NATIONAL SCIENCE POLICY IN CANADA

NATIONAL SCIENCE POLICY IN CANADA

1910 TO 1920 AND 1935 TO 1945

By
LORETTA J. BARBER, B.A.

A Thesis

Submitted to the School of Graduate Studies
in Partial Fulfillment of the Requirements
for the Degree

Master of Arts

McMaster University

February, 1980

MASTER OF ARTS (1980)
(History)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: National Science Policy in Canada; 1910 to 1920 and 1935 to 1945

AUTHOR: Loretta J. Barber, B.A.

SUPERVISOR: Dr. George James Grinnell

ABSTRACT

This thesis is a study of national science policy in Canada from 1910 to 1920 and from 1935 to 1945. The formation of this policy is found to have often been beyond the political control of the federal government and to have been directed by both British and American political and industrial interests. In illustration of this fact is an examination of the development of the dominant industrial technologies and of the bureaucratic machinery of the public sector science organizations in combination with their aims to industrialize Canada and to exploit the use of natural resources. Throughout this study, the repeated overlapping of scientific developments and industrial technologies with military developments, as in the case of wheat, the refining of metals, and the development of atomic power, reveals the strong inter-connections between industrial and political interests.

TABLE OF CONTENTS

I

INTRODUCTION

According to Maurice Lamontagne the lack of clear-cut science policy is detrimental to the national unity of Canada. So strong was his conviction that he and his Senate Committee on Science Policy (1967) devoted an entire volume of their report to an analysis of previous failures to co-ordinate science within public agencies. The government's concern about science policy was not new. More than fifty years before, the Honourary Council for Scientific and Industrial Research had grappled with the same problem. How was Canada to be made into a developed country, fully industrialized, owned by Canadians, staffed by professional scientists educated in this country, and dependent mainly upon Canadian scientific research?

The demands of war stimulated the exploitation of natural resources which then encouraged new technology and a new bureaucratic machinery. For the purpose of analysis, I have dealt separately with different aspects of this development. But in fact all aspects of it are deeply inter-related and none can be isolated without sacrificing comprehension of the relationships among them. The totality of those relationships has impinged upon - to the extent of composing - science policy in Canada.

The principle tenet upon which national science policy in Canada has been based is the desire for development of natural resources. These resources range from timber to wheat, nickel to uranium, and hydro power to atomic power. Every resource was considered as potential wealth, best realized through the application of industrial refinement and production on a large scale. Since industry is financially successful when the processes used are technologically superior to those of competitors, access to reliable and innovative research and to the researchers themselves was of paramount importance. Implementation of effective science policy had to contain the two priorities of expanding graduate university education in the sciences and establishing an institution within which researches could be conducted. The former priority was the major concern of the Honourary Council for Scientific and Industrial Research established in 1916. A more basic problem had been solved before this initial step was taken. The Commission of Conservation, established in 1909 and headed by Clifford Sifton, had surveyed the extent of many of Canada's natural resources and had thus begun to lay the necessary background to development.

By themselves, the original aims of the science policy seem sound. However, unlike the limited political jurisdiction of a government, science has an irrevocably international character. As a scholarly activity, the results of scientific research are disseminated through journals, in lectures, and from person to person regardless of national boundaries. Thus research results are widely accessible. Their availability, however, is influenced by the interests of technology. Defined as "the organization of knowledge for the achievement of practical purposes", technology gives vested interests to scientific research when the results are useful to industry for the development of processes involving mass production.[1] The aim of the federal government of developing Canadian natural resources by uniting science with industry ensured an enforcement of this vested interest. However, since this was a government organization, political and military interests which threatened the balance of stability between industrialized countries were also involved. Thus, science activities and policy formation in Canada fell under the influence of international tensions.

Scientific research which is openly accessible to everyone and which is pursued only from a theoretical interest has been virtually nonexistent in the twentieth century. For not only does science have an international character but so too does technology, so too does industrial manufacture, and so too does war. All four interact. Consequently science must be regarded as a building block which is just one activity among others. Verbal accuracy upholds the description of 'basic' rather than 'pure' science. Basic science follows the social, political and economic pressures of any given period. Scientific research and science policy in Canada were responsive to these pressures. The research conducted was principally of a basic form and with the stimulus of government control during war, the policy, attitudes, and research reflected these pressures increasingly.

With all of these interactions the critical question becomes what forces or what people determined national science policy in Canada? While I admit the desire of Canadian politicians was originally to develop natural resources and to achieve this by uniting scientific research efforts with industry, I also contend that this aim did not alone account for the success or failure of this original science policy. The interceding complicating factors of applied technology, industrial manufacture, and war all played an important role and made the formation of any policy for the development of science, with control to be exerted by the federal government, a very difficult if not impossible task. The body of this thesis is an exploration of these complicating factors as they affected the goal of developing Canada's natural resources. Accomplishment of this task is crucial to an appreciation of the potential of science when it is under the wing of government as well as to the limits of any attempt to mould science policy at a legislative level.

II

THE GREAT WAR: DEMAND ON NATURAL RESOURCE PRODUCTS AND STIMULATION OF SCIENTIFIC RESEARCH AND ORGANIZATION

The first step towards establishing a national governmental science organization was taken on June 6, 1916 when the Government of Canada appointed, by an order-in-council, a sub-Committee of the Privy Council.[1] Members included the Minister of Trade and Commerce, who was also the Chairman, and the Ministers of the Interior, Agriculture, Mines, and Inland Revenue and Labour. Because of the pressure of other work the Minister of Trade and Commerce, Sir George Foster, was unable to present to Cabinet his final proposals for further membership until November 29, 1916.[2] On that date an Honorary Advisory Council for Scientific and Industrial Research, composed of nine members representing both scientific and industrial interests, was constituted.[3] This advisory group was better known as the 'National Research Council'. With Professor A.B. Macallum as Administrative Chairman, the duties of the Advisory Council were assigned as follows:

a)To ascertain and tabulate the various research agencies in Canada.
b)To note and schedule the researches and investigations.
c)To co-ordinate all research agencies so as to prevent overlapping.
d)To tabulate the technical and scientific problems that confront the present industries.
e)To study the unused natural resources of Canada and the by-products of all basic industries.
f)To increase the number of trained research men.
g)To stimulate the public mind in regard to the importance and utility of scientific research and its application.[4]

To perform this large array of duties were volunteer members who occupied all posts except that of Administrative Chairman and secretary. Among them were Ministers of Government, university professors, a banker, and engineers. The council met only four times per year and in the first full year spent only $61,000. The sum rose to $121,000 by 1925. While the concentration in those years, economically at least, was on financing university science graduate students and, to a lesser extent, on solving certain problems posed by the war, a lobby for a change in emphasis soon appeared. By 1919 appeals were made to the Dominion Government to acquire permission and finances to establish a national research laboratory, though they were not granted until 1927.[5]

The facts of the establishment of the National Research Council are clear; the original causes which led to its formation are less clear. The effect of the Great War must be a primary consideration particularly with relation to the Imperial Government's demand on certain Canadian products and its stimulation of scientific research and organization.

