadian firms. Although there was considerable commercial and financial expansion abroad by Canadian investors before 1914, only a very small proportion of it took the form of direct investment in manufacturing.²⁴ Among the older industrialized countries of the North Atlantic, the number of firms establishing foreign manufacturing subsidiaries before

19. Naylor, op. cit., Vol. II, pp. 162-199.

20. Brown and Cook, op. cit., p. 91.

21. Fowke, op. cit., p. 100.

22. Ibid., p. 97. Naylor quotes Mackenzie King, introducing the Combines Investigation Act of 1910: "I would like the House to understand that in introducing this legislation, no attempt is being made to legislate against combines, mergers, and trusts." Naylor, op. cit., Vol. II, p. 193.

23. Fowke, op. cit., p. 100.

24. Naylor, op. cit., Vol. II, pp. 219, 247-50.

1914 has been estimated as follows: United States: 122; United Kingdom: 60; continental European countries: 167.²⁵ These subsidiaries were outgrowths of export selling arrangements, and where they were successful in entering world markets, it was often because they were developing new products. Franko observes that "[U.S. and European] manufacturing firms almost always seem to have begun the process of becoming multinational by exporting on the basis of oligopolistic advantages in technological innovation."²⁶

Fowke and others have noted the centrality of technological change among the "conjuncture of favourable circumstances" which marked the transition from the nineteenth to the twentieth century in Canada: "Technological changes.....spread throughout the nations contiguous to the North Atlantic in the latter part of the nineteenth century with ramifications sufficient to merit description as a new industrial revolution."²⁷ It is to this increased importance of technological change in the industrial process sometimes called the "second industrial revolution", that attention will now be turned.

The "kaleidoscope" of technological changes which fed and were fed by the upsurge of industrialization and urbanization in the later nineteenth century are grouped by Landes into three categories: 1) new materials and ways of preparing old materials; 2) new sources of energy and power; and 3) a new spurt in the degree of mechanization and division of labour.²⁸

25. L.G. Franko, "The Origins of Multinational Manufacturing by Continental European Firms", Business History Review, Autumn 1974, p. 284.

26. Ibid.

27. Fowke, op. cit., p. 70.

28. David Landes, The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present (Cambridge, 1970), Chapter 5, especially p. 249 ff.

Underlying and fed by these were, of course, great advances in transport and communication.

Specific industries whose emergence can be traced to the period in question include:

- a) the electrical industry, with its emergence as a power source having profound effects on manufacturing, on communications, in municipal and larger utilities, and home consumer goods;
- b) much of the chemical industry, which had previously consisted mainly of an alkali industry serving the textile industry for bleaching;
- c) new metallurgical industries, including the great expansion and sophistication of the steel industry via the Bessemer and Siemens-Martin processes, as well as new ferro-alloys, aluminum, and nickel made feasible by electro-metallurgy;
- d) the automobile industry and widespread use of the internal combustion engine;
- e) the petroleum industry, widely used as a fuel and lubricant (with, of course, a great impetus from the automobile industry); and beginning to expand toward a wide variety of industrial chemical uses.

Straddling the borders among the electrical, chemical, and metallurgical industries were the new processes based on electrochemical technology, which emerged from the 1880's, some of which will be central to this

thesis. L.F. Haber, historian of the chemical industry to 1930, has found this group one of the two most important developments of the turn of the century.²⁹ (Incidentally, Haber mentions two of the Canadians discussed in the next chapter on an informal international honour roll of eight "pioneers of electrical engineering" drawn from seven countries.³⁰) These new processes relied to a greater extent than other industries on a source of cheap and abundant electrical power, a factor which made Canada's potential for the generation of hydroelectricity particularly significant.

An important feature of these emerging industries was an "ever-closer marriage between science and technology".³¹ As Polanyi noted, "Social not technical invention was the intellectual mainspring of the Industrial Revolution. The decisive contribution of the natural sciences, to engineering was not made until a full century later when the Industrial Revolution was long over".³² Although there is some dispute as to the timing of this alliance, "it is the second half of the nineteenth century that first saw close systematic ties between [science and technology] in important branches of industrial activity; and it was success in these areas that set the pattern and provided the incentive for further collaboration."³³

There are two senses in which new industries of the late nineteenth century can be regarded as depending on science. One sense is that in which an industry involves processes that could not have been imagined without prior conceptual transformations accomplished by earlier nineteenth

29. L.F. Haber, The Chemical Industry 1900-1930, (Oxford, 1971), p. 76. The other concerns the fixation of nitrogen.

30. Ibid., p. 78.

31. Landes, op. cit., p. 323.

32. Polanyi, op. cit., p. 119.

33. Landes, op. cit., p. 323-4.

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century science; for example, the electrical dynamo of the 1870's was impossible without the work of Maxwell, Faraday and others on electromagnetic induction in the early years of the century. The other is the sense in which the application of scientific theory and experiment is practiced within the firm or institutions serving it on a systematic basis. It is this latter sense, and its institutionalization - from the participation of one scientific and/or technologically knowledgeable member in a firm to the full-blown industrial research laboratory - which is likely to increase the rapidity and importance of technological innovation in industrial development. This institutionalization took place at varying rates among the countries of the North Atlantic economy; the German chemical industry of the 1870's was the leader, while "inventor-entrepreneurs" from a variety of countries helped the new technologies³⁴ to percolate through the international economy on varying scales.

The changes in industry brought about by the rise of science-related technologies were many and complex. They included great gains in productivity (Freeman notes, for example, the high rate of productivity advance achieved in the chemical industry by the conversion from batch to flow processes³⁵), which would have as one consequence the search for larger markets. They created an increase in importance and variety of inter-industry exchange of materials and equipment, e.g., electrical machinery, industrial chemicals, new mineral alloys.³⁶ They increased the

34. Christopher Freeman, The Economics of Industrial Innovation, (Harmondsworth, 1974), pp. 46-53.

35. Ibid., p. 43.

36. "The chemical industry is the most polygamous of all industries." A. and N.L. Clow, The Chemical Revolution (London, 1952), p. 130.

incidence of new products which had to create their own markets rather than serving markets already perceived. This was true both in consumer goods (e.g., home electrical appliances) and in industrial goods (e.g., industrial chemicals³⁷). And in increasing the flow of new, precisely-definable products and processes (as compared with the products of rule-of-thumb industrial practices), they augmented the degree to which the patent systems within and among the various countries could be used as instruments of market control. In general, one of the fundamental shifts of twentieth century industry seen by Donald Schon is from the firm based on a product to the firm based on process.³⁸ Technological changes of the "second industrial revolution" can be seen as contributory to this shift.³⁹

A shift in the nature of the industrial process presupposes a shift in the nature of entrepreneurship. Basically, entrepreneurs are the group who fulfill the social responsibility to "initiate, maintain, and aggrandize".⁴⁰ As an economy moves in complexity away from, for example, the family firm manufacturing a single product, the capabilities required of the entrepreneur evolve through stages that Cole calls, "rule-of-thumb, informed, and sophisticated."⁴¹ Information on finance, marketing, accounting

37. "The manufacture of heavy chemicals became...an involved process, in which one part was dependent on the others and almost every effort to prevent waste involved the manufacture of some new product". S. Miall, History of British Chemical Industry, quoted in Clow, op. cit., p. 92.
38. Donald Schon, "The Future of American Industry", The Listener, July 2, 1970, pp. 8-12.
39. In the context of a shift from "product" to "process", it is interesting to note that Alexander Graham Bell's patents concerned, not "a telephone" but "all and every mode of transmitting speech electrically." Scientific American, Nov. 20, 1886.
40. Arthur H. Cole, "Meso-economics: A Contribution from Entrepreneurial History," Explorations in Entrepreneurial History, 2nd series, VI,1,(Fall 19. The entrepreneurial function may of course be performed by other than business institutions, but it is the latter that primarily concern us here
41. Ibid., p. 23.

procedures and, of particular interest here, technological change, become increasingly necessary to the entrepreneur. The process of development is fostered, not only by increasing access to information within firms, but by the "exfoliation" of institutions which provide or spread information. Cole mentions business schools, financial publications, and professional societies;⁴² in the present context, engineering schools (especially with the addition of electrical and chemical engineering), and scientific and/or technological publications and societies are of comparable interest.

In discussing a period of rapid socioeconomic development such as Canada was experiencing in the years preceding 1914, it is perhaps useful to make a distinction between "routine" or imitative entrepreneurship, and innovative, or "N"-entrepreneurship. The term "N-entrepreneurship" is used by Leibenstein to describe "the activities necessary to create or carry on an enterprise where not all the markets are well-established or clearly defined and/or in which the relevant parts of the production function are not completely known...not all the markets exist and the entrepreneur, if he is to be successful, must fill in for the market deficiencies."⁴³ Leibenstein suggests a visual image of the economy as a network of "nodes and pathways, in which routine entrepreneurship operates in open, well-lit parts, while N-entrepreneurship deals in impeded, incomplete, and dark parts of the network."⁴⁴ The N-entrepreneur, to be successful, must be a "gap-filler", able somehow to compensate for the obscurity of elements in his economic environment.

42. Ibid., pp. 14-17.

43. Harvey Leibenstein "Entrepreneurship and Development", American Economic Review, LVIII, 2, (May 1968), 73.

44. Ibid., pp. 76-7.

D. "N-Entrepreneurs": A Sample

The group of "N-entrepreneurs" to be examined in the next chapter have been chosen on the basis of their ability to "gap-fill" in the sense of supplying technological information to the Canadian economy.⁴⁵ Much of the historical research necessary to describe the group of technically knowledgeable entrepreneurs of which the present cases are three examples has not been done. Studies of the industrial élite of the period⁴⁶ do not allow assessment of the "technological information" component. Valuable sources do exist: company histories; summaries such as Warrington and Nicholls' History of Chemistry in Canada,⁴⁷ which, unlike much history of science, emphasizes industry, and J.J. Brown's compendious history of Canadian invention, Ideas in Exile,⁴⁸ three of whose fourteen chapters concern the period in question. But⁴⁹ much remains to be done.

45. It is also of interest that they were leaders on a world scale in innovating new technologies of the "second industrial revolution".
46. For example, T.W. Acheson, "Changing Social Origins of the Canadian Industrial Elite, 1880-1910", in G. Porter and R.D. Cuff, Enterprise and National Development (Toronto, 1973), pp. 51-79.
47. C.J.S. Warrington and R.V.V. Nicholls, A History of Chemistry in Canada, (Toronto, 1949).
48. J.J. Brown, Ideas in Exile, (Toronto, 1967). Brown ascribes the failure to develop in Canada the wealth of inventions made here to "our basic problem as a nation: a conservatism carried to the extreme of idiocy." (p.3).
49. Useful work is being done under the auspices of the Institute for the History and Philosophy of Science and Technology of the University of Toronto, 191 College Street, Toronto, by Bruce Sinclair and others.

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If one cannot generalize too much about the technological N-entrepreneurs of the "second industrial revolution" as a collection of individuals (as Acheson has done with the industrial élite), one can summarize a few characteristics of their environment.

First, it was an extremely "open" environment in several senses. Those segments of the economy which were based on export staples were very sensitive to fluctuations in world prices and markets.⁵⁰

It was open, too, in the sense that information - spread by publications, educational institutions, professional societies, etc. as Cole noted was characteristic of an increasingly sophisticated business environment - passed freely among Canada, Britain and the United States, with no language barrier except in the case of French Canada. This flow of information is evident, for example, in the pages of the Canadian Manufacturer.

Finally, it was unusually open in respect to the exchange of people. Immigration was an essential feature of the working out of the National Policy; emigration was a perennial concern. "Expatriate entrepreneurship", the movement of industrial entrepreneurs both in and out of Canada, was common. What Faucher has said on a different subject is probably significant enough to be a factor in the environment of the potential technological entrepreneur: "la politique de libre circulation des personnes et des capitaux aux frontières canado-américaines; du moins

50. W.T. Easterbrook, "The Entrepreneurial Function in Relation to Technological and Economic Change", in Hoselitz and Moore, Industrialization and Society (UNESCO, 1966), p. 61 and passim, among other sources.

with which Canada was particularly well endowed. Why, then, is their legacy largely restricted to the pages of technological journals and histories? Why, we may ask for purposes of illustration, are the names of Willson, LeSueur, and Gibbs so much less known than that of, for example, Herbert Dow, founder of the Dow Chemical Company, whose initial technological innovation, industrial operation, and geographical dispersion from traditional metropolitan centres, were analogous to theirs?

Based on the foregoing historical and analytical framework, and the case histories of the next chapter, the third chapter will attempt to develop and evaluate a series of explanatory hypotheses for the lack of resonance of Canadian technological entrepreneurship in present-day industries based on technologies of the "second industrial revolution".

The first two hypotheses identify factors within the internal dynamic of Canada's socioeconomic development as being responsible for this limited resonance:

- a) Could it be that the conservative orientation of the Canadian financial community is responsible? Tom Naylor has examined the period 1867-1914 and accuses both Canadian investors and the federal government of having fostered a continuation of the commercial relation⁵² to Empire at the expense of industrial development.
- b) Could it be that a lack of "social infrastructure" -- specifically an educational system conducive to industrial development based on new, increasingly sophisticated technologies -- has been an inhibiting factor?