In July of 1915, Britain established a Department of Scientific and Industrial Research, DSIR, to mobilize its research facilities for war. At the same time a suggestion was made, through the Committee of the Imperial Privy Council, that each Commonwealth country create a similar agency to participate in a co-ordinated chain of organizations. This advice was instrumental in Canada's decision to form a NRC. Though still in its infancy by the end of the war, a strong framework had been constructed. The precedent of having scientists allied with government, whether they were located in universities, industry, or with the Council, had been set. The most recent branch of the Canadian Section of the Society of Chemical Industry had been established in December, 1917 and by January, 1918 the chairman of this section announced that the annual convention of the Canadian Section of the Society and a convention for all Canadian chemists would be held together in Ottawa. The formation of an Associate Committee of chemists, the establishment of the NRC, and the work of the Imperial Munitions Board combined to draw a large influx of chemists to this government city.[6]

The Canadian Section of the Society of Chemical Industry, (S.C.I.), was a member of the original English S.C.I. and was first established in the Dominion in January of 1902 at the suggestion of a prominent rubber technologist, Mr. Harold van der Linde. As has been stated, a prime impetus for the establishment of the Honorary Advisory Council for Scientific and Industrial Research came from the suggestion of the Imperial government. Finally, the Imperial Munitions Board, though operating in Canada, was a purely executive body, controlled and financed principally by the British government.[7] It initiated the employment of over 250,000 workers as well as some professors who had responded to a British request sent directly to the universities without the consent of the federal government.[8] In each of these areas or organization, professional scientists, the government science institution, universities, and industry, the Imperial government was prominent. Thus the precedent of having scientists allied with government included both the Dominion and British governments.

Before the demands which the war and Great Britain particularly placed on Canada can be explored it is necessary to retreat backwards to consider an agency which though separate from the function of the NRC may be regarded as an early administrative attempt to deal with the growing need of a national governmental science organization.

Established in 1909, the Commission of Conservation was an advisory committee which, as Prime Minister Meighen said, was "to investigate and advise as to the right lines of development of public policy in the conservation of Canadian resources."[9] Clifford Sifton, Chairman of the commission from its inception until February, 1919, described the work as that of, "investigating and advising on the attainment of ends which are universally commended as essential to the highest degree of national welfare." This could be achieved, he said, by promoting, "the economic utilization of resources."[10]

The Commission shared many characteristics of the early NRC. Its members included academic scientists (from each province with a university), members from the private sector, and the government. Included in this last category were the Ministers of Mines, Agriculture, and the Interior, as well as the members of each provincial government who were responsible for natural resources. Dr. Henry M. Tory, then President of the University of Alberta and a member of the Commission, later became the Chairman of the NRC, holding the post from 1923 to 1935.[11]

The Commission had no administrative authority as was the early case with the Honorary Advisory Council.[12] Also, since it was an independent body there was no attachment to any specific department. Presentations for financial votes were made by the Minister of Agriculture, a practice which was continued by the Minister of Trade and Commerce for the NRC after 1921.[13]

Though the excuse that the cost of the Commission had become too great to bear, having climbed from $12,000 to $104,000 annually, was repeatedly cited as a reason for the repeal of the Conservation Act it sounded a hollow tone.[14] For, at the same time, the National Research Bill was before Parliament. Its powers included granting administrative functions and awarding money for a national laboratory. As those who opposed it were quick to point out, abolishing the Commission of Conservation in order to save $140,000 per year only to provide four to five hundred thousand dollars for the creation of a scientific research bureau (and only for the erection of the building at that) was decidedly uneconomic.[15]

The other primary reason which Meighen gave for the repeal bill was the overlapping of the Commission's work in the area of other Departments, allegedly a result of its independent status.[16] Suggestions that establishment of a connecting link to bring the Commission under the authority of a responsible minister and thus abandoning the need of the Honorary Advisory Council were ignored.[17] The Conservation Act was repealed on May 26, 1921, two days after the National Research Bill had been passed.

From its inception in 1916 the members of the Honorary

Advisory Council attempted to increase the numbers of Canadian graduate students in the university science departments. A moderate amount of research was also undertaken through the volunteer services of university scientists, some of which related directly to problems issuing from the war, the rest being concerned with more general national problems. The connection between the Commission of Conservation and the NRC is evident from the common subjects of certain research projects. The Commission of Conservation had investigated the possibility of using low-grade lignites from Western Canada to replace coal as a heating fuel so that the four million dollar expenditure on high-grade anthracite annually imported from the United States could be reduced.[18] The NRC began a similar investigation into the briquetting of lignites in 1917 and established a Lignite Utilization Board in 1918 to study actual briquetting processes.[19]

The war and Britain's situation in particular had brought a swift increase in the need for high soil productivity to produce the greatest possible quantity of food. At the same time it was realized that the depletion of nitrogen in soil could be restored by additions of nitrogenous fertilizers. In 1916 Sifton wondered if fertilizers might be an important new product.

> Is it too much to predict that, before many years, coke will be the fuel and that the by-products now dissipated in smoke and ashes will furnish the fertilizers which will render yet more and more productive the grain fields of the west? [20]

Carried away with the potential of such a product he even went so far as to suggest that the possibility of the British Isles producing all of its own food with this aid was not ludicrous![21] Since water power was the primary means of fixating nitrogen and making it available for practical use, the Commission's early studies of Canada's water power soon became very important. Research on increasing the nitrogen in soil was eventually carried on by the NRC. Annual reports indicate that much of it centred on attempts to determine requirements necessary to neutralize acidic soil through the use of lime or other inexpensive chemicals.[22] Nevertheless, the fact that Dr. J.C. McLennan, Professor of Physics at the University of Toronto and the researcher most interested in nitrogen, was automatically placed in charge of all committees in any way relating to this subject indicates that more varied research was carried out. Nitrogen, after all, was a key ingredient in the manufacture of explosives during World War I.[23]

Some evidence of attempted co-operation between the two government science agencies is apparent from the NRC's resolution of January 5, 1917:

> That a committee consisting of Mr. Ross, Dr. McLennan, Dr. Ruttan, be appointed to wait upon the Commission of Conservation and similar organizations, with an offer to co-operate with them about the proper utilization of our water powers and the stimulation of Canadian industries in connection therewith. [24]

This move was reasonable considering that the Commission of Conservation, as an economic and geographically nationalistic guardian of Canada's natural resources, offered advisory reports on Canada's water systems. However, an ulterior purpose of the NRC committee surfaced in 1918, after the Aluminum Power Company of Massena, New York applied, with the backing of the United States

Secretary of War, for additional hydro power to construct a weire in the St. Lawrence.

The Commision of Conservation traditionally offered advice to the International Joint Commission on such boundary water applications.[25] A similar proposal had been made by subsidiaries of the concerned company, the Long Sault Development, and the St. Lawrence Power Company, in 1910. At that time the Commission had argued adamantly against such vested interests of Canadian water power by private companies in the United States and the advice had resulted in refusal of the application. However, in 1918 the Aluminum Company was supplying the armies with approximately sixty per cent of their aluminum requirements. If Britain and Canada expected to keep an important ally the best interests of the Commonwealth lay in approving this application.[26] Consequently, when the Secretary of the Commission, James White, appeared before the International Joint Commission to give his position, he found the Solicitor-General, Hugh Guthrie, also present. Their voices, and thus the voice of the Commonwealth, were not in accord. White advised against the exploitation of Canadian water by private enterprise in the United States. The Dominion Government denied the right of the International Joint Commission to deal with the question, demanding that a treaty between the two governments should be made in order to allow joint development of water power. By drawing up an order-in-council the Dominion Government attempted to by-pass the time consuming process involved in ratification of a treaty. However, on September 14, the International Joint Commission decided to award the application request.[27] Sifton resigned his chairmanship soon after, having apparently been disgusted at the abuse of the independence of the Commission in this instance. Though the Commission of Conservation existed for a few more years it lacked a full-time, competent chairman from 1918 and seemed marked for removal.[28] The constituted independence of the Commission of Conservation had been indirectly denied by the Dominion Government.

The question arises of whether the aim of the Commission of Conservation differed essentially from that of the NRC. Did the formation of the Council represent a transformation of the government's attitude to science policy or was it merely the appearance of a new skin after the old one had been shed? The latter seems to be the case. Meighen's arguments for the repeal of the Conservation Act had rested on its expense and its duplication of the work of other departments. Neither was justified, especially in view of the equally high cost of the NRC and the structural composition which allowed it to remain independent of any specific department. Research interests between the two organizations had been similar. The Commission of Conservation had been concerned with conservation in the interests of future resource exploitation, while the NRC's purpose aimed directly at co-ordination of scientific organizations for the immediate development and exploitation of natural resources by means of scientific research. Herein lay the change. By 1917 the time had arrived for refining Canada's natural resources by technical means and scientific research in order to produce high yields, as in the case of wheat, and supplies of new metal, as in the case of nickel, both to appease Imperial pressures and satisfy Commonwealth 'duties' in the emergency of war as well as to make short-term financial gains. The early studies conducted by the Commission of Conservation on the existence and classification of natural resources in Canada merely aided in forming a basis for the exploitation of these resources.

III

ADMINISTRATIVE STRUCTURE OF NATIONAL SCIENCE ORGANIZATIONS

Establishment of an Honorary Advisory Council by all of the Commonwealth countries was suggested by Great Britain in 1916. Australia, New Zealand, Canada, and later South Africa and India acted on this suggestion. While the structure of the Canadian Advisory Council varied from the original British model, the differences were minimal and were restricted to the unique situation of this country. Also, the previous experience and insight which Great Britain acquired through the formation of its Council were apparent in the structure of the Canadian counterpart.

Britain's Department of Scientific and Industrial Research (DSIR) first met in August, 1916, though it had been formed on July 2, 1915. This Advisory Council was responsible to a special Committee of the Privy Council. An early proposal had placed the Council under the aegis of the Board of Education since development of science education and organization was a prime aim. However, since the Board of Education was constitutionally unable to administer the scheme uniformly throughout England, Ireland, Wales, and Scotland the proposal was rejected. The Treasury favoured the Board of Trade which had responsibility for all of these areas, as well as for industry.[1] Ultimately neither of these departments took responsibility for the new Council. Canada followed the decision to make the Honorary Advisory Council responsible to a sub-Committee of the Privy Council. In Canada, the Minister of Trade presented the financial vote to Parliament, but this was only an administrative duty. Also, the Ministers who sat on the sub-Committee of the Privy Council were responsible for national departments: Ministers with provincial portfolios were excluded, in distinction from the members of the Commission of Conservation. Thus control of the Honorary Advisory Council, though not responsibility for it, rested in the hands of select members of the Dominion Government, as was the case in Great Britain. Similarly the Council was composed primarily of academic scientists and lacked representatives from the industrial and manufacturing sectors.

Sir George Foster, Minister of Trade and Commerce for the federal government presented the first Research plan for the Council to the Prime Minister on May 25, 1916. Regarding the composition, Foster wrote:

> My idea is to have seven or nine on the Board, and to have two of these representatives of the industrial interests - and five scientific men, men versed in industrial research work - We want men of science, of course, but we also want men of a practical turn who have business in them.[2]

In fact, Mr. R. Hobson, President of the Steel Company of Canada, was the only representative of industrial interests selected for membership in the Council. Viewed from all angles, the industrial interests had only a minority, if not a token position. This arrangement was little varied from the British example.[3] Though several manufacturors and industrialists were considered by the British Board of Education, none had been selected. Of the three industrial chemists who were members of the Council, one died during 1915,[4] and another, presumably Sir Richard Threlfall, was distrusted by some major British chemical manufacturors. Max Runciman, Chairman of the United Alkali Company, Britain's largest chemical company, claimed that a ssociation with the Advisory Council (DSIR) was impossible since one industrial chemist was, "a most bitter rival...who in pre-war times was closely interlocked with German interests, and since the war began has taken every step to block our interests in certain instances in conjunction with German firms."[5] The thorny problem of neutralising or appeasing trade interests within national science organizations was overcome by virtually excluding (leading) men of industry from official membership in both Honorary Advisory Councils.

The original independent and essentially undefined political status of the DSIR was repeated in Canada's NRC. Responsibility to a particular government department and to a specific Minister was lacking. The chain of responsibility leading to the public arena of investigation was absent. Though of a federal rather than provincial status, national science policy grew from blurred legislative boundaries.

Structurally, the NRC resembled its predecessor, the Commission of Conservation, though the latter had been allegedly abolished partly because of its independent status and widespread functions which allowed research normally reserved for specific departments to be undertaken.