52. Naylor, op. cit., Vol. I, pp. 3-15 and *passim*.

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The first two hypotheses identify factors within the internal dynamic of Canada's socioeconomic development as being responsible for this limited resonance:

- a) Could it be that the conservative orientation of the Canadian financial community is responsible? Tom Naylor has examined the period 1867-1914 and accuses both Canadian investors and the federal government of having fostered a continuation of the commercial relation⁵² to Empire at the expense of industrial development.
- b) Could it be that a lack of "social infrastructure" -- specifically an educational system conducive to industrial development based on new, increasingly sophisticated technologies - has been an inhibiting factor?

52. Naylor, op. cit., Vol. I, pp. 3-15 and *passim*.

The remaining two hypotheses focus on external factors arising from Canada's insertion in the dynamic of the continental and North Atlantic economy to explain this limited resonance:

- a) Could it be that by the time in question the process of technological innovation had been "industrialized" in more advanced Western economies to an extent that Canada could not compete with them?
- b) Could it be that the "spill-over" engendered by the emergence of multinational corporate manufacturing enterprise (chiefly in the United States) became an
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inhibiting factor?

53. The term "spill-over" is borrowed from Mira Wilkins' The Emergence of Multinational Enterprise : American Business Abroad from the Colonial Era to 1914, (Cambridge, 1970). She uses the term in a general, metaphorical way which comprehends both factors operating vis-a-vis North Atlantic countries in general (e.g., the transition from manufacturing for a national market, to selling abroad, to manufacturing abroad), and factors specific to Canada (e.g., geographical contiguity, a congenial market, the pull of resources such as minerals and timber.)

Here, the term "spill-over" will be restricted to factors affecting the group of industries related to new technologies of the "second industrial revolution". In these industries, the relative sizes of the United States and Canadian markets might have a special significance: a larger market, indicating the greater possibility of economies of scale in production processes, would make more likely the availability of capital for the previously less important functions of innovation and product development. Such capital would also be important to the process of vertical integration, both backward (by acquisition or development of novel sources of supply, e.g., bauxite, nickel) and forward - extending the process of product development to the creation of distributing operations able to market and sometimes service unfamiliar products.

CHAPTER II : THREE ELECTROCHEMICAL ENTREPRENEURS

N-entrepreneurship was defined in Chapter I as "the activities necessary to create or carry on an enterprise where not all the markets are well-established or clearly defined and/or in which the relevant parts of the production function are not completely known."¹

Establishment of firms in the electrochemical areas involved such major changes in technique that the capital and labour requirements and the markets sought, were drastically altered for a variety of categories of industries. In addition, entirely new products for which a market had to be created emerged - intentionally or otherwise - in the spate of experimentation on the applications of electricity to chemical processes. These included:

- a) cases of production of established products by new means (e.g., the manufacture of caustic soda and chlorine by an electrolytic cell method instead of the established European chemical methods - the Leblanc and Solvay processes);
- b) cases of artificial substitutes for natural products (e.g., abrasives);
- c) products of new processes which made it commercially feasible to market metals whose value could be demonstrated by comparison to previous materials (e.g., aluminum, nickel and various alloys);
- d) products previously known only as laboratory curiosities which had to seek an entirely new market (e.g., calcium carbide, acetylene).

1. Leibenstein, "Entrepreneurship and Development", p. 73.

These new electrochemical processes bred whole new sets of market relations, such as those

- a) between themselves and the developing hydroelectric power industry
- b) among themselves, and between themselves and existing smelting and other well-established chemical industries, for industrial chemicals, tools, and other equipment
- c) between themselves and manufacturers of consumer goods, both old and new. (For an example of the new, the carbide industry led to a whole new set of manufacturers of acetylene gas generators, lamps, etc.).

Thus, these new processes, with the many "linkages" they created, had the potential of a powerful spur to economic development and social change, but only with the aid of considerable entrepreneurial activity.

The background of these developments went back to the invention of commercially feasible and reliable electric generators, or dynamos, in the 1870's (although the principles on which they were based went back to Faraday in the 1830's). The development of generators led to a period of rapid technological change which culminated in the establishment of large-scale hydroelectric power generating stations in the middle to late 1890's. It was during the late 1880's and early 1890's that industrial processes themselves (as opposed to the use of electricity for lighting and as a substitute form of power for driving machinery) became a widespread subject of experimentation throughout Europe (especially in Switzerland, Germany, France and England), and in the United States and Canada. These processes were of two types:

- 1) electrolytic processes: thermal and chemical means of achieving oxidation or reduction have a range of no more than 5 volts. Electrically induced changes could be obtained without voltage limitations.
- 2) electric-furnace processes: because there is no electrical analog of the adiabatic maximum flame temperature, an electric furnace can attain much higher temperatures than any flame, and thus produce chemical changes previously impossible.²

A cheap means of generating electric power was, of course an advantage in implementing these processes. A writer in the Scientific American in 1890 predicted that Switzerland would become the leading industrial nation of Europe because of her water power distribution.³ The natural advantage of Canada in this respect was summarized by a "grand old man" of Canadian engineering, Thomas Coltrin Keefer, in his Presidential Address to the Royal Society of Canada in May, 1899, entitled "Canadian Water Power and Its Electrical Product".

Amongst the many partially developed resources of Canada, perhaps there is none more widespread, or more far-reaching in future results, than her unsurpassed Water Power.... when the prime mover is water, we have the cheapest power, and perhaps the nearest approach to perpetual motion which it is possible to obtain; - one which is always "on tap", and, like gravity maintained without cost and applied without delay.⁴

2. The technical information in the above paragraphs was drawn from: F.S. Taylor, A History of Industrial Chemistry, (London, 1957), Ch. 23; D.S. Landes, The Unbound Prometheus, (Cambridge, 1970), pp. 284-87; C.J.S. Warrington and R.V.V. Nicholls, A History of Chemistry in Canada, (Toronto, 1949), Ch. 7 and 8; and C.H. Langford (private communication).
3. Scientific American, Jan. 11, 1890, p. 18.
4. Thomas Keefer, "Canadian Water Power and Its Electrical Product", PAC pamphlet 2415, 1899, p. 1.

The importance of cheap and abundant electric power for electrochemical processes in particular was also recognized by Keefer:

When water is applied for light and power purposes its economy is always the important factor; but it is chiefly to its value for electrochemical industries that Canada will look to reap the greatest benefits, because in these, it is not merely a question of competition among power producers, but one in which intense electricity has the monopoly, and in the case of some of them, as in the production of aluminum, calcium carbide, carborundum, etc., their existence depends upon ample supplies of an intense electric current, for the generation of which abundant and cheap water power is indispensable.⁵

In a review of Canadian chemical industries read at Niagara Falls in 1910 by J.A. DeCew, a Montreal chemical engineering consultant, it was stated, "It is perhaps due to the economic availability of our water power developments that the growth of the carbide industry has taken place in Canada simultaneously with that of other countries."⁶

But while geographical advantages were important, the entrepreneurial activities needed to create new industries were also essential. The cases of three Canadians who played critical roles in the application of electrochemical processes within industry will be examined: those of Thomas Leopold Willson (1860-1915), Ernest Arthur LeSueur (1869-1953), and William Taylor Gibbs (1868-1910).

5. Ibid., p. 12.

6. J.A. DeCew, "Chemical Industries of Canada", Transactions of the American Institute of Chemical Engineers, III, (1910), 263.

A. THOMAS LEOPOLD WILLSON (1860-1915)

T.L. "Carbide" Willson, born in Princeton, Ontario, was the grandson of a Speaker of the Legislative Assembly of Upper Canada from 1825 to 1829; his father was ruined by a defaulting friend and Willson grew up poor in Hamilton where a house was his mother's sole inheritance at his father's early death. He graduated from Hamilton Collegiate Institute, and apprenticed himself to a blacksmith who agreed to provide work space for his experiments. He attracted some attention by building a dynamo and demonstrating electric arc lighting in such places as a clothing factory, the Royal Hotel, and Dundurn Castle, but a combination of frustration and debt drove him to New York: "in reply to a letter from W.E. Sanford of Hamilton, he wrote bitterly he would have preferred to stay at home, but no firm offer had been made to him so he had accepted a position in New York that promised advancement. He also proudly denied Mr. Sanford's right to enquire into the extent of his indebtedness to Mr. Mackelcan in Hamilton. There were letters to a few people enclosing \$5.00 on account, promising more later."

Willson's departure for the United States in 1881 at the age of 21 led to 15 years' residence there. During this period he held a series of jobs, beginning as an inspector for the Fuller Electric Light Company, and later working for the Remington Arms Company. Experimenting continually, he patented several developments ranging through arc and incandescent lighting, electric locomotive and dynamo improvements, a cannon, electric furnaces, and the electrical smelting of ores. His first short-lived attempt to form a company - to produce an electric lighting

7. Marian Roberts, "Carbide Willson 1860-1915", Up the Gatineau, The Historical Society of the Gatineau, June 1976. Mrs. Roberts is Willson's daughter.

device - occurred at Akron, Ohio when he was 26; he subsequently formed at least two more companies in the New York-New Jersey area, where he made two contacts of importance in his subsequent life. One was his future wife, who played an important role in his later Ottawa career as a "captain of industry". She was a daughter of a Speaker of the California legislature who was living with her relatives the Swards (the nephew of Lincoln's Secretary of State, remembered for the purchase of Alaska in 1867). It took him seven years (1888-1895) to persuade her to marry him, which he finally did just before his return to Canada.

The other contact was with James Turner Morehead, and probably also occurred through the Swards; his last U.S. employer, according to Canadian Men and Women of the Time (1912 edition) was Seward and Morehead, N.Y. It was this contact which led to his subsequent fame and temporary fortune as an industrial innovator.

Major Morehead, Confederate veteran, had developed a water power at Spray, North Carolina, with a variety of milling and other enterprises which amassed enough of a fortune to make him one of the "most prominent and wealthy men in North Carolina". However, a railway promotion venture, which, though built, was a financial disaster due to a Baring Brother's failure in 1888, left him in a position where, in 1891, "he had two main assets -- a minor stream at Spray -- and an unshakable belief in the potential of the electric arc furnace."

8. Ibid.; and private communication; H. Morgan (ed.), Canadian Men and Women of the Time, (Toronto, 1898), p. 1089.

9. John Motley Morehead, "James Turner Morehead", An Address before the International Acetylene Association, Chicago, October 27, 1922.

10. Ibid.

11. Malcolm Greenhalgh, "Carbide", ms. for Union Carbide public relations publication Update, 1976.

With Morehead, Willson formed the Willson Aluminum Company at Spray in 1891, "for the manufacture of aluminum, bronze, and further experimental work in the electric furnace".¹² Two of Willson's assistants were Jesse King, who later became general manager of the Canada Carbide Company (and author of the article just cited), and John Morehead, the Major's son, who, having just graduated from North Carolina State University, took a slightly supercilious attitude toward Willson's lack of formal education.¹³

Willson's theory that the higher temperatures possible in an electric arc furnace would result in the reduction of aluminum proved to be unworkable. It is not clear whether he and his associates were aware of the commercially feasible electrolytic process, which had been developed by Charles Hall in Ohio in 1886 (and simultaneously by Héroult in France); first commercially operated by the Pittsburgh Reduction Company in 1888; and subsequently used by the Northern Aluminum Company of Shawinigan Falls, Quebec (incorporated 1899, operating in 1901).

It was the "further experimental work in the electric furnace" which was ultimately to pay off in the production of calcium carbide and its hydrolysis product acetylene which were to be Willson's dominant commercial interests for the next twenty years and the basis of his reputation as an electrochemical entrepreneur. But the discovery on May 2, 1892, was inadvertent.¹⁴ Limping along by producing an aluminum-copper alloy of very

12. J.C. King, "The Canada Carbide Company, Limited", Canadian Chemical Journal, Aug. 1919, p. 262.

13. Morehead, op. cit., p. 2. Morehead was later employed by Union Carbide.

14. It is not uncommon for scientific discoveries to occur by chance in the process of looking for something else -- but as for the recognition and use of the product so created, there is a cliché among science teachers: "Chance favours the prepared mind." Other well-known examples are the discoveries of mauve dye by Perkin, a pioneer in the British dye industry (Landes, op. cit., p. 274) and of polyethylene in the laboratories of ICI (Freeman, op. cit., p. 99).

limited commercial use, Willson and his assistants decided to try to make metallic calcium as an intermediate step in their main goal of reducing aluminum.

There was in the storeroom of the plant at the time a quantity of lime used for whitewashing. This lime was slaked and mixed with coal tar which was kept on hand, along with ground carbon, for patching the furnace. No calculations were made as to the proportions of the lime and tar. The slaked lime was merely worked up with all the tar that it would absorb, and it was the merest matter of luck that the proportions of contained calcium and contained carbon fell within the rather narrow limits which will produce calcium carbide. ¹⁵

When the product was removed, cooled and its gas ignited, the brilliant and sooty flame spelled in immediate terms, failure to produce metallic calcium. Although disappointed in their main goal, Willson and his team continued to experiment with the product, verified its identity by referring to F.C. VENABLES at the North Carolina State University and in a letter of September 16, 1892 to Lord Kelvin in Glasgow; and by 1895 obtained U.S., Canadian, British and other patents.

The Spray plant continued its unprofitable course until it burned in 1895. Willson and Morehead sold rights to the process; eight U.S. carbide companies were started in the years between 1892 and 1897. ¹⁶ All but one failed. That one was at Sault Ste. Marie, Michigan and was the first component of Union Carbide. F.H. Clergue, the grandiloquent developer of Sault Ste. Marie, mentioned this company in an address to the Northwest Electrical Association, printed in The Canadian Manufacturer in 1898, claiming, among other accomplishments, that "our company" had

15. Morehead, op. cit., p. 3.

16. Greenhalgh, op. cit.

concluded a four million dollar contract for 20,000 horsepower of electricity from "our canal" with the Calcium Carbide Company, which, with the aid of an improved electric furnace invented by "our electrical engineer", was to be a "combination of all calcium carbide interests of the continent."¹⁷ If the record of the present day Union Carbide Company of Canada is to be believed, this was the only surviving U.S. plant at the time,¹⁸ and Clergue seems to have been unaware of Willson's Canadian career, to which I will now turn.

At his return to Canada in 1896, Willson had established the technical basis for his later recognition at the first commercial-scale developer of carbide and acetylene. He possessed the Canadian patent for carbide production and six patents on the generation and purification of acetylene;¹⁹ and the capital obtained from the sale of his U.S. patents. The crucial stages of innovation:- production and marketing - remained.

Although carbide and its product were later to have a variety of uses in industry, perhaps most importantly oxy-acetylene welding and monomer synthesis for plastics, the creation of the initial market was based on the use of acetylene for lighting. Willson had already taken steps toward publicizing its use. He had prepared an address to the Franklin Institute in Philadelphia in 1895²⁰ and had sent samples to others for demonstration. For example:

17. F.H. Clergue, "The Electrical Industries of Sault Ste. Marie", Canadian Manufacturer, July 15, 1898, p. 36. As in other cases, Clergue was overoptimistic, or at least premature.
18. Greenhalgh, op. cit.
19. Loris Russell, "Carbide Willson", CANADA : An Historical Magazine, III, 1976 (galley proof).
20. T.L. Willson and J.J. Suckert, "The Carbides and Acetylene Commercially Considered", Journal of the Franklin Institute, CXXXIX, (1895), 321-341.

On January 16, 1895, Professor Vivian B. Lewes of London exhibited the properties of calcium carbide at the Society of Arts before an audience that included leading engineers of the English gas industry. Using a little staging, Professor Lewes showed how a dazzling white light could be produced by burning the acetylene from a simple generator containing calcium carbide and water. The detailed coverage of this event in technical journals, both British and American, included some very discerning comments on the possibilities and limitations of the new fuel.²¹

The Canadian Manufacturer first mentioned the possibilities²² of acetylene lighting in late 1895.

As for production, the Canadian Manufacturer also noted in its column "Captains of Industry", that "The Willson Carbide Works Company of St. Catharines, Ontario have been incorporated at a capital stock of \$200,000."²³ Willson had selected a site on a raceway of the Welland Canal in Merritton (just south of St. Catharines) early in 1896, and, operating out of a hotel in St. Catharines, he planned to be in production by July. On September 19 he was ready to invite the editor of the St. Catharines Daily Standard to view the "first electrochemical factory in Canada"²⁴ at work. The plant used an existing railway siding and grist mill to deliver and process the lime and coke; a massive new building housed the power plant (containing two "immense dynamos of a new type made by the General Electric Co."²⁴) and the furnace room, described by the visitor:

21. Russell, op. cit.

22. Canadian Manufacturer, Dec. 6, 1895, p. 454.

23. Canadian Manufacturer, January 1, 1897, p. 26.

24. Russell, op. cit.

A visit was then made to the furnace room where the fusing of coke and lime was going on. Into a furnace electrically supplied with heat, workmen were shovelling the mixed coke and lime, and the terrific heat within six hours made the finished product. At present the furnace room is not complete. A temporary furnace only is making the carbide, but soon fourteen new furnaces, which are now under contract, will fill the big room, and the capacity of the works will be increased to 10½ tons per day. 25

The progress in production during 1897 is reflected in Archibald Blue's Annual Report of the Ontario Bureau of Mines: for the first half of the year, production for local consumption ranged from 3000 to 9000 pounds per month, and increased to 118,000 pounds for the month of December. Exports for the year were almost double the local consumption (745,816 pounds vs. 401,556 pounds). 26

Willson continued to promote interest in acetylene for lighting; in June 1897 it was reported:

Mr. Willson, of the Willson Carbide and Acetylene Works, recently gave a demonstration of the new illuminant in the Parliament Buildings, Ottawa, before a large number of members of Parliament and Cabinet Ministers. Replying to questions, Mr. Willson stated that acetylene gas can be burned at a cost of 4/5 of a cent an hour for a 50 candle-power light, that carbide will soon be on the market all over Canada, and that farmers will be able to light their homes more cheaply than with coal oil. The Company have recently purchased a water power in the Lake St. John district, Quebec, and expect within a year to develop 20,000 H.P. to be used for the manufacture of carbide. A large quantity of carbide is being exported to Europe. 27

Several companies sprang up to manufacture the equipment needed for acetylene lighting; Blue's report notes eight companies in 1897, located in Hamilton (2), Niagara Falls, Woodstock, Guelph, St. Mary's,

25. St. Catharines Daily Standard, quoted in Russell, op. cit.

26. quoted in Canadian Manufacturer, May 20, 1898, pp. 36-37.

27. Canadian Manufacturer, June 4, 1897, p. 441.

London, and Welland. Advertisements for other such companies located both in Ontario and in Quebec continued to appear in the Canadian Manufacturer.

As the demand for acetylene grew, Willson expanded his interests in several directions. He promoted two new carbide factories: the Ottawa Carbide Company, incorporated in 1899 and in partial operation by 1900, and the Shawinigan Carbide Company, incorporated in 1900 but not operated until 1904. For the former, he constructed a mill on Victoria Island, using the Chaudière Falls. (The building still stands; its most recent use was as the Native People's Embassy in 1974.) The latter was one of the group of industrial users recruited for the Shawinigan Water and Power Company's development of the falls from 1898 (the others being the Belgo Canadian Paper Company and the Northern Reduction Company - which became the Aluminum Company of Canada). In neither case did Willson retain control, although he retained for the time being both stock and the licensing rights for his patents, as well as playing a leading role in the companies' formation and construction. He was the first vice-president of Shawinigan Carbide. In the process of searching out hydroelectric sites for these and other potential factories, Willson obtained from the Quebec government in 1900 rights to the water power at the intersection of the Shipshaw and Saguenay Rivers. His extensive early efforts to interest industrial users in the then-remote site met little success. Indeed, his retention of these rights was due to the fact that "the Provincial Minister thought the scheme utterly impractical so did not exact that development take place within the time specified in the contract."

28. Canadian Manufacturer, May 20, 1898, pp. 36-37.

29. Roberts, op. cit., p. 18.

30. Ibid., p. 17.

In 1901, when the Willsons moved to Ottawa "where it would be possible to make contact with the financial interests by association with Members of Parliament and Senators influential among capitalists³¹ and industrialists," the market for carbide was considerable; indeed there had been grumbling in the previous year in the Canadian Manufacturer that the supply was not keeping up with demand, with the result that³² manufacturers of acetylene lighting equipment were failing. Acetylene lighting had two chief advantages compared to electricity: its usefulness in isolated locations, and compared to other gases, its extreme brightness; twelve times that of coal gas, it was the nearest approximation to artificial sunlight. It was used in early bicycle and horseless carriage headlights; in mines; in lighthouses; in country homes and on farms: "farmers were able to work their fields in the cool of the night instead of the searing heat of the summer afternoons -- and they reported that egg³³ production increased when they hung the light in their poultry houses". The Winnipeg Tribune, via the Canadian Manufacturer, invited the carbide³⁴ manufacturers to take advantage of the utility of carbide lamps for farms. Willson succeeded in obtaining a contract for the lighting of railway carriages with William Van Horne.

Acetylene also competed briefly with gas and electricity for town lighting. The Canadian Manufacturer noted that the town of Amherstburg,³⁵ Ontario, had voted in favour of acetylene in 1901. Willson established the Acetylene Construction Company in connection with the St. Catharines

31. Ibid., p. 18.

32. Canadian Manufacturer, July 20, 1900, p. 12; Dec. 7, 1900, p. 19; Feb. 13, 1901.

33. Greenhalgh, op. cit.

34. Canadian Manufacturer, February 21, 1902, p. 25.

35. Ibid., August 16, 1901.

works in 1903 for the purpose of building town lighting plants for the North West. E.A. LeSueur (q.v.) devised for the Ottawa Carbide Company, also in 1903, a safe method for shipping acetylene (by freezing it to a solid) which supplied Maxville, Ontario, with acetylene lighting for several years.

One of the main uses, a use which survives today, was in buoys and beacons for navigation. Serious accidents occurred, including one at Kingston (where four men were killed by an explosion of compressed acetylene in a buoy on board the Scout, a gas buoy tender employed by the Department of Railways and Canals between Montreal and Kingston.) Willson patented in 1904 a safer self-generating water-to-carbide buoy and manufactured it in his International Marine Signals Company, which was located on what has been called "the longest building in the British Empire" north of Wellington Street in Ottawa. This company sold its buoys, beacons, and other equipment not only in Canada, but to "the Governments of Great Britain, U.S.A., Brazil, Columbia, Argentina, India, Korea, Guatemala."³⁶

Willson's life in Ottawa from 1901 on was that of a prosperous man of affairs. The family lived in an imposing home at 188 Metcalfe Street (where the Algonquin Hotel now stands). Willson began acquiring property on Meech's (now Meach) Lake in the Gatineau in 1906, and in 1907 built an elegant mansion there, where his family subsequently lived half the year. Parliamentarians, British and American investors and Ottawa debutantes crossed paths at these houses. The young Mackenzie King was a frequent guest. Mary Willson was interested in the arts and put up visitors to Ottawa such as Rupert Brooke and the British composer Percy Grainger, as well as welcoming local men of letters such as Duncan Campbell Scott, a

36. Canadian Who's Who, (London, 1910), p. 238.

good friend of the family. Willson is said to have been the first owner of a car in Ottawa, as well as the first owner of a second and a third.³⁷ (Senator Connolly recalls seeing him roaring through Chelsea in a chauffeur-driven limousine with his flowing white hair giving him a distant resemblance to Laurier.)

Willson's interests, both technologically and entrepreneurially, diversified during this period and he seems to have been more interested in developing new projects than in consolidating leadership in the carbide industry. He continued to acquire rights in the Shippaw-Saguenay area and to attempt to interest investors in building pulp and paper, carbide, and other industries there. But at the same time he was constantly experimenting in a laboratory in the basement of his Metcalfe Street home (completed in 1903) on a variety of projects not always related to carbide. His patents during this period included: a process for direct smelting of iron and steel (1903), for producing nickel from nickel silicate (1904), for the smelting of potash feldspar with phosphates (1906); a series of patents on acetylene-based marine signals (1907 and 1908); one for a multiple-burner gas light (1907) and for a multiple-station telephone system (1908) which he had developed because of the need of a phone connection to Meech's Lake; a series on fertilizers from 1910; and one for cement in 1913. Many of his fertilizer patents were jointly assigned to Maximilian Matthews Haff, a chemist who was associated with him as early as 1906 and extensively by 1912.³⁸

37. This paragraph is based on M. Roberts, op. cit., and private conversation.

38. Russell, op. cit., Warrington and Nicholls, op. cit., p. 80.

Willson's hope of revolutionizing the artificial fertilizer industry led to his withdrawal from the carbide industry. In June 1911 he sold all of his carbide patents and holdings in carbide to the newly-formed Canada Carbide Company, the successor of the Shawinigan Carbide Company, which had become a wholly-owned subsidiary of the Shawinigan Water and Power Company in 1909.³⁹ This company operated the plant at Merritton, closed the one in Ottawa, and continued the plant at Shawinigan Falls which became the kernel of an important chemical industry during World War I and later (in 1927) part of Shawinigan Chemicals Ltd. The fate of the International Marine Signals Company is a bit unclear; according to Mrs. Roberts' article he sold its patents to a Buffalo group⁴⁰ in 1909 and subsequently used the plant as a machine shop. According to The Canadian Men and Women of the Time,⁴¹ however, he was still its president in 1912.

In 1911 Willson built a dam, a powerhouse, and an experimental pilot plant for his artificial fertilizer processes near his Meach Lake home (the remains are there today). "He was proud of the acid tower he built and believed it to be a perfect acid condensation plant, the first⁴² Phosphoric Acid Condensation Plant in the World." The patents which he put to use here included "the production of phosphoric acid in the electric furnace, then the preparation of artificial phosphates, then the manner of adding phosphoric acid to natural phosphates to produce 'super-phosphate', and finally the addition of ammonia to further enrich the⁴³ potential of the fertilizer."

39. J.H. Dales, Hydroelectricity: Quebec 1898-1940, (Cambridge, 1957), p. 59.

40. Roberts, op. cit., p. 21.

41. H. Morgan, (ed.), The Canadian Men and Women of the Time, (Toronto, 1912), p. 1173.

42. Roberts, op. cit., p. 21.

43. Russell. op. cit.

A chemist from the J.P. Morgan interests is said to have predicted that Willson's process could put every other fertilizer company⁴⁴ in the world out of business. At any rate Willson was sufficiently convinced of its potential that he sought to mortgage his remaining assets in order to go into production. In 1913 he escorted James B. Duke on a trip through his Shipsaw-Saguenay holdings. Duke had been responsible, since a U.S. Supreme Court decision of 1911, for breaking up his family trust, the American Tobacco Company, and hydro-electric power was one of his chief new interests. He took a mortgage on all of Willson's property and rights there, and when Willson was unable to make a mortgage interest payment, Duke assumed control. He later sold the property to Arthur Vining Davis, while remaining a shareholder.