Continued structural inadequacies, notably the lack of responsibility to a specific federal government department or Minister and the consequent removal of the NRC from Parliamentary and thus public scrutiny, repeated from the Commission of Conservation and similar to the British DSIR show a cavalier disregard for the system of responsible government. The independence of the NRC may have been allowed because scientists as researchers in academic disciplines need to have authority to choose which investigations to pursue without the interference of politicians. Even if that were the ostensible reason, nevertheless the independent status served to put the services of a large government scientific organization at the disposal of a small government control group. The NRC thus became an institution over which the public had no direct control.

The apparent differences in the two organizations rest with functions more than structures. Such limited documented research as the Commission of Conservation conducted was replaced by the new policy inherent in the NRC Act for the immediate exploitation of certain natural resources. One member of Parliament expressed the difference when he said that the effect of the NR Institute would be, "...to encourage original investigation, to tap new sources of energy, to develop our natural resources, to make our soil more productive, our forests renew their trees, our fisheries a greater asset, and our mines of greater use in the development of our country."[6]

On April 22, 1919, the Special Committee of the House of Commons Appointed to Consider the Matter of the Development in Canada of Scientific Research, otherwise known as the Cronyn

Committee, was established. Hume Cronyn, the chairman, was charged with investigating whether the construction of a NR Institute was desirable. Less than three months later, on July 1, 1919, Cronyn presented an interim report recommending the generous support of national research plus the establishment of a Canadian Bureau of Standards. The reasons for this advice included a)attaining or maintaining Canada's standing in the Commonwealth, b)making natural resources available with more certainty, and c)having native industries achieve better positions in world markets.[7] Considering the short investigative period and the mere one and a half page report, the study conducted by the members of the Committee was clearly less than exhaustive. The final report of April 27, 1920 was somewhat bolder. It advocated the immediate support of a NR Institute and outlined its duties. Yet even this report was only three pages long and resembled a piece of draft legislation more than a comprehensive study. Cronyn's naive opinion that science was, "the 'Master Key to the treasury vaults of the entire globe" was thoroughly representative of the Committee's attitude and, by inference, explains the superficiality of the reports.[8] With such an attitude support for a NR Institute was a foregone conclusion.

The Parliamentary discussion surrounding the Research Amendment Act revealed the blurred aims and proposed breadth envisioned for National Research laboratories. Some examples include the recommendation that "Guilds for Research" be established to apply scientific knowledge to industrial production.

There was also Sir Sam Hughes' suggestion that individual inventors should be able to conduct research at the expense of the federal government in its laboratories.[9] Hughes' proposal was based on his experience in World War I and was not put forward in a sympathetic interest for private inventors. Rather, he recalled the valuable military ideas of a Mr. Fessenden who in 1914 had a device to detect the presence of submarines and one to locate enemy batteries. After interviewing this man, Hughes sent him to the United Kingdom in hope of having these inventions developed and adopted in Britain. The second invention was finally adopted in 1917, but only after Italy and France had put a similar device to use. Britain's delay had been directly attributable to the fact that Mr. Fessenden was not allowed to conduct research in the government laboratories.[10] Neither Hughes' recommendation nor the Guilds for Research was accepted although each carried the suggestion that the private sector, through both the industrialist and the individual, should be allowed to participate in the national science program.

By 1919 the industrial sector had been excluded from formal involvement in national science organizations in both England and Canada. The "Guilds for Research" was a concept which was not adequately developed in Britain and which never passed preliminary planning stages in Canada. Neither the industrialists nor individual inventors nor amateur scientists were welcomed officially into the NRC or its laboratories.

During the lengthy debates on whether the NRC should be under the jurisdiction of the Minister of Trade and Commerce and whether a NR Institute should be established, repeated references were made to the need to develop Canada's natural resources and industries so that each would hold a better position on the world market. The means by which these goals were to be achieved, mainly the application of original scientific and technical knowledge to natural resources to create secondary, marketable products for Canadian industry, were deemed crucial to the economy of any industrialized country. In the final Cronyn Committee report the urgency of the need to establish national laboratories was based on fear of post-war foreign trade competition and the need to meet the "huge burden of debt imposed by the war". This monetary debt was to be erased by,

> ...the conversion of our natural resources into developed wealth...through the application to them of science of the most highly advanced type. 11

The work of Louis Pasteur and Faraday became objects of fond reminiscences, particularly with the realisation that Pasteur's profit equalled Canada's war debt and Faraday's discovery exceeded this amount in the electrical industry.[12] One report issued by the NRC stated the point quite bluntly when proclaiming that,

> During recent years public opinion in all progressive countries throughout the civilized world has come to realize with increasing clearness that scientific research properly directed always pays even from a dollar and cents point of view. 13

These observations focused on monetary rewards.

Apparently, however, no one perceived the change which such a national science program would bring about. Sir Sam Hughes still had faith in the creativeness of amateur inventors, and those promoting "Guilds for Research" still refused to acknowledge the impossibility of effectively uniting government science research organizations and industrial trade interests. The opinion of a Muskoka parliamentarian that Departments of Scientific Research "have passed the stage where they can be left to private individuals, or even to provincial governments" betrayed a more realistic conception of the size of these undertakings.[14]

IV

WHEAT PRODUCTION AND THE GREAT WAR

Traditionally, Canadian historians refer to the staple products sold and exported abroad when speaking of natural resources. However, to speak only of the amount of furs sold, fish caught, timber felled, and wheat produced is not sufficient to an understanding of science policy and its effects. A financial stocktaking predictably reveals only monetary aspects of a situation. The production level of any staple or semi-refined product is always ultimately limited by the natural availability of that staple or resource rather than by effective market demand. A study of wheat production in Canada during World War I is included to illustrate this fact. For, during this period, the belief that effective market demand could be the only limit to wheat production prevailed. The devastating effects on the fertility of prairie soil and on the farming families dependent on it shows the ecological basis upon which all natural resource production rests. It also proves that the long-term availability of staple products is contingent upon more than financial interests. With this knowledge in hand we may gain an appreciation of the effects of a science policy goal aimed at pushing the production of natural resources into potentially unlimited developed wealth through the aid of applied science.

In 1917 the Chairman of the Commission of Conservation noted with envy that, "Germany has not neglected the greatest of all resources - the productivity of the soil."[1] His observation would have been astute had it not been marred by the belief that the use of scientific techniques and applications of chemical fertilizers rather than proper agricultural technique would preserve soil stability and fertility. Sifton, like many Canadians, realized that with England's imperative and immediate need of food the high productivity rate of the soil on which that food was to be grown was extremely important. Indeed, given the sudden decrease of soil productivity in the prairie provinces after 1915, in the land from which the large wheat export crop came, concern over soil productivity was to be expected.

Between 1914 and 1919 the total number of acres seeded expanded greatly and amounts of wheat exported doubled. There were two reasons for this dramatic change. Economically, the increase in wheat production (which led to almost complete dependence on this mono-crop) was practical because Britain provided an insatiable market and the price per bushel had climbed to almost three times its pre-war level by 1917.[2] Wheat, the fourth successive staple in the Dominion's history, had reached a financial peak. This was enthusiastically welcomed by prairie farmers especially after the 1913-1914 recession. Induced by drought in southern Saskatchewan and Alberta and low international prices, the recession illustrated the danger of dependence on one crop. But the lesson was ignored. Short-term profit plus the imperial duty which Canada readily shouldered to aid a starving Britain coupled to push the productivity of prairie soil to its limit.

The effect of this abuse soon appeared in the form of drastically lowered crop yields. Whereas the yield for 1914-1915 was 26.05 bushels per acre, by 1917-1918 it had been reduced to a mere 11 bushels. During the same period, the total number of acres seeded spiralled from 39,140,460 to 51,427,190 but the total wheat crop plummetted from 393,542,600 to 189,075,350 bushels.[3] Only the uncommonly high price paid for wheat, which had been fixed in the spring, prevented widespread financial collapse among the prairie wheat farmers.

Seasons of extreme crop failure, or vastly lowered productivity, had occurred before the war in 1889 and in 1900.[4] Typically, such disasters were blamed on the weather, periodically low rates of rainfall being regarded as unfortunate occurrences in the arid prairie provinces, particularly in the southern parts of Saskatchewan and Alberta.[5] To decrease the negative effects of such occurrences by retaining more moisture in the ground the practice of dry farming was advisable. This consisted of summerfallowing and fall plowing. After producing two grain crops, one-third of improved land was left to weeds which were plowed under before consuming too much moisture. In areas with less than an annual rainfall of sixteen inches half of the land had to be left to weeds. The technique of fall plowing involved turning stubble under in the fall, allowing absorption of moisture from the winter snowfall.[6]

The methods of 'dry farming', though necessary if crops are to be cultivated in arid soils, is ultimately, "destructive of soil fertility and structure, and result in the long run in the total loss of top-soil." Not only must dry farming be practiced on arid soil if fertility is to be maintained. In time farmers "are almost bound to ruin their own livelihood, unless they take to stock-raising as a primary technique of soil exploitation.[7]

In the rush of the war years to produce more wheat many farmers seeded acres which should have been left to summerfallow. Also, instead of performing the laborious task of fall plowing, farmers began to sprinkle kerosene on their fields to burn off the stubble. This last practice was particularly unwise because it robbed the soil of precious moisture as well as valuable nitrogen and organic matters.[8]

In accordance with Canada's official policy to aid Britain, the Dominion Department of Agriculture recommended that every possible effort to produce wheat should be made to meet the wartime emergency, including the suggestion that fields which should have been left to summerfallow be seeded and stubble burned.[9] Farmers acted on these suggestions, increasing the effects of drought in 1918 and 1919.

The policies of the Dominion Government worked against making better Western farmers. The failure to change the high transportation costs which faced producers on stock shipments, to supply adequate cold storage facilities for carcasses, or to make credit for stock raising as easy to obtain as credit for grain production all hampered the farmers' financial abilities and incentives to keep livestock.[10] The resulting widespread dependency on a wheat crop came back to haunt the country in the next decade of peace. Dr. Frank T. Shutt, Dominion Chemist at the Experimental Farm in Ottawa, examined the prairie soils in 1932, noting that, "After thirty-eight years of grain growing, results showed a very large loss of soil nitrogen." This result showed conclusively that, "continuous grain growing had proven to have a disastrous effect on the soil." Significantly, he stated that in prairie areas where there was mixed farming or rotation with nitrogen-fixing plants the soil was found to be very rich, particularly in organic nitrogen content.[11]

Other methods, aside from the partial abandonment of dry farming, were used to attempt to increase the crop yield. These involved scientific research, first in the development of more productive hybrid strains of wheat, and then in attempts to employ wheat which would be resistant to the damaging effects of wheat rusts.

The development of Marquis wheat in 1908 greatly increased the yield per acre by 1914 (in spite of decreased soil fertility) principally because it ripened seven to ten days earlier than the common Red Fife, thus missing early frosts and widening the area suitable for wheat growth.[12] An estimated $100,000,000 per year was realized by this development.[13] Though well satisfied with the Marquis, the fact that approximately $25,000,000 per year was lost due to wheat rust led to the undertaking of an extensive research program on the many forms of this menace and economic saboteur. Begun in 1917, the program, directed by an

Associate Committee of the NRC on Cereal Grain Rust, was carried on in the three prairie provinces by the universities and the Federal Department of Agriculture.[14] The research had been further spurred on by the estimated loss of 100 million bushels of grain in 1916 from rusts, the failure to summerfallow having contributed to an attack of stemrust, the first wide-spread loss since 1904.[15]

Professor W.P. Thompson of the University of Saskatchewan reported in 1919 that he had a variety of wheat which ripened two weeks earlier than the Marquis, thus allowing the further avoidance of early frosts and a wider span of suitable acreage, and many varieties which were immune to a number of types of wheat rust. But he had yet to successfully combine these varieties.[16] By 1925 no variety of wheat which merged the two desired characteristics existed. Though the Associate Committee of the Research Council increased research efforts by financing the construction of a rust laboratory at the Manitoba Agricultural College in Winnipeg, a devastating infestation occurred in 1927, resulting in the loss of 100 million dollars worth of grain.[17] This was four times the estimated annual loss of the plagued war years.

Failure to summerfallow was not the only contributing factor to outbreaks of stemrust. These periodic epidemics had been occurring for decades. The monoculture farming, wherein large regions were planted in only one crop, increased the danger of disease infestation by the loss of diversity.[18]

Significant advances in developing quick growing and highly rust resistant wheat were made by the early 1930's.[19] By this date however the collective economic effect had little of the impact which such a scientific advance might have had in the early years of the Great War. Certainly the immigration and amount of homestead settlement increased after the recession which hit Prairie farmers in the early twenties. Additional railway lines also followed the settlement paths, totalling 28,000 miles in Saskatchewan and Alberta.[20] Export markets were maintained and continued disruption in Russia effectively removed that competitor from the international grain trade until 1930.[21] The importance of the wheat staple had nevertheless been overshadowed and the new concentration in metallurgical resources, accompanied by technical refining methods involving the use of hydro-electric power, composed the new major resource for exploitation.[22]

The abuse of prairie soil in order to meet Britain's demands for wheat led to exploitative agricultural practices. Canada met the imperial duty and conveniently attempted to gain financially in the process. But, to the chagrin of farmers and government economists alike, the years when wheat prices were highest coincided with drastically lowered rates of soil productivity. Attempts were made to ensure that such an opportunity was not missed again. Thus, in the year of its inception, the NRC began a research program with the specific aim of developing a wheat hybrid which had a higher productivity due to its shorter growing season and was resistant to the costly parasitic rust infestations.