Willson, then, was ruined. He made one last great entrepreneurial effort. Discovering that the patents he had sold did not cover Newfoundland, he sought British capital and legislation to permit him to develop power sites and associated factories - fertilizer, carbide, and other - at Junction Brook, Newfoundland and Hamilton River, Labrador. He had raised sufficient funds by July 1914, but the legislation was not passed until after the outbreak of World War I, after which such sums could not be transferred out of Britain. Willson was in New York City seeking alternative⁴⁵ sources of capital when he died of a heart attack in 1915.

44. Roberts, loc. cit.

45. M. Roberts, op. cit. Mrs. Roberts was five at the time of her father's death. Her mother moved the ruined family to New York; the daughter returned to Canada in about 1930 and married a Canadian artist. A surviving son lives in California.

Assessment of the success of this example of Canadian N-
entrepreneurship requires a look at the firms which resulted from
Willson's work, aside from the question of his personal career.

Of the three plants which Willson was instrumental in starting,
it was the one at Shawinigan which became the centre of the Canadian indus-
try. The reason for this was perhaps its symbiotic relationship with the
Shawinigan Water and Power Company, which came to rely on it as a market
for off-peak power.⁴⁶ The power company obtained a controlling interest
in the carbide company by 1908 and made it a wholly-owned subsidiary in
1909.⁴⁷ In 1911, when all of Willson's rights and plants were purchased,
the company's name was changed to the Canada Carbide Company; the Merritton.
plant continued in operation until sold to Union Carbide in 1924;⁴⁸ the Ottawa
plant was closed. Canada Carbide at Shawinigan carried out extensive im-
provements in the electric furnaces used, including conversion from a
batch to a flow process, and a great increase in the size and productivity
per kilowatt hour of the furnaces.⁴⁹

As a postscript, it should be noted that this early carbide
company did survive to become a participant in modern chemical industry.
During and after World War I, Canada Carbide became the focus of a new
set of industries related to carbide. The first was the Canadian Electro
Products Company, also a subsidiary of Shawinigan Water and Power, which
was formed to produce acetone and acetic acid from acetylene, for the
Imperial Munitions Board of Britain (Britain had no carbide industry.)

46. For a very favourable account of the entrepreneurial performance of
Shawinigan Water and Power Company, see J.H. Dales, Hydroelectricity:
Quebec 1898-1940, Chapters 3 & 4, especially pp. 62-64.

47. Dales, op. cit., p. 59.

48. Warrington, op. cit., p. 171.

49. King, op. cit., p. 263.

These products were essential for wartime purposes such as cordite manufacture and airplane "dopes". The team of chemists recruited for this project remained to become important figures in the post-war expansion of peacetime uses for acetylene not only in welding, but as a source of a variety of synthetic organic industrial chemicals. They included H.W. Matheson, a graduate of Dalhousie and former employee of Dupont; H.S. Reid, of McGill and Consolidated Mining and Smelting Company (B.C.); and A.J.G. Cadenhead of Queen's; all became members of the research staff of Shawinigan Chemicals, Ltd., which was formed by a merger of Canada Carbide and Canadian Electro Products in 1927. Among the peacetime markets served by this time were those in synthetic fibres, paint and lacquer solvents, components of laminated glass and electrical insulation.

As well as developing its own products, Shawinigan Chemicals entered agreements with other companies; as well as licensing its processes, it jointly founded manufacturing operations at Niagara Falls; at Springfield, Massachusetts; and at Shawinigan itself.

At the close of World War II, Shawinigan Chemicals was still in that "distinctive class" of chemical industries "which originated in Canada and established a world export trade." It remained a leader in

50. Dales, op. cit., p. 236, n.12; Warrington, op. cit., pp. 171-177.

51. Dales, op. cit., p. 82.

52. The Niacet Chemical Corporation, 1925, jointly run with a subsidiary of Union Carbide (Dales, op. cit., p. 238, n. 40).

53. Shawinigan Resins Corporation (1937), with Monsanto (Warrington, op. cit. p. 179.)

54. Canadian Resins and Chemicals (1941) with Union Carbide (ibid.).

55. Warrington, op. cit., p. 286.

research and innovation in its industry. Its comparative importance, however, was diminished by the technological change by which petroleum-derived acetylene began to replace carbide-produced acetylene as a major source of synthetic organic chemicals. This process was worked out in Germany during World War II and became practical where petroleum was cheap; hydroelectricity was no longer a requirement.

Shawinigan Chemicals remained competitive into the 1960's but it has been purchased by Gulf and Western, which is in the process of deciding whether to close it down.

B. ERNEST ARTHUR LESUEUR (1869-1953)

Ernest Arthur LeSueur, son and grandson of civil servants, was born in Ottawa on February 3, 1869. His father, William Dawson LeSueur, a native of Quebec City, had been employed by the Post Office since the age of 16 but he was evidently something of a scholar too, being a fellow of the Royal Society of Canada and author of the Life of Count Frontenac in the "Makers of Canada" series. From 1888 until his retirement in 1902,⁵⁶ he was the Secretary of the Post Office.

Ernest LeSueur attended the Ottawa public schools and Ottawa Collegiate Institute, and became a student at the Massachusetts Institute of Technology, graduating in electrical engineering in 1890. His first venture in scientific N-entrepreneurship, and the one for which he is best known, was an outgrowth of his student work at M.I.T. It centred around the invention of a commercially viable diaphragm cell for the electrolytic decomposition of salt into caustic soda and chlorine. Like

56. Canadian Who's Who (1910), p. 132.

Willson, he was concerned with the application of electric power to chemical industry; unlike Willson, who exploited the great heat available in an electric furnace, LeSueur was exploring the commercial possibilities of electrolysis.

LeSueur was experimenting with such a cell as early as 1887, in conjunction with a friend, Charles N. Waite, who gave assistance and lent him facilities at Newton Upper Falls, Massachusetts. He may have devised his first successful cell in Ottawa during the summer vacation of 1888. Work related to his cell design formed the topic of his thesis research at M.I.T.: "When Professor Charles A. Cross at M.I.T. in 1890 gave me permission to embark on an investigation of the percentages of useful decomposition under various conditions of salt solution undergoing electrolysis for my graduating thesis, he told me I should be quite free from leading strings, seeing that neither he nor anyone else on the faculty or staff knew the first thing about such matters." LeSueur had developed the cell on which his patents were based by the spring of 1890 when he graduated from M.I.T.

From October 1890 to May 1891 he and Waite ran an installation of his cells in conjunction with a paper mill at Bellows Falls, Vermont. In May, LeSueur made a trip to England "with the purpose of presenting his process at the seat of the alkali industry". (Unlike Willson's case, it was

57. Charles L. Parsons, "The LeSueur Process for the Electrolytic Production of Sodium Hydroxide and Chlorine", Journal of the American Chemical Society, XX (1898), 868.
58. Warrington, C.J. & Newbold, J.T., Chemical Canada, (Ottawa, 1970), p. 38.
59. E.A. LeSueur, "Some American and Canadian Chemical History", Canadian Chemistry and Process Industries, March 1940, p. 114.
60. His British patent was issued in April 1891; his U.S. patent was reported in a list of U.S. Patents to Canadian inventors in the Canadian Manufacturer in early 1894 (March 16, 1894, p. 249.)

the process, by no means the product, which was new.) He approached the two leaders in the British industry, Brunner Mond, Ltd., and United Alkali Company, Ltd. to see if they wished to licence his process, and received some scientific but no commercial encouragement in his work.

"The eminent scientist Ferdinand Hurter, consulting chemist to the United Alkali Company, after having burnt his fingers in an attempt, gave as his opinion that it would be useless to try to meet, let alone undercut, the costs of the Leblanc process by any electrical method".⁶²

Whether or not it was his original intention, then, LeSueur turned to the possibility of being his own entrepreneur.

Back in the United States, LeSueur succeeded in interesting a group of six capitalists from the Boston area. A site was chosen in 1892: a 130-foot fall on the Androscoggin River at Rumford, Maine, which "was at the newly arrived⁶³ end of steel, in a rough and slightly tough district". Building of the plant commenced in August 1892 and the Rumford Falls Electrochemical Company began production in 1893. The plant superintendent, Charles B. Barton, noting that "the paths of early workers were not strewn with roses", felt that LeSueur was not given a sufficient role in the management of the company.

Speaking to the American Institute of Chemical Engineers at a 1920 Montreal meeting, he said, "After the original management had demonstrated that they could not run the plant at a profit, LeSueur was made manager but there was so little money available for experiments and

62. LeSueur, op. cit., p. 113. Ironically, it was an article by Hurter which had originally inspired LeSueur's work: E.A. LeSueur, "Adventures in Electrochemistry," Chemistry and Industry (Society of Chemical Industry), February 8, 1947, p. 83.

63. Ibid., p. 114.

development that the plant could not be developed to a commercial
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success". LeSueur himself expressed some bitterness at the way he was
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shoved aside in the early stages. Under LeSueur's direction, however,
the plant had some success between 1895 and 1898; C.L. Parsons gave a
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very optimistic report on it to the American Chemical Society in 1898.

According to another report, the plant's difficulties had an
external cause: foreign competition (British and German) caused the price
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of bleach to drop from \$50 to \$20 per ton during this period. Among
LeSueur's last accomplishments at the Rumford company was the brief estab-
lishment of the first American chlorate plant. "When the Spanish-American
War came along in '98, Spain proclaimed chlorates contraband, and, as the
U.S. was at first inclined to take Spain's navy more or less seriously,
and as all chlorates came from overseas, the price went away up, purely
through consumers trying to provide ahead for their requirements. At
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Rumford we rapidly installed a chlorate plant."

In 1899, however, the owners of the Rumford company sold the
plant and process to the Burgess Sulphite Company and it was moved to
nearby Berlin, New Hampshire; it later became part of the Brown Company
(a paper manufacturer). As the LeSueur patents had been assigned to the

64. C.B. Barton "Early Commercial Electrolytic Cells," Transactions of the American Institute of Chemical Engineers, XIII, 1, (1920), 3.
65. E.A. LeSueur, "Inception & Development of Electrolytic Alkali Manufacture," Transactions of the Electrochemical Society, LXIII, (1933), 187.
66. C.L. Parsons, "The LeSueur Process for the Electrolytic Production of Sodium Hydroxide and Chlorine", Journal of the American Chemical Society, XXI, (1898), 868.
67. L.D. Vorce, "Historical Development of Caustic-Chlorine Cells in America", Transactions of the Electrochemical Society, LXXXVI, (1944), 70.
68. LeSueur "Some Early American and Canadian Chemical History". loc. cit., 1940, pp. 113-114.

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Electrochemical Company, the sale of the plant prevented LeSueur from further promotion of his cell".⁶⁹ Charles Barton, who remained plant superintendent at Berlin for over 40 years, and who was the only associate remembered fondly by LeSueur from this venture, drew a moral in his Montreal speech in 1920: "The history of the development of the diaphragm electrolytic cell emphasizes the well-known point that new processes are best developed by well-organized corporations engaged primarily in some other business that can bear the financial burden."⁷⁰

In 1899, upon the demise of the Rumford Company, LeSueur returned to Canada and embarked on a quite different venture. He was hired by the Lake Superior Corporation to develop one of the electrochemical components of what F.H. Clergue then envisioned as a great conglomerate of electricity-related enterprises on both sides of the border at Sault Ste. Marie. The objective was to obtain large quantities of oxygen for use in the smelting of ores. LeSueur's accomplishments were, first, to establish that liquid air contained a higher fraction of oxygen than had previously been thought, and second, to design a new method for the liquefaction of air involving the use of a turbine. He had an experimental plant in operation by 1901.⁷¹ He managed this assignment in the face of the fact that, in spite of his firm conviction that the de Laval turbine would have suited his purposes perfectly, he was forced to build his own turbine.

69. Vorce, op. cit., p. 73.

70. Barton, op. cit., p. 7.

71. Warrington and Nicholls, op. cit., pp. 56, 343-4.

Unfortunately, the [Consolidated Lake Superior] Company's policy was to purchase nothing that could by any means be made by one of its subsidiaries at the Soo, and I was ordered to design the turbine. I appealed vainly to the chief (F.H. Clergue) telling him my ideas were very vague and I had never even seen one. Under protest, I did what I could...It was a great relief when this rough makeshift enabled the production of tons of liquid rich in oxygen.⁷²

This project was one of several victims of the collapse of
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Clergue's empire in 1902. LeSueur eventually sold his May 1900 patents to La Société l'Air Liquide, which established a plant in Montreal in 1910, and served as a consultant to the company.⁷⁴ He published a paper describing this work in 1910.

Between 1902 and 1905, LeSueur did further low-temperature re-
⁷⁵search work with George Westinghouse. Some of this work involved his
⁷⁶presence on Westinghouse's private experimental staff in Pittsburgh, although there is evidence that he returned to Ottawa to live during this time; for example, his 1903 patents on gas transport and treatment gave
⁷⁷his address as Ottawa. It is interesting to note that the newly-reorganized Canadian Westinghouse Company licensed as its agent the leading Ottawa
⁷⁸electrical manufacturing firm, Ahearn and Soper, in 1903. Also in 1903, LeSueur worked with Willson in Ottawa on the problem of storing and shipping acetylene. "With an originality that characterized all his varied work --

72. "Notes by LeSueur" on file at the Chemical Institute of Canada, Ottawa, n.d.

73. LeSueur seems to have felt that Clergue was overly concerned with impressing shareholders by comparison with solid development (ibid.).

74. E.A. LeSueur, "Commercial Oxygen", Chemical and Metallurgical Engineering, VII, (1910), 234.

75. Canadian Who's Who, 1910, p. 132.

76. L.E. Westman, "A Review of the Work of E.A. LeSueur", Canadian Chemistry and Metallurgy, VI, (January & February, 1922), 32.

77. Canadian Patent Office Record, 1903.

78. Canadian Patent Office Record, 1903.

he decided to solidify it and ship it as 'dry ice' in insulated containers. Using the crusts chipped from the carbide 'pigs' at Ottawa Carbide Company's plant, he generated acetylene gas, converted it to the solid state, and shipped it by passenger express to Maxville, Ontario, where it was used for a number of years for town lighting purposes, until electricity rendered it further use uneconomic."

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After 1905, LeSueur's chief interest seems to have been in explosives. He had established more or less permanent residence in Ottawa, at 50 McLaren Street, and was for a time president and general manager of General Explosives, Ltd. in Hull. He continued to serve as a consulting chemical engineer on a variety of projects. Although participation in the explosives industry during this era of the building of the second transcontinental railroad can scarcely be called "N-entrepreneurship", he did continue to demonstrate technical originality in taking out a series of patents for improved explosives. He described some of them in a paper read in New York in 1913 entitled "Recent Developments in Commercial Explosives".

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In the same article he foreshadowed what was to be another opportunity for him to utilize his technical ingenuity. He noted that "the flood of current patent applications for explosives containing tri-nitro-toluol [TNT] reminds one of nothing so much as that which occurred some ten years ago for acetylene generators". At the outbreak of war in 1914, there were no facilities in Canada for the manufacture of TNT.

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79. Warrington and Nicholls, op. cit., pp. 168-69.

80. E.A. LeSueur, "Recent Developments in Commercial Explosives", Transactions of the American Institute of Chemical Engineers, VI, (1913), 161.

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LeSueur, who was at the time in charge of an explosives plant at Desoronto belonging to Sir Donald Mann (of the Canadian Northern) undertook to fill an emergency order from Belgium for 25,000 pounds of TNT, more or less designing, or adapting the plant as he went. The following excerpts from his account illustrate the makeshift nature of the project:

The man in charge of the nitrator was not a seasoned hand, but was taken on for the occasion only. His last job had been that of a locomotive fireman. None of my hands knew what it was we were doing... In investigating this aspect of the matter [powdering the crude TNT], I took a sample of the TNT and a 4-lb. steel hammer and went off to the neighbouring Canadian Northern right-of-way and experimented by striking both direct and glancing blows on portions of the stuff placed on a 72-lb. rail, and derived comfort from the indifference with which this treatment was received. I then had 200 lbs. broken up to about 1" size with a wood tool and brought in beside the mill. I sent all hands off the place and put the lot through the mill myself. This being accomplished without disagreeable consequences, I felt at liberty to turn the job over to a workman, and this was duly accomplished without incident.⁸¹

While LeSueur's post-1914 career does not concern us here, he, unlike Willson and Gibbs, lived to a ripe old age as "Dean of Canadian Chemical Engineers". In 1904, he had addressed the first Ottawa meeting of the Canadian section of the Society of Chemical Industry (Britain); he was a founding member of the American Society of Chemical Engineers (1908) and of the Canadian Institute of Chemistry (1920). In 1922 he was maintaining in Ottawa both a consulting practice and "semi-commercial⁸² electrochemical laboratories". He received the Canada Medal of the Society of Chemical Industry (Britain) in 1946.

When he died in 1953, he was still embittered by the fact that, although his technological innovation had been generally recognized in his⁸³ profession, its fruits had eluded him.

81. LeSueur, "Some American and Canadian Chemical History", loc. cit., p. 148.

82. Westman, op. cit., p. 5.

83. D. Emmerson, Chemical Institute of Canada, private communication.

C. WILLIAM TAYLOR GIBBS (1868-1910)

The career of William Taylor Gibbs (1868-1910) differs from those of Willson and LeSueur, in that, while born outside Canada, he pursued his business career entirely in Canada. He was born on a farm near Bath, England, and attended the Merchant Venturers' School at Bristol, said to be England's first technical school.⁸⁴ He received a scholarship to study chemistry and geology at the Royal College of Science in London from 1886 to 1888, engaged briefly in electrolytic research, and came to Buckingham as a chemist for a London-owned phosphate mining company which collapsed shortly after his arrival.⁸⁵ Remaining in Buckingham, he made several pioneering contributions to the application of electricity to chemical processes in industry - of both the electrolytic and electric furnace types.

Buckingham, near the confluence of the Lièvre and Ottawa rivers, was the seat of the James MacLaren Company, Ltd., a lumbering company which made extensive use of the water power for sawing, planing and pulp mills. It was also located near the first-discovered (1829) and for a time the most important Canadian sources of phosphate rock for use in fertilizer (1875-1890). These included the North Star and Emerald mines, closed in 1890 when U.S. phosphate became cheaper. Gibbs' first independent electrochemical venture utilized the financial help of both of these interests.

84. Charles Law, "Canadian Vignette; William T. Gibbs", C.I.L. Oval, Dec. 1961, p. 14.

85. Fred J. Hambly, "A History of the Electric Reduction Company of Canada, Ltd." (unpublished manuscript) 1950, p. 11.

Gibbs developed a process (patented in 1893) for the electro-⁸⁶lytic production of potassium and other alkaline chlorates, with the collaboration of S.P. Franchot, a U.S. citizen who was managing a local phosphate company, and with further financial assistance, from A. Maclaren, son of the founder of James Maclaren, Ltd., a plant was built at Masson. This plant burned a year later, which caused the Maclarens to lose interest, and the process was transferred to Niagara Falls, New York, where Franchot and others set up the National Electrolytic Company, with Gibbs as a⁸⁷ director.

Gibbs, however, remained in Buckingham and his next venture was his most durable entrepreneurially. His aim was to produce elemental phosphorus by means of an electric furnace, a goal which utilized ideally the local phosphate rock (apatite) and the hydroelectric resources available. Again he had help - technical help from J.C. Hobbs, who had served as plant superintendent for the short-lived Masson chlorate plant, and financial help from Walter Williams of Buckingham, who helped him acquire the site and hydraulic rights of the defunct Buckingham Pulp Company. The plant began the production of phosphorus in 1896 under the name of William and Gibbs; Gibbs managed to interest English capitalists in it in 1897, and the Electric Reduction Company, Ltd., was formed, with Gibbs and Williams⁸⁸ as managing directors. Gibbs invited a former classmate at the Royal College of Science, F.J. Hambly, to join the company as chemist in 1898.

86. Canadian Patent Office Record, March 1893, p. 230.

87. Warrington and Nicholls, op. cit. p. 161.

88. Ibid. pp. 161-2.

With the financial backing of the English investors, the hydroelectric power capacity of the company was expanded in 1898, and Gibbs, Hambly and Williams sought other electrochemical uses for the increased capacity.

The financial and legal history of the Electric Reduction Company between 1897 and 1903 was to have long-term effects on its career. The first British backers in 1897 were the Anglo-Continental Gold Syndicate, represented by C.P. Pielsticker. They had insisted on a 51% interest in the company and its head office was in London. To supplement Canadian sales, they facilitated export sales to Germany, Austria and Switzerland through Messrs. Leisler Bock of Glasgow, as well as making possible the plant extension.

The legal vicissitudes of the Electric Reduction Company in this period reflect well the fact that "In the 20-year period from 1890-1910, the application of electrical energy for metallurgical and chemical processing developed so rapidly that the patent literature is quite voluminous on the subject of electric furnace designs and operating techniques." The Electric Reduction Company became the object of the patent litigation which was the frequent consequence of this proliferation.

In retrospect, the originator of an electric furnace process for phosphorus production seems to have been J.F. Readman of Edinburgh (1888). His patents were obtained by Albright and Wilson of Oldbury, who had previously manufactured phosphorus by chemical methods. In 1898 they founded the Oldbury Electrochemical Company at Niagara Falls, New York,

89. Hambly, op. cit., p. 15.

90. J. Van Wazer, ed. Phosphorus and Its Compounds, London; Interscience Publishers, 1961, Vol II, p. 1153.

91. Ibid., p. 1150.

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and obtained U.S. and Canadian patents. According to Hambly, the first time he or Gibbs knew of Readman's patents was when they read a file of recent Journals of the Society of Chemical Industry which Hambly brought in 1898 from England.

In 1900, Albright and Wilson sued the Electric Reduction Company in the Exchequer Court of Canada for infringement of their patents. The Electric Reduction Company counterfiled for cancellation of Albright and Wilson's patents on the basis of failure to manufacture in Canada within two years. By late 1902, according to Hambly, "[Albright and Wilson] had probably realized, in view of the evidence submitted, that in the development of electric furnaces in the 1890's, it might be difficult to establish the broad claims of their patents; also that Williams and Gibbs had independently developed an electric furnace for phosphorus production, and it might prove better to absorb the Buckingham venture than to try to squelch it."

Also by 1902, the Anglo-Continental Gold Syndicate had had its South African interests tied up by the Boer War, and the upshot was in 1903 the Electric Reduction Company became a subsidiary of Albright and Wilson.

Gibbs, who was "always keenly interested in the utilization of the minerals of eastern Canada", continued to investigate a series of processes which could utilize both the available minerals and the hydroelectric power. One of the earliest, starting about 1896, was an attempt to produce potash from feldspar in an electric furnace. He patented such a process in

92. Hambly, op. cit., p. 22.

93. Ibid., p. 26.

94. Warrington and Nicholls, op. cit., p. 80.

1904, and although he continued to experiment, he had not found a commercially viable process at the time of his death. He was more successful with an electrolytic process for making chromates; this patent was assigned the Vermilion Chemical Company which he, Franchot and others, set up for the purpose at Niagara Falls, and which was shortly amalgamated with their National Electrolytic Company.

As recounted in Canadian Chemistry and Metallurgy, the Electric Reduction Company utilized its enlarged plant to produce "ferro-phosphorus, Ferro-silicon, and ferro-chromium."⁹⁵ The interest in ferro-chromium had at least three sources: the rising interest in England in stainless steel; the availability of a suitable ore at Black Lake; and the above-mentioned excess power capacity. Gibbs did extensive experiments with and adaptations of the type of electric furnace that was coming into use in the carbide plants, and the Electric Reduction Company made extensive sales of chromium alloy to Sheffield, England, from 1900 until 1906. At that time the Black Lake mine was closed, and the company returned to extended phosphorus manufacture.⁹⁶

Gibbs' work with electric furnaces led to his appointment as one of two technical directors of the Shawinigan Carbide Company during its third year of operation (1906). One of the most important adaptations he worked on was the conversion of the furnaces from a batch to a continuous form of production. During the remaining four years of his life (1906-1910), he continued in charge of the Electric Reduction Company,

95. "The Manufacture of Phosphorus Products in Canada", Canadian Chemistry and Metallurgy, V, (May 1921), 128.

96. Warrington and Nicholls, op. cit. pp. 163-64.

with a series of patents being issued to him in Buckingham and assigned either to that company or to the National Electrolytic Company at Niagara Falls.⁹⁷

Gibbs' death at the early age of 42 was a result of heart failure related to a hunting accident. It was a shock to the community of Buckingham, if a local obituary is to be believed: "Suffice it to say that no death has occurred in recent years in Buckingham which has occasioned more widespread regret or called forth more genuine expressions of sympathy with those a translated mortal has left behind."⁹⁸ Gibbs' interest in the Electric Reduction Company passed to Albright and Wilson, as did his partner Williams' upon his resignation two years later.

Gibbs' role in the creation of the Electric Reduction Company is an example of N-entrepreneurship in the high-technology use of Canadian resources for local manufacture. In an area which had been important for the mining and at most milling of phosphates, he made possible and profitable a sophisticated manufacture for whose raw material the world market had disappeared. (Even the Electric Reduction Company found it cheaper to import a 'pebble' phosphate from Florida at most stages in its development).

Unlike Willson and LeSueur, his business career was geographically limited to Canada. Like them, though, he had ties to the United States and British technical and business community. He was one of twelve Canadians (six industrial, six university or other) among the 350 founding members of the American Electrochemical Society inaugurated at Philadelphia in 1902,

97. Canadian Patent Office Record, 1903, 1908, 1909.

98. Newspaper clipping, 1910, files of ERCO, Buckingham. Among those left behind was a daughter whose marriage to a member of the Maclaren family subsequently helped to heal a water right dispute between the Maclarens and the Electric Reduction Company (Hambly, op. cit., p. 51.)

as well as remaining a director of the National Electrolytic Company at Niagara Falls, New York.

A further note on the history of the Electric Reduction Company would be in order. (In 1974 its name was changed to ERCO Industries Ltd.; this name will be used for convenience here.) From the time of its purchase by Albright and Wilson, a three-way relationship was established among the parent company in England and its two North American subsidiaries, with ERCO apparently in a subordinate position to the Oldbury Electrochemical Company of Niagara Falls (e.g., its books were to be kept at Oldbury and thence forwarded to the head office, until 1920 when Price Waterhouse and Co. of Montreal were appointed auditors for Buckingham).⁹⁹ Production continued to expand with substantial new power plants being established between 1912 and 1920. As in other chemical industries, World War I was a spur to development. During the 1920's and '30's, the expanding uses for phosphoric acid, phosphates, and chlorates in a wide variety of products led to expansion of the Canadian market; in 1932, the Sales division, and in 1935, the company itself, were finally incorporated as the Electric Reduction Company of Canada with head office at Buckingham.