This program was continued into the thirties. Eventually higher yield hybrids were produced which were resistant to many of the common strains of rust. Though the yield per acre was higher and the danger of rust infestation was decreased, there was however a major flaw in the new technology. The nutrient value of the crop was lowered. It is now known that the more nitrogen we find in a crop, the less we can expect the yield to be. Likewise, the higher the yield, the lower the nitrogen content. Since nitrogen is found in all proteins, it may be taken as an indication of the protein level of the crop. Feed grain in 1911 had a mean protein concentration of 10.3 per cent. By 1950, however, the top grade contained only 8.8 per cent protein.[23]

Attention to the structure of the soil, the arid climate, and the consequent inescapable need for dry farming would have resulted in better crop yields sooner. Diversification into other crops and livestock farming would also have reduced farmers' dependence on this mono-crop.

V

INDUSTRIAL GROWTH AND NATIONAL SCIENCE POLICY

Though Canadians in general were worried about payment of the war debt and the fierce trade competition which would ensue with the ending of war their concerns would seem to have been relatively unnecessary. For despite the debt that had been incurred the industrial and manufacturing sectors had thrived during the hostilities. A broad comparison of the gross value of manufacturing production shows more than a one hundred per cent increase between 1910 and 1917. This war-inspired spiral continued until the Depression.[1] A more specific examination reveals that some industries expanded more than others during the war period. Chemical and other allied industries produced commodities to a gross value of $45,410,486 in 1915. By 1917 this amount had increased to a total of $133,618,073 and in 1918 was further stretched to an unprecedented $173,649,073. Similarly the iron and steel products industry made a monetary advancement of $279,962,666 from 1915 to 1917. A further increase of over forty-five million dollars was added by 1918.[2]

The value of munitions and materials exported from Canada under the authority of the Imperial Munitions Board rose spectacularly in 1917 from the minimal export of 1914.[3] Production increases in the chemical and steel industries were largely due to this demand for war weapons and tools. By the end of the war, Canada's steel producing capacity had grown from one and one quarter per cent to two and one quarter per cent of the world's total production capacity. This was the largest increase of any steel producing country in the world.[4] Forced development of mineral and metal resources provided an impetus to the mining of coal, iron, copper, nickel, zinc, molybdenum, antimony, and aluminum.[5] Though their growth is rarely connected to war, since they constitute the by-products of the munitions industry, changes in the methods of production and refining of these metals as well as that of certain chemical industries were also stimulated.

The fact that weapons of war have peacetime uses has blurred the common conception of the composition of the munitions industry. Military weapons, ammunition, and equipment have paramilitary uses and may often be identified solely with the latter function. Chlorine and the lethal mustard gas, dichlorodiethyl sulphide, used in the First World War were for instance simple industrial chemicals adapted by scientists to a new use (in spite of the provision in the Hague Convention of 1908 against the use of poison gas in war).[6] Also, Canada's production of calcium cyanamide was originally used only as a nitrogen fertilizer, but from 1916 the American Cyanamid Company produced ammonia by hydrolysis and then oxidized this to nitric acid for use as an explosive. With the expanded market resulting from war and a technical change from the Erlwein and Frank process to resistance ovens and the electric arc process vastly expanded production became possible.[7]

Worth noting is the fact that the major impetus for locating the cyanamide plant in Niagara Falls, Ontario, aside from the nearby location of lime resources, had been the availability of cheap hydro power, the cost of this energy constituting the major expense for the industry.[8] Similarly, in its decision (or concession) to build a nickel refinery in Canada, International Nickel chose Port Colborne due to the inexpensive and vast supply of hydro power necessary to its industrial process. From a previous example involving the clash of federal government policy and that of the Commission of Conservation over requests by the Aluminum Company in 1918 for additional hydro power along with earlier requests by the Long Sault Development and the St. Lawrence Power Company to acquire rights to Canada's supply of cheap hydro power, the importance of this resource to industries is further underlined. All of these industries, ranging from chemical to metal production were dependent upon Canada's mighty water-falls because in keeping with modern engineering trends throughout the British Commonwealth and the United States each used the electric arc process.

From the above cases an extended and more accurate conception of the munitions industry can be gained which includes not only the obvious weapons of war but also the industries associated with their production. These range from nickel refining, to cyanamide or fertilizer production, to hydro-electric power. Each was adapted for use in times of peace and war and each industry expanded due to the war.[9]

Since the development of water power was basic to industrial advancement, as well as to the national and British munitions industry, the government intervention which occurred on occasion was to be expected. Clashes between provincial and federal factions as well as an apparent conflict between the priorities of Dominion or continental interests broke out.

The International Boundaries Water Treaty limited the amount of water available at Niagara Falls, Canada. A great deal of this water had been contracted by Ontario-nased power companies (The Electric Development Company, the Canadian Niagara Power Company, and the Ontario Power Company) to various industries on both sides of the Niagara River. Though the publicly operated Ontario Power Company supplied domestic service to towns as far away as Guelph, Berlin, and Waterloo, the generating cycle was geared to industrial, not domestic, use. These consumers were plagued by blackouts beginning in 1916 and continuing til 1919 due to the increased demand for hydro by Canadian munitions industries and the inability of producers to break previous American contracts. During this time Adam Beck, Chairman of the Hydro-Electric Power Commission, which controlled the Ontario Power Company, requested that the federal government halt sales of Canadian hydro to the United States.[10] This attempt to pit the federal government against the provincial government in an area where the former lacked constitutional control revealed the inability of each to enforce strictly national goals in the development of an important natural resource. For, all of the hydro companies continued to sell power to industries in the United States.[11] The Ontario government never, of course, intended to stop this activity. The federal government, on the other hand, had been unsuccessful in its attempt to contract a continental treaty in the case of the Aluminum Company due to Britain's need of certain munition supplies which that company produced. James White's defence of national interests before the arbitrating agency, as a member of the Commission of Conservation representing the federal government, was invalidated by the unprecedented interference of the Solicitor-General whose advice was in the interest of the Imperial government and which was governed by the short-term aim of winning the war. Both the United States and Britain obtained what they wanted, one receiving more hydro power, the other receiving munition supplies; both gained their objectives with the aid of Canada's water power.

The development of mining in Canada during the Great War took place under both Imperial and American pressure. Again, attempts to assert national goals, even though in the service of Commonwealth interests, provided only decorative covering over the actual issue. The country with the world's largest nickel fields, Canada became geologically important once more for a raw resource which was a staple to the war diet. This time however little long-term profit was to be gained since the mines remained mostly in American hands.