Today, the company has five plants (Long Harbour, Newfoundland; Varennes, Quebec; Buckingham; Port Maitland, Ontario; and Vancouver); a sales office in Montreal and head office and research laboratories in Toronto. Its products are used in detergents, food processing, the match industry, metal treatment, the pulp and paper industry, textiles, and water treatment. Two new plants are under construction in Louisiana and in Thunder Bay, Ontario.

99. Hambly, op. cit., p. 27.

One of its most promising new projects is an effluent-free bleaching process for the pulp and paper industry, developed jointly by ERCO and Professor Howard Rapson of the University of Toronto chemical engineering department. It involves the sale of sodium chlorate, plus the design, manufacture and installation of generators to produce the chlorine. (If U.S. environmental legislation should require "best-known" rather than simply the local "best practical" technology, this process would have an enormous market. It is presently in operation at the Great Lakes Pulp and Paper Company, Thunder Bay).

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ERCO today is a relatively decentralized, though wholly-owned, subsidiary of Albright and Wilson, which in turn is controlled by Tenneco, a U.S. conglomerate.

100. For this and other information I am indebted to Lorne Cullen, Personnel Manager, and Allen Todd, Environmental Control Superintendent, ERCO, Buckingham.

CHAPTER III : FACTORS AFFECTING CANADIAN ENTREPRENEURSHIP

Among the group of industries mentioned as characteristic of the "second industrial revolution": electrical, chemical, metallurgical automobile, and petroleum, all are today seen to be dominated by large and generally non-Canadian firms. In many cases, this situation stems from the period between Confederation and the first World War. For example, the petroleum and automobile industries had significant beginnings in Ontario in the 1860's and 1890's respectively, but were under international (chiefly American) control by the 1890's and 1900's respectively. In metallurgy, the aluminum and nickel industries, which utilized electro-chemical technology, developed entirely under American control (in the latter case, Mond provided British participation.) Chemical industry growing from the traditional roots of explosives, bleach, and dyes, was, or came rapidly, under British and American control. (The formation of Canadian Explosives, Ltd. in 1911 was the result of agreement between Nobel of Britain and Dupont of the U.S., for example).

The purpose of this chapter is to throw some light on the present-day lack of Canadian control in a group of industries, by placing some of the recent experience in the light of the few cases of the emergence of "second industrial revolution" technologies through Canadian initiatives explored in Chapter II. What forces in the evolution of the Canadian and North Atlantic socioeconomy between 1870 and 1914 discouraged or impeded the long-term success of Canadian entrepreneurship and led to displacement by other groups and other forms of enterprises?

1. W.J. Reader, Imperial Chemical Industries: A History, Vol. 1, The Forerunners, (London, 1970), p. 173.

As suggested in Chapter I, four hypotheses, two emphasizing internal factors and two underlining external factors, will be tested against the evidence of the case studies.

A. Internal Factors

The internal hypotheses to be considered concern the commercial orientation of the most powerful business interests and, of specific interest in examining scientific and technological input, the educational system.

(1) The first of these, which implies reliance on a "routine" kind of entrepreneurship, is extensively argued by Tom Naylor. He sees the "history of Canadian business" from 1897 to 1914 as an extension of the colonial relation to Empire, with the major financial institutions oriented to the provision of commercial infrastructure at the expense of all industrial development, and on the part of the government a willingness to import the technological component of industrial development. References to Canada as primarily a source of raw materials, a gold mine of "staples" as they were to be known later, are frequent in British periodicals of the time, and this view was often reflected by Canadian writers in both private and public roles. For example, the purpose of the Geological Survey in providing exhibits at expositions of Philadelphia (1876), Paris (1878), London (1886), and Chicago (1893) was spelled out as "contribut[ing] greatly to making Canada's resources known abroad to powerful capitalists and men in public life." Also, there were other factors encouraging routine

2. Naylor, op. cit., On technology, see especially Vol. II, Chapter X, "Patents, Foreign Technology and Industrial Development," p. 38 ff.

3. quoted in M. Zaslow, The Opening of the Canadian North, 1870-1914, (Toronto: 1971), p. 81.

rather N-entrepreneurship in industry: for, example, the need to fill gaps in the incomplete spectrum of industries which were appreciably developed by the 1870's.⁴ Also there was the likelihood that the bonusing schemes of the many small towns in Ontario and Quebec would be directed toward widely known, and therefore routine, kinds of industries.

The three cases under consideration do not lend Naylor's view strong support. Willson's partners in his first two ventures (St. Catharines and Ottawa) were primarily, though not entirely, Canadian (one backer was James Sutherland, M.P. from Woodstock from 1880 to 1905); in the case of Shawinigan, the investors were roughly the same group of Boston and Montreal entrepreneurs who created the Shawinigan Water and Power Company. The fate of the International Marine Signals Company reflects a continuing involvement with American capital, as does the loss of his Shipsaw-Saguenay interests to James B. Duke. His last project in Newfoundland would have required so much capital that it is not surprising he sought it in Britain and the U.S. It will be noted that LeSueur sought to exploit his invention in the British chemical "establishment" before implementing it himself; and in his Canadian career as a consultant he represents the "exfoliations" of institutions serving industry, rather than the entrepreneurship of industry itself. This is probably indecisive. Gibbs' initial funding was obtained "on location"; his later seeking of British funding is evidence of "expatriate" entrepreneurship, with no necessary implication of foreign control. The take-over by Albright and Wilson was the result of patent litigation, an external problem rather than a problem of Canadian investment

4. The five "strong sectors" in the 1860's were boot and shoe, metal-working machinery, sugar-refining, breweries and distilleries. Langdon, "Central Canada from the 1840's to the 1870's," Ch. 3.

patterns. The Canadian patent law operated to Gibbs' advantage. In the three instances under study, genuine technical initiative in Canada does not seem to have been undone by the factors Naylor identifies. Whatever role his hypothesis may play in explaining the rarity of cases like the ones under study, it does not seem to account for the problems encountered in Canadian electrochemical N-entrepreneurship.

(2) A second hypothesis concerning Canadian N-entrepreneurship in science-related industry concerns educational infrastructure: was it adequate, and if not, did it matter?

Concern over the lack of technical education became a public issue around the time of the establishment of the National Policy in 1879. "If Canada is to take any rank as an industrial nation, and to achieve success in manufactures, or in the development of the mining wealth of the country, something must be attempted in technical education." The campaign for a federal role became more active after 1896, though concrete action awaited the establishment of the Royal Commission on Industrial Training and Technical Education in 1910, and the Technical Education Act of 1919.

The Canadian Manufacturers' Association was a vigorous advocate in this campaign (particularly through an interest in a skilled labour force), and extended its concern to post-secondary scientific and technical training; for example, it editorialized in the Canadian Manufacturer in 1901 on "the great demand that has sprung up of late for practical scientific training

5. Robert M. Stamp, "Technical Education, the National Policy, and Federal-Provincial Relations", Canadian Historical Review, LII, (1971), 404-423.

6. G. Mercer Adams, Canada Educational Monthly, 1881, quoted in Stamp, op. cit., p. 404.

in view of the example of Germany and the great strides taken by that Empire toward commercial and industrial supremacy, admittedly owing to the instruction given in the material sciences in German schools and colleges." ⁷ Again, "the race is now and will in future be to the most scientifically competent and to the most ingenious adapter of scientific knowledge to human needs. Let us not be afraid of too much material prosperity." ⁸ (Scientific training was even to cure capitalistic excesses: "I believe this form of education in the physical realities of life is the only one which will win the interest of the man of business and of affairs as against that of money-making and money spending." ⁸)

Science had been taught as part of general arts courses such as those of Dalhousie, the University of New Brunswick, Laval, McGill, Toronto and Queen's since at least the 1850's. More specialized courses developed between the 1870's and 1890's, as well as institutions stressing engineering and the applied sciences, e.g., the School of Practical Science on the Toronto campus from 1878 (originally founded by the Ontario government as a "College of Technology" in 1873, it became part of the University in 1887 and received substantial government support from 1907); the Ecole Polytechnique in Montreal in 1874 (refused by Laval in 1872 but affiliated to it in 1887); the McGill Faculty of Applied Sciences (founded in 1878); and the Kingston School of Mines, long promoted by Queen's professors and founded in 1893. ⁹ Graduates of the Toronto "S.P.S." were employed in large numbers by the transcontinental railroads. They were moreover "almost

7. Canadian Manufacturer, April 5, 1901, p. 9.

8. Ibid., May 17, 1901, p. 10.

9. Robin S. Harris, A History of Higher Education in Canada 1663-1960, (Toronto, 1976), pp. 145-6, 164-8, 189.

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exclusively the engineers in that epoch-making venture in public owner-¹⁰
ship, the Hydroelectric Power Commission of Ontario". It was common
among the first graduates of the Kingston School of Mines to become
prominent in American mining, until Ontario's mining industry was able to¹¹
absorb them.

While scientific training was available, scientific research¹²
was less common. No Ph.D.'s had been granted by 1890, and Harris finds
it significant that when G.M. Dawson surveyed "The Progress and Trend of
Scientific Investigation in Canada" in his presidential address to the
Royal Society of Canada in 1894 he found its locus to be chiefly various
departments of the federal government, and saw fit to omit the "numerous¹³
educational institutions in which scientific training is given." Harris
finds evidence of the first "brain drain" in the 1890's: 30 graduate
students at Johns Hopkins, 50 at Cornell, 60 at Harvard, 80 at the¹⁴
University of Chicago. Dawson, on the other hand, found cause for satis-
faction in those areas where "results of immediate and tangible value"
were needed and where therefore "the State may reasonably be expected to¹⁵
exercise its activity." (These included the Geological Survey, the
Meteorological Service, the Dominion Lands Survey, the Experimental Farms
of the Department of Agriculture, and the Department of Marine and Fisheries.)

10. W.S. Wallace, History of the University of Toronto 1827-1927, (Toronto 1927),
p. 215.
11. D.D. Calvin, Queen's University at Kingston, (Kingston 1941), p. 206.
12. Harris, op. cit., p. 187. It should be noted that the first U.S. Ph.D.
school, Johns Hopkins, was founded only in 1876.
13. Harris, op. cit., p. 193; G.M. Dawson, "The Progress and Trend of Scien-
tific Investigation in Canada", Proceedings of the Royal Society of Canada, 1894.
14. Harris, op. cit., p. 190.
15. Dawson, ibid.

Among the employees of these institutions, a Canadian undergraduate degree, followed by graduate study in England, on the continent, or in the U.S. was common, as to a lesser extent was ~~the~~ already educated immigrant.

Dawson also made reference to professional scientific and technical societies as a forum for scientific investigation. Some of these do not concern us here (entomological, medical); some are more relevant (Engineering Institute of Canada, 1887, chiefly a civil engineering group); Canadian Institute of Mining and Metallurgy, 1898. The Canadian section of the (British) Society of Chemical Industry was found in Toronto in 1901. It was characteristic of Canadian scientists and engineers to belong to British and American societies as well.

Because of the degree to which scientific and technical training was available in Canada, and the ease with which it could be imported, either by Canadians abroad or by immigrants, its lack cannot be seen as an inhibition to Canadian entrepreneurship.

Even in industries which had become technologically complex, degrees had not always become a prerequisite. Willson's training, for example, was still of the apprentice type. His early involvement with the then-leading edge of electrical technology - arc-lighting - in Hamilton, followed by work with early electrical companies in New York and Ohio, was his preparation for industrial entrepreneurship. It is interesting to note that the two most renowned electric entrepreneurs in the United States - Edison and Westinghouse - lacked higher education; Edison attended public school for a total of three months, while Westinghouse was denominated an "engineer" at the age of 18 after one year in the Union Army. Foremost among the technological innovators of General Electric and Westinghouse

were Charles Steinmetz and Nicolas Tesla, imports from Europe. LeSueur represents the case of technical training received in another country and available to Canadian entrepreneurs; while Gibbs' sojourn at the Royal College of Science from the ages of 18 to 20, followed by his importation of F.J. Hambly, a more highly trained chemist, illustrates the importation-by-immigration route (the one also taken by Steinmetz and Tesla). Another example of this route, who played a more successful entrepreneurial role than the three cases chosen here, is Frederic Nicholls, born in England in 1856, educated in Stuttgart and Wurtemberg, who came to Canada in 1874. Among his accomplishments were a critical role in the establishment of the Canadian Manufacturers' Association, the founding of the Canadian General Electric Company in 1892 (which, though founded with participation from branches of the U.S. company, became financially independent of it), and the establishment of the Electrical Development Company with Mackenzie and Pellatt, an institution which represented the chief opposition to the founding of Ontario Hydro.

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The fact that a significant amount of Canadian scientific and technical knowledge was imported may have contributed in a minor way to the degree to which the industrial community saw itself operating in an international rather than national meso-economic network. Also the challenge of exploiting the agricultural and geological potential of Canada may have drawn scientific interest away from the industries of the "second industrial revolution", but the educational system cannot be considered a decisive factor in the pattern of industrial entrepreneurship.

16. H. Morgan, Canadian Men and Women of the Time (Toronto, 1912), p. 851; C. Hall, "Electrical Utilities in Ontario under Private Ownership 1890-1914", (unpublished Ph.D. thesis, University of Toronto, 1968), passim.

B. External Factors

It is next proposed to examine two factors of external origin as possible inhibitions to the success of Canadian N-entrepreneurship in science-related industry: the "industrialization" of the process of technological innovation, and the "spill-over" effect associated with the emergence of multinational enterprise in the U.S. Insofar as the former was an instrument of patent control, and thus market control, the two are related.