The International Nickel Company held a virtual monopoly of the nickel industry which was offset only by the British-financed Mond. W.O. Main has pointed out the collusion that existed between these companies by explaining the ways in which

International Nickel attempted to force all other competitors out of the market. A major threat to these companies was the British America Nickel Corporation which owned the former properties of the Canadian-financed Dominion Nickel-Copper Company and the North American rights to the electrolytic Hybinette process for refining nickel. For, despite the obstacle presented by long-term contracts, the Hybinette process to be used by British America was a proven competitor to the former's Orford process. Cheap electric power required in the Hybinette process cost less than the coke and oil for fueld needed in the Orford process. Also, all of the precious metals in the ore could be reclaimed with the Hybinette process, instead of the small portion procured in the Orford.[12] Owing to its advanced engineering technique, the British America Nickel Corporation presented an added threat to the near monopoly of the International Nickel Corporation. Consequently, as with its predecessors, the British America Nickel Corporation found that financial assistance from the United States was unobtainable.[13]

The British America Nickel Corporation, Limited finally received assistance when it came under the financial control of the British government (which secured $14,500,000 of the $20,000,000 capital stock) and which assured a market for the duration of the war by contracting to buy most of its production.[14] When in 1920 the British government cancelled its ten year contract for an annual six thousand tons of nickel[15] the fact that this company had been supported only because Britain wanted to secure a supply of nickel for munitions was obvious.

Once again the internationality of the forces combining in the application of scientific advancement is evident. A new engineering process had been developed by a Norwegian named Hybinette. The metals on which this process would be used were found principally in Canada. The American financiers who owned Canadian nickel mines and who attempted to control the market found their control threatened by this new technique. Amid this potential industrial disruption was the Great War. The munitions industry in Canada was expanded because Great Britain gave government support to an otherwise doomed competitor, British America Nickel.

In July, 1916 news reached the public that a German submarine, the Deutschland, had landed on the east coast of the United States and received a cargo of refined nickel, allegedly from International Nickel. A repeat occurrence followed in November. Each incident added pressure to the concern over the foreign ownership of Canada's nickel sources (though no mention was made of the welcome cargo of in-coming chemicals[16]). In the furor two Ontario Liberals won by-elections over the issue by arguing for government ownership.[17] Despite a Liberal resolution for public ownership presented to the Legislature in February of 1917 no such action was initiated. Instead, the British Admiralty censured the European export agents of the accused International Nickel Company.[18] Also, at this time the British government acquired financial control of the British America Nickel Corporation, Limited. Each of these actions was a short-term attempt to keep the supply of nickel under imperial control for the remainder of the war. For this reason each action was taken by the British rather than the Canadian government.

Any pretense that the Canadian government, either on a provincial or federal level, was effective in deciding the future course of this raw resource industry is unsubstantiated. The usual example that International Nickel moved its nickel refinery from New Jersey to Port Colborne in response to the Liberal proposition for government ownership of this industry and the public outcry over the Deutschland incidents cannot be maintained. For, in fact, technologically the Orford process of refining metal had become outdated with the introduction of the Hybinette electrolytic process. The Royal Ontario Nickel Commission established in September of 1915 and chaired by George Thomas Holloway, vice-president of the British Institute of Mining and Metallurgy, concluded that the Hybinette method was well suited to refining of nickel in Ontario.[19] Since construction of a refinery was already underway the advice contained in the report, dated March 19, 1917, appeared 'after the fact'. The appreciation of electrolytic technology which was dependent upon the availability of inexpensive hydro power was well placed. However, the belief that Canadian political pressure on International Nickel was responsible for the relocation was fallacious. The demands of a superior engineering process dictated the move.

During the Great War the metal and chemical industries in Canada flourished. Two specific causes made this possible. Demand for munitions offered increased markets conducive to the growth of a variety of industries. Changing technology in the form of the electric arc and Hybinette processes increased the efficiency of production by allowing recovery of previous industrial wastes and by reducing operating costs with the availability of inexpensive hydro power. Though often not Canadian owned, controlled, or financed these companies used Canadian resources both as the raw materials of production and as an energy source to fuel industrial processes. Equally, though high profits were typical for many industries this money was earmarked for other than the repayment of Canada's war debt. For this reason government leaders remained concerned over their monetary burden.

Neither the federal nor provincial governments managed to assert nor even to attempt to institute national goals on industries located in Canada during the war years. The ideals of private enterprise reigned supreme and were only briefly interrupted by the activity of the British government. While the nickel industry remained under the near-monopolistic control of International Nickel the Liberal cries for public ownership of this company reverberated as the echoes of political opportunism.

Like the federal and provincial governments, the NRC left private industry unmolested, and kept the goal of developing natural resources in the forefront. Though the Council itself lacked industrial representation the objective of finding various means of utilizing the waste products of industrial production received attention.[20] In 1918, three of the ten major research grants undertaken in universities and funded by the NRC aimed at the transformation of waste products into additional saleable commodities or commodities which were previously available only on foreign (non-British) markets.

The smallest project, financially, involved a study of the amount and character of sugar in sulphite liquor waste. It was undertaken in order to obtain ethyl alcohol and other commercial products from the waste. Such sulphur-derived chemicals were in great demand by the pulp and paper industry.[21] The industrial waste in question was a noxious gas burnt off during the smelting of many Canadian metals, particularly nickel at Sudbury. These fumes killed all surrounding vegetation. When the Orford Copper and Nickel Company had previously taken their nickel matter from Quebec to be refined in South Wales opposition from farmers whose crops had been destroyed by sulphur fumes had led to the relocation of the smelters in the United States.[22] The problem of sulphur pollution needed to be solved and the best motivation that could be given to the industry was the opportunity of profit by transforming the waste into a saleable commodity. It was a government organization, the NRC, however, which had to effect this transformation. The industry was not motivated to undertake the research.

An investigation of Canadian waste tobacco was financed in hope that a means of preparing nicotine sulphate, a major insecticide used on shrubs and trees, could be found. This substance was needed because the high wartime price increases by the monopoly producer in Kentucky prohibited its purchase by Canadian fruit farmers.

The third grant involved the distillation of waste straw in order to produce a gas for heating and lighting houses as well as a carbon residue which could be used as a fuel for other purposes.[23] This last research grant, as well as the work on briquetting of lignites, was motivated partly by the shortage of coal which began when the United States, principal supplier of coal to Canada, entered the war. On July 12, 1917 a Fuel Controller for Canada had been appointed and the necessity of finding a new source for the coming winter, particularly on the prairies, haunted Canadians.

The involvement of the young NRC in chemical and mineral industries remained minimal just as the policies of Canadian governments in relations with private industry and the British government remained compliant. As has been seen, these industries were dependent on Canada's natural resources and aside from technology their extreme growth during the war period was spawned by the munitions market.