(1) To what extent can the inhibition of Canadian N-entrepreneurship in science-related industries be attributed to the process of "industrialization" of technological innovation which emerged in the Atlantic economy between 1870 and 1914? Today, the systematic injection of internally generated scientific and technical knowledge into the production process - the "professionalization of R and D"¹⁷ as Freeman calls it - is a routine matter, at least for the large multi-nationals. But before the 1870's the relations between science and industry were occasional and were not institutionalized.

David Landes speaks of the late nineteenth century in Europe as follows:

One general trend is manifest: the ever-closer marriage of science and technology. We have already had occasion to observe the essential independence of these two activities during the (original) Industrial Revolution, and to note that such stimulus and inspiration as did cross the gap went from technology toward science rather than the other way. Beginning in the middle of the nineteenth century, however, a close alliance develops and if technology continued to pose fruitful problems for scientific research, the autonomous flow of scientific discovery fed a widening stream

17. Freeman, Industrial Innovation, pp. 24-27.

of new techniques...(but) this is one marriage that requires permanent mediation to work...The link is provided by two intermediaries: applied science, which has as its aim control rather than knowledge, and engineering, which takes the generalities of applied science, along with a host of other considerations, economic, legal, and social, and extracts those elements needing to solve a particular technical problem.¹⁸

Landes goes on to note that successful "marriages" in certain branches of industry arising in this period "set the pattern and provided the incentive for further collaboration." Perhaps the first branch to set the pattern in Europe was the organic chemical industry. Christopher Freeman, in sketching the historical origins of systematic process development, notes utilization of in-house R and D in three German chemical firms¹⁹ by the 1870's for the production of synthetic dyes. By the turn of the century, he continues, "the new importance of an in-house process development capacity was evident not only in the commercial introduction of new²⁰ products but also in the production of old-established basic chemicals."

Perhaps the most important other branch to embody at an early date the "marriage" of science and industrial technology was the electrical machinery industry. Its scientific basis was laid chiefly in Europe but it emerged in parallel in Europe and North America from about 1870. David Noble, in his study of the relations among science, technology, and the rise of corporate capitalism in the U.S., gives it a central role:

In the period between 1880 and 1920 the first and second generations of men who created and ran the modern electrical industry formed the vanguard of science-based industrial development in the United States. These were the people who first successfully combined the discoveries of physical

18. Landes, Unbound Prometheus, p. 323.

19. Freeman, op. cit., p. 48.

20. Ibid., p. 51

science with the mechanical know-how of the workshop to produce the much-heralded electrical revolution in power generation, lighting, transportation, and communications; who forged the great companies which manufactured that revolution and the countless electrical utilities, electric railways, and telephone companies which carried it across the nation. At the same time, it was they who introduced the now familiar features characteristic of modern science-based industry: systematic patent procedures, organized industrial research laboratories, and extensive technical training programs.²¹

The "marriage of science and technology", the combination of "the discoveries of physical science with the mechanical know-how of the workshop" occurred through a series of institutional innovations that occurred gradually from the 1870's on and culminated in the founding of large-scale organized industrial research laboratories. In Europe, as has been noted, such laboratories had developed first in the organic segment of the German chemical industry, and to a lesser extent in the British alkali industry. It was due to the leading position of these European chemical enterprises that the North American initiative was taken instead in newer industries, especially the electrical industry.²²

Some examples of firms which, before 1914, 1) were prominent in their industries in Canada, and 2) had developed large, centralized research laboratories in the United States serving many plants, including those in Canada, are as follows: General Electric-Canadian General Electric (formed by merger in each country in 1892) established its research lab in 1900 (though Edison's "team" went back to 1876). Westinghouse, in Canada by 1896, had its lab by 1903. The American and Canadian Bell Telephone Companies had a financial and technical relationship from 1880;

21. David Noble, America by Design, (New York, 1977), pp.6-7.

22. Noble notes that this situation in the chemical industry was rapidly reversed following U.S. seizure of German patents following World War I. Noble, op. cit. pp. 16-17.

the central laboratory was founded in 1907. Dupont entered Canada via the American Powder Trust in 1876; it centralized its laboratories in 1888 (for explosives) and 1902 (for dyes and organic chemicals).²³

The "industrialization" of technological innovation took many forms besides that of the establishment of industrial research laboratories. Though most of these came to fruition after 1914, they were germinating well before then. Among them were institutions which linked industry to industry: private contracting firms, consulting engineering firms, trade association laboratories. As well, institutions arose which linked industry to education: industrial fellowships and training programs which linked, for example, M.I.T. with the Lynn, Massachusetts, component of General Electric. Shortly, too, particularly under the impetus of World War I, government services to industry such as standardization, geological surveying, etc., were to be supplemented by direct involvement in industrial research, both in the U.S. and in Canada.

Two examples in the N-entrepreneurship of institutions linking research to industry are Arthur D. Little, founder in 1886 (before his graduation from M.I.T.) of the prototypical consulting firm which bears his name; and Robert Kennedy Duncan, innovator of a system of university-industry fellowships and founder of the Mellon Institute, the earliest U.S. private research institute (1913.) These two were in addition the foremost

23. The dates of entry to Canada are from Marshall, Southard, and Taylor, Canadian-American Industry, pp. 72, 73, 83, 127-28; those for the laboratories are supplied by Noble, America by Design, pp. 112-13, 116. Dupont employed 250 chemists by 1914 and 652 at the close of the war. (Frank D. Adams, "The Need for Industrial Research in Canada", Honorary Advisory Council for Scientific and Industrial Research, Bulletin No. 1, Ottawa, 1918, pp. 4-5.)

U.S. publicists of research for industry.

To return to our question, can the inhibition of Canadian N-entrepreneurship in the cases under consideration be assigned to the emergence of the process of the "industrialization" of technological innovation as described above? By itself, it probably cannot be considered a major factor, at least for this period. For one thing, the formalization of the research laboratory was but one aspect of the more general phenomenon of the emergence of oligopolistic large corporations; the laboratories' contribution to the establishment of patent control was just one among many instruments of market control. The relative sizes of the Canadian and U.S. markets, and the relative feasibility within the two countries of evolving rapidly from serving a local or regional market, to serving a national or international market, were factors that were likely to override in importance that particular evolving feature of the internal organization of a company. This point will be developed more fully in the next section.

24. Noble, op. cit., pp. 122-25. Duncan is interesting in the present context as a case of "expatriate entrepreneurship"; he was born in Brantford, Ontario and graduated from the University of Toronto. An example of his activities as a publicist comes from his survey to 1907 of the uses of chemistry in industry: "The substitution of real knowledge and high technical skill for the "rule of thumb" of our ancestors has created a revolution in industry. This revolution took its rise in Germany, and it is spreading rapidly to every corner. It is spreading silently too because it does not pay to tell. During the next five years the small manufacturer who is swept out of existence will often wonder why. He will ascribe it to the economy of large-scale operations, or business intrigues, or what-not, never knowing that his disaster was due to the application of pure science that the trust organizations and large manufacturers already are beginning to appreciate." (R.K. Duncan, The Chemistry of Commerce, (New York, 1907), p. 66.)

Secondly, we are looking at three initiators of "entirely new" processes, and the institutional circumstances under which their inventions would become innovations were still in a state of flux throughout the Atlantic economy. (As is generally true in scientific and technological advance, it cannot be said that without them the advances would not have taken place; Willson was one of two "simultaneous discoverers", the other being Moissan in France; LeSueur's cell was one of perhaps ²⁵ six types of cells which emerged rapidly after his in North America, while one was developed slightly earlier in Germany; and a furnace process resembling Gibbs' had been developed in England). The range of methods by which electrochemical processes were first innovated included the selling of patents, the use of special-project employees and the ~~work~~ of inventor-entrepreneurs. A particular geographical factor was likely to keep electrochemical industry more dispersed than its "parent" electrical and chemical industries: that is, the necessity of abundant, cheap, usually hydroelectric power. (In the case of Niagara Falls, geography acted as a magnet, but at the time, this meant an accumulation of small new plants.) However, the close relationship between electrochemistry and its "parent industries" meant that it evolved extraordinarily fast once it was begun.

Let us see where if at all the process of the "industrialization of research" impinged on the careers of Willson, LeSueur, and Gibbs.

In the case of Willson himself, he seems to have been unaffected by the model of research within industry; he carried on extensive research activities on his own, and with M.M. Haff from 1906, with the aim,

25. One of these, the Gibbs cell, was developed by Arthur Gibbs, the brother of W.T. Gibbs, while in the employ of the National Electrolytic Company at his older brother's suggestion; it was later employed at Wyandotte, Michigan, and in the Canadian Salt Company, Windsor, in 1911.

if he had lived, of setting up one or more companies in a totally different field (phosphate fertilizers). In this he resembles the model of the inventor-entrepreneur. As for the companies formed from his carbide patents, both Canada Carbide and its American competitor Union Carbide were proceeding on the basis of expanding their markets. While extensive design improvements were carried out in both cases, establishment of organized research laboratories was a post-1914 development.

The major part of LeSueur's career seems to have been that of an industrial consultant, a very successful solver of particular problems for a variety of companies. In that sense he represents a case of the type of interstitial entrepreneurship so vividly exemplified by Arthur D. Little. But there is evidence that he was dissatisfied with this role. In the case of his work for Clergue, he may be seen as a member of a premature, over-extended industrial research team. In the case of his original venture in N-entrepreneurship, where he resembled the model of the inventor-entrepreneur, he was the victim of unfortunate encounters vis-a-vis both management and the patent system; his financial failure to reap the benefits of the process for which he is remembered in history cannot be ascribed to the "industrialization" of technological innovation in competing companies, since by the time he was out of the business, such firms did not exist in his field. During his brief career at the Rumford Electrochemical Company, however, he did create what might be considered an embryonic form of the industrial research team, a form which is characteristic of the earliest stage of a new industry. As he put it many years later, "I believe I have done distinguished work in a direction that you would hardly guess.

It is as a manufacturer of inventors.....Every man jack we had in the cell-
shed became an inventor".²⁶

In Gibbs' experience with the Electric Reduction Company, research accompanied production from the beginning of the firm to his death. In addition to his own work, as has been seen, Gibbs hired an experienced chemist (Hamby) in 1898, and an assistant chemist, Fred Dunscombe, in 1900. When the company was purchased by its chief competitor, Albright and Wilson, in 1903, some reallocation of its production processes took place, particularly in relation to Albright and Wilson's other North American subsidiary, the Oldbury Electrochemical Company of Niagara Falls, New York (founded 1898), but there is no evidence that research in the phosphorus and related industries was any more formalized elsewhere than at Buckingham, up to 1914.

Thus, up to 1914, the impact of industrialization of research and technological innovation was not determinant. Can it be seen as a limitation after 1914? A look at the cases of ERCO and Canada Carbide/Shawinigan Chemicals is useful in this context.

In the case of ERCO, the British parent company assumed control at too early a stage in its development for a factor such as the industrialization of research to have operated in either the parent or the subsidiary. There is, however, evidence of decentralization of research in the current operations of the company.

Shawinigan Chemicals, however, developed and ran an effective industrial research laboratory at an internationally competitive level, and was successful until petroleum replaced carbide as a source of acetylene

26. E.A. LeSueur, "Adventures in Electrochemistry", loc. cit., 1947, p. 86.

and its derivatives. The ultimately greater success of its chief U.S. competitor Union Carbide cannot be assigned chiefly to superiority in research (it did develop a centralized laboratory in 1921), but perhaps to greater diversification which eased survival of a major technical change related in turn to a larger market.

(2) A final hypothesis that could help explain lack of long-term success in Canadian high-technology N-entrepreneurship would be that the "spill-over" effects of the emergence of U.S. multinational enterprise acted as a key inhibiting factor.

"Spill-over" refers here to emerging domination of international markets by firms which had the financial and organizational capacity to operate in certain new ways called forth by the technologies of the "second industrial revolution." These new capabilities included a more complex process of product development. (An 'invention' may be accomplished relatively cheaply, but its transformation into an "innovation" in the marketplace is much more expensive.) Sometimes the ability to integrate backwards into sources of supply for new materials, such as those needed in a variety of new alloys, would be an advantage. Often the financial flexibility to adapt new industrial processes to the manufacture of different products, depending on the state of the market for each, could be useful. The resources to obtain and litigate patents, and to defend infringements, would be increasingly important. The capacity to integrate forward into distribution, marketing, and, in cases like electrical equipment, service and repair, would be particularly advantageous with new, unfamiliar products. U.S. firms, having a greater volume of production for a larger national market, would be more likely than Canadian firms to command the large capital resources necessary to perform some or all of these functions contributory

to successfully marketing a technological innovation.

It has been shown that these factors played an important part in setting the patterns of concentration in large firms within the U.S. by 1910. "[Between 1890 and 1903] mergers occurred more frequently and were more successful in the modern metals, and the new machinery and chemically oriented groups, than in the older, longer established ones."²⁷

[By 1910] big businesses were much more likely to succeed if they were in technologically advanced industries which achieved genuine economies of scale. The difficulty and expense of creating new, competitive firms in such industries as steel, non-ferrous metals, petroleum, autos, rubber, machinery, electrical manufactures, and chemicals usually either discouraged most outside competitors from venturing into those areas or explained their lack of success if they did. The big companies in such industries had by the early twentieth century a very long lead in terms of capital investment, managerial talent, scientific or technological expertise, and established market positions. Others found it very difficult (though not impossible) to enter and compete with the existing giants.²⁸

Such "giants" were prominent among the early multinational firms.

The emergence of U.S. multinational enterprise between 1865 and 1914 has been described by Mira Wilkins, who divides the period roughly into two phases: 1865-1892 and 1893-1914. The first period

27. Alfred D. Chandler, Jr., "The Structure of American Industry in the Twentieth Century: A Historical Overview," Business History Review, XLIII, 3 (Autumn 1969), 269.

28. Glenn Porter, The Rise of Big Business 1860-1910, (New York, 1973), p. 81.

29. Mira Wilkins, The Emergence of Multinational Enterprise...to 1914, (Cambridge, 1970). As noted in Chapter I, the term "spill-over" is borrowed from her, but its meaning is quite different from its use here. She uses it in a general way merely to indicate the greater intensity of the "emergence" in geographically contiguous areas - Mexico, Canada and the Caribbean - than in other parts of the world.

(1865-1892) was primarily a period of extension of the domestic market. It was made possible by two pre-conditions which had come into existence by 1865 and continued to develop as time went on:

- 1) rapid communications, on the North American continent and with Europe;
- 2) the transformation of local and regional enterprises into national enterprises.

Wilkins emphasizes that the initial phase was an outgrowth of marketing strategy rather than a search for raw materials. Companies typically went through stages in marketing, starting with the use of an independent agent in the foreign country, proceeding to a salaried export manager, to a permanent resident abroad, and finally (and this is where direct investment made a significant entrance), construction of a finishing, assembling or manufacturing plant to serve the new market. The process was largely similar to that of expanding from a local or regional market to a national market domestically. In the further case of acquiring or merging with a competitor, the process was again similar to the domestic one. The pioneer example was Singer; other early examples were in metal-working, electrical equipment, the telegraph, telephone, chemicals (medical, film and explosives), and oil. In all of these cases England, the rest of Europe, and Canada were the first hosts because of their developed market.

Additional factors operating in the second period, from 1893-1914, included the depression of 1893-97, which increased the intensity of the search for external markets, and facilitated mergers of failing with

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surviving companies, thus increasing their size and the likelihood of their international expansion. Second, the Sherman Anti-trust Act of 1890, by forbidding agreements between independent companies, encouraged mergers, thus also producing giant companies capable of expanding internationally. In addition, it emerged that foreign affiliates or subsidiaries could act vis-a-vis European competition in a way that was illegal for U.S. companies. An outstanding example is the Northern Aluminum Company (1907), the forerunner of Alcan.

The "spill-over" in marketing and manufacturing had become cause for alarm in other industrialized countries besides Canada. A British observer wrote in 1901:

The most serious aspect of the American industrial invasion lies in the fact that these newcomers have acquired control of almost every new industry created during the past 15 years...What are the chief new features in London life? They are, I take it, the telephone, the portable camera, the phonograph, the electric street car, the automobile, the typewriter, passenger lifts in houses, and the multiplication of machine tools. In every one of these, save (one), the American maker is supreme; in several he is the monopolist.³⁰

Although Wilkins does not analyze the place of technological innovation in the process of spill-over, this quotation hints at its importance. Also Wilkins provides a list of major "innovators" in multinational enterprise between 1890 and 1914. Of fifty-five companies

30. Fred A. Mackenzie, The American Invaders, New York, 1901, p. 31 quoted in Wilkins, op. cit., p. 215, 217. The "one" exception was the automobile!

31. As has been noted, this phenomenon was arising simultaneously in Europe; Germany and Switzerland were international leaders in several industries of the "second industrial revolution" prior to World War I. It is interesting to note that, while the world wars tended to disperse and weaken such firms in Europe, at least temporarily, they tended to strengthen them in the U.S., as well as to draw Canada and the U.S. closer in some ways. If it had not been for the wars, this institution might not have been so predominantly American.

in Canada (thirty-one in Canada and other countries; twenty-four
in Canada only),³² approximately twenty-nine, or slightly over half,
had technological content related to the "second industrial revolution".

Can the "spill-over" of multinational firms commanding the
capital to innovate the new technologies of the "second industrial
revolution" help to explain the low resonance of Canadian technological
entrepreneurship in the pre-1914 period? The hypothesis receives some
support from the figures identifying areas of high foreign control in
later periods. In 1936, the industries with the largest number of foreign
companies (over 40%) were: rubber, machinery, automotive goods, electrical
apparatus, non-ferrous metals, non-metallic minerals, and chemicals.³³
Among the six Canadian industries whose total sales as of 1963 were over 90%
foreign-controlled, at least four correspond to the groups typical of the
"second industrial revolution": electrical industrial equipment; import-
tant segments of the chemical industry - plastics, synthetics, ammunition
and explosives -; petroleum refineries; and motor vehicles, parts and
accessories.³⁴

Evidence from the three cases studied in Chapter II also
lends some support.

32. Wilkins, op. cit., pp. 212-14. The total number of manufacturing subsidiaries was around 300. (Marshall, Southard, and Taylor, Canadian-American Industry, p. 21.)
33. Marshall, Southard, and Taylor, op. cit., p. 173.
34. John McManus, "The Theory of the International Firm," in G. Paquet, ed., The Multinational Firm and the Nation State (Don Mills, 1972), p. 69.

Willson's early Canadian career shows the development of a parallel rather than a spill-over pattern as between U.S. and Canadian companies. The group to whom he had sold his patents gradually formed affiliations yielding a firm of "national scope" (at least considerably more than regional) - the early stage of Union Carbide. Willson participated in the founding of three carbide companies which were affiliated as Canada Carbide in 1911. At the time of the founding of these three companies, in a brand new industry, it must have seemed reasonable that Canadian and U.S. markets could co-exist. Later, however, the merger that created the Union Carbide and Carbon Corporation in 1917 led to a much more diversified company than the Shawinigan Carbide-based successors of Canada Carbide.

Willson's dealings with Duke represent a kind of indirect spill-over; capital resources from the tobacco industry were eventually re-directed (with the aid of U.S. anti-trust law) to participation in the spill-over of the aluminum industry represented by the development of Arvida.

35. Union Carbide Canada Ltd. today has over 40 plants (Union Carbide Canada Ltd., "A Part of Canada.....a Part of Tomorrow"); the Union Carbide Corporation (New York) has over 500 (Union Carbide Corporation, "The International Responsibilities of a Multinational Corporation", 1976).
36. For accounts of the emergence of the Canadian-American aluminum industry (based on an electrochemical process dating from 1886), see Marshall, et. al., pp. 102-107, and Warrington and Nicholls, op. cit., pp. 192-200.

Although it is not a case of U.S.-Canada spill-over, the fate of LeSueur's electrochemical plant in Maine is consistent with this hypothesis. It could be seen as a victim of the merger wave brought on by low prices in the depression of 1893-97, which contributed to the degree of concentration in technologically-oriented industries. It could also be seen, as LeSueur's friend Barton suggested, as an illustration of the greater success of large corporations in introducing technological innovations. (Incidentally, the Brown Paper Company, which acquired the plant and process, was active as a developer of LaTuque, Quebec from 1905.)

The fact that Willson and LeSueur spent significant parts of their careers in the U.S. would seem to illustrate historical circumstances which might facilitate "spill-over". Willson's connections with U.S. corporate capital fostered the process, directly, on a small scale, with regard to the International Marine Signals Company, and indirectly, on a larger scale, in regard to Union Carbide and the Duke property. The proximity of the U.S. business system could be seen here both as a spur to Canadian innovation and enterprise, and as a factor tending to cut off consolidation of that enterprise.

Gibbs' Electric Reduction Company was the object of spill-over, but from a less common source; portfolio investment was by far more characteristic of British investment in Canada. Stopford mentions eight companies manufacturing in Canada before 1914, not including Albright and Wilson, which he later mentions as an early example of "outpost manufacturing."³⁷

37. For a survey of early British direct investment, see John M. Stopford, "The Origins of British-based Multinational Manufacturing Enterprises," Business History Review, Autumn 1974, p. 303 ff., especially pp. 316 and 324.

As we have seen, Albright and Wilson sought to enter both the U.S. and Canadian markets via the Oldbury Electrochemical Company of Niagara Falls, and acquired ERCO in the process of subsequent patent litigation.

In short, the "spill-over" from single-plant to multi-plant to multinational enterprise, occurring in firms whose size and concentration gave them advantages in technological innovation, would appear to have become a significant factor in the Canadian entrepreneurial environment by 1914. It would, of course, become much more so later.

CHAPTER IV : CONCLUSION

The emergence of Canada as an industrial capitalist nation in the decades preceding 1914 coincided with a series of transformations in the Atlantic economy. According to Polanyi, these were the years of maximum spread of the "market economy" and of the emergence of vigorous protective countermovements by nations and socioeconomic groups. It was also a period of technological change significant enough to have been dubbed by several writers the "second industrial revolution." The echoes of this "revolutionary" process on Canadian entrepreneurship have been tentatively probed by means of three case studies.

The careers of Thomas Willson, Ernest LeSueur, and William Gibbs can be seen as representative of the process of the introduction of science-related technology into industrial development, a process which is one of the principal characteristics of the "second industrial revolution". Willson, LeSueur and Gibbs were pioneers on an international basis in the electrochemical industry, an industry in which, because of its demand for cheap, abundant power, Canada's hydroelectric resources gave her a particular advantage. All three had a degree of "N-entrepreneurial" success; that is, they illuminated "dark parts of the net" of an economy by playing a managerial role in carrying into production entirely new processes whose market relations could not yet be known. Yet with the possible exception of Shawinigan Chemicals, they failed to establish industries of a particular Canadian orientation in the long term. While the kind of entrepreneurial activity of which they were examples matured to the point of becoming routine entrepreneurship, it did so very often in the framework of extra-Canadian organizations.

It is not their personal successes and failures which are at issue, but the question of the survival, the viability in a Canadian context, of the kind of institution which their initiatives were instrumental in founding. How can one explain the low resonance of their efforts?

Possible contributory factors, both internal and external to the Canadian socioeconomy, have been explored: a commercial rather than industrial orientation on the part of Canadian investors; the adequacy of the Canadian educational system in an increasingly scientific and technological age; the evolution of the process of the "industrialization" of technological innovation in the Atlantic economy; and "spill-over" by firms (chiefly U.S.) whose size and concentration gave them advantages in developing the technologies of the "second industrial revolution". All four explorations have given evidence of both the advantages and disadvantages, with regard to the utilization of science-related technology, of the "openness" of the Canadian socioeconomy to British and increasingly American environmental tendencies. While it has not been possible to validate any of these four hypotheses on the basis of the evidence of three cases, the fourth hypothesis - "spill-over" - seems to be the one most closely corroborated and least disconfirmed by our case studies.

The foregoing interpretation has tied the fate of Canadian entrepreneurship in science-related economic development to the evolution of corporate capitalism. Whether such entrepreneurship has proven more viable in the public sector, before and since 1914, is an interesting question for further work. For example, one might certainly argue that the Experimental Farms of the Department of Agriculture played a dynamic role in the introduction of new strains of wheat during the period in

question. It is more difficult to judge whether the Geological Survey played an N-entrepreneurial role or a more passive one in the development of Canada's resources.¹ Could a more dynamic role of the state in fostering for Canadian purposes scientific and technological innovation of the kind discussed in this thesis have made a difference?

The institutional innovation represented by Ontario Hydro has been extensively documented² and assessed.³ How have its performance and "resonance" compared with those of private organizations? Nelles feels that, although it kept the provision of power out of the hands of "monopoly capital, Canadian or American,"..."Ontario Hydro never became the beach-head for an ongoing critique of industrial capitalism."⁴

Since 1914, a series of efforts have been made to recognize and create explicit links between government-sponsored science and the Canadian economy, from the Honorary Advisory Council for Scientific and

1. Morris Zaslow's Reading the Rocks: The Story of the Geological Survey of Canada, (Toronto-Ottawa, 1975) is a useful reference in this respect.
2. For example, W.R. Plewman, Adam Beck and the Ontario Hydro (Toronto, 1947); Merrill Denison, The People's Power, (Toronto, 1960).
3. H.V. Nelles, The Politics of Development: Forests, Mines and Hydro-electric Power in Ontario, 1849-1941, (Toronto, 1974.)
4. Ibid., pp. 492-3.

Industrial Research of 1916, to the Senate Committee on Science Policy of 1973 and beyond.⁵ How have these and parallel provincial efforts affected Canadian socioeconomic development?

This essay has addressed one small part of an immense task: to recognize, evaluate, or create innovative Canadian responses, public or private, past or future, to the situation seen by Abraham Rotstein in The Precarious Homestead:

Premature despair in the face of the new technology has been widespread recently...In these prophecies of despair man usually stands alone, whereas the social history of the market society and the counter-movement against the eroding effects of the free market is one instance of the tendency to collective protection through new institutional forms.⁶

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5. See, for example, Peter Meyboom, "In-House vs. Contractual Research," Department of Supply and Services, Ottawa, 1974, especially pp. 7-13. Meyboom identifies three "generations" of companies which deal with government in science-and technology-related fields. The first -- large, foreign-controlled, with most scientific activity performed abroad -- corresponds in large measure to the "spill-over" firms of this essay. The second and third "generations", characterized by high scientific and technological content, and by Canadian ownership, he sees as a hopeful sign in the effort to develop Canadian innovative capacity and, (among other things), rectify a current trade deficit in the category of management and technological services of \$1 billion per year (ibid., p. 12).
6. Abraham Rotstein, The Precarious Homestead, (Toronto, 1973), p. 213.

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