Though not a mineral resource the development of the lumber industry in Canada was also accelerated by the high demand imposed by the Imperial Munitions Board. Both fir and (sitka) spruce trees were required for the construction of ships and aeroplanes. The Commission of Conservation advised Sir Joseph Flavelle, head of the Board, on the location and suitability of these species to production needs with the aid of earlier studies which had been conducted on the composition of Canadian forests.[24] All lumber in British Columbia was soon at the disposal of Great Britain via the Imperial Munitions Board since the provincial government would only authorise export clearances through this agency. Expansion in the lumber trade was immediate and an ultimate total of 24,000 labourers working for ninety-three mills to cut fir and fourteen to cut spruce advanced into the virgin forests of northern British Columbia. While a great deal of money was pumped into the economy by this venture, the waste or excess cutting of trees was tremendous. Only thirty per cent of the spruce cut met the requirements of the Inspection Department and of the five hundred million feet of fir cut a mere nine and one quarter million feet were accepted![25] In this instance the intention of the Commission of Conservation "to investigate and advise as to the right lines of development of public policy in the conservation of Canadian resources" comes into full focus.[26] Development consisted of expedient usage for the Imperial war cause and involved over-expansion with excess production, the overflow being channelled into private markets where the lumber, though it was absorbed, was not particularly needed. The conservation for which the Commission had been named was a financially and militarily exploitative value bearing no vestiges of ecological restraint and wholly lacking in any preservative concept. In each of these ways the industrial, political, scientific and even the agricultural communities were similar. And, while acting on these values (both positive and negative) these communities maintained mutually compliant policies.

Harold Innis has accurately described how,

> ...Canada found herself in possession of vast quantities of raw materials, of which the supply of older countries was being exhausted and for the exploitation of which the mature technique of these older countries was at hand.[27]

In one succinct sentence Innis describes the development of natural resources in Canada from their primary to industrialized state, from 1909 to the end of the First World War. The development of Canadian science organizations, from the unofficial, but preparatory, Commission of Conservation to the National Research Council, was guided by this exploitative attitude and industrial technique and responded with thoroughly compliant policies.

APPENDIX A

Canada
Nickel Production, Trade and Consumption
1889–1966

	Production[2]	Exports[3] In matte, speiss or oxide	Exports[3] Refined Metal	Exports[3] Total	Imports	Consumption[5]
	(tons)	($)	(tons)	($)	($)	(tons)
1889[1]	415	..	–	..	..	..
1890	718	89,568	–	89,568	3,154	..
1891	2,018	667,280	–	667,280	3,889	..
1892	1,207	293,149	–	293,149	3,208	..
1893	1,991	629,692	–	629,692	2,905	..
1894	2,454	559,356	–	559,356	3,528	..
1895	1,944	521,783	–	521,783	4,267	..
1896	1,699	658,213	–	658,213	4,787	..
1897	1,999	723,130	–	723,130	4,737	..
1898	2,759	1,019,363	–	1,019,363	5,882	..
1899	2,872	939,915	–	939,915	9,449	..
1900	3,540	1,031,030	–	1,031,030	6,988	..
1901	4,595	751,080	–	751,080	12,029	..
1902	5,347	1,007,211	–	1,007,211	15,448	..
		(tons)		(tons)		
1903	6,350	6,350	–	6,350	26,177	..
1904	5,274	5,617	–	5,617	14,682	..
1905	9,438	8,659	–	8,659	19,076	..
1906	10,745	10,327	–	10,327	15,976	..
1907	10,595	9,688	–	9,688	19,511	..
1908	9,572	9,710	–	9,710	36,870	..
1909	13,141	12,808	–	12,808	14,930	..
1910	18,636	18,007	–	18,007	23,266	..
					(tons)	
1911	17,049	16,310	–	16,310	308	..
1912	22,421	22,111	–	22,111	334	..
1913	24,838	24,730	–	24,730	296	..
1914	22,759	23,264	–	23,264	310	..
1915	34,154	33,205	–	33,205	355	..
1916	41,479	40,221	–	40,221	446	..
1917	42,165	40,636	–	40,636	427	..
1918	46,254	42,884	855	43,739	319	..
1919	22,272	15,198	5,310	20,508	200	..
1920	30,668	25,851	4,249	30,100	368	..
1921	9,647	4,032	2,397	6,429	166	..
1922	8,799	8,384	7,225	15,609	683	..
1923	31,227	14,485	11,449	25,934	413	..
1924	34,768	18,356	12,993	31,349	438	..
1925	36,929	20,104	15,058	35,162	530	..
1926	32,857	19,589	12,349	31,938	559	..

	Production[2]	Exports[3]				Imports[4]	Consumption[5]
		In matte, speiss or oxide		Refined Metal	Total		
	(tons)	(tons)		(tons)	(tons)	(tons)	(tons)
		In matte or speiss	In oxide				
1927	33,399	18,229	2,598	14,508	35,335	1,227	..
1928	48,378	18,185	4,804	25,594	48,583	583	..
1929	55,138	14,815	5,801	34,204	54,820	803	..
1930	51,884	22,445	1,867	21,561	45,873	691	..
1931	32,833	16,644	1,554	13,566	31,764	391	..
1932	15,164	7,585	868	7,583	16,036	269	..
1933	41,632	19,163	3,832	21,046	44,041	496	..
1934	64,344	29,172	2,542	27,362	59,076	345	..
1935	69,258	29,232	1,317	40,814	71,363	286	500
1936	84,870	30,812	2,661	53,346	86,819	467	500
1937	112,452	40,404	2,554	68,427	111,385	491	900
1938	105,286	44,324	1,842	52,686	98,852	491	657
1939	113,053	47,051	2,426	67,914	117,391	697	635
1940	122,779	38,484	3,864	82,168	124,516	594	1,509
1941	141,129	42,616	7,240	87,739	137,595	1,011	3,464
1942	142,606	41,263	9,224	88,308	138,795	499	4,509
1943	144,009	36,415	3,892	95,240	135,547	545	3,440
1944	137,299	33,848	1,242	97,509	132,599	424	2,350
1945	122,565	28,295	1,759	78,168	108,222	762	2,410
1946	96,062	30,625	517	80,797	111,939	1,602	1,820
1947	118,626	39,767	6,534	70,756	117,057	1,376	1,670
1948	131,740	50,801	9,792	71,247	131,840	1,364	1,887
1949	128,690	56,902	1,152	69,088	127,142	1,448	1,749
1950	123,659	53,090	1,667	66,894	121,651	1,337	2,226
1951	137,903	57,882	944	72,357	131,183	1,306	2,744
1952	140,599	63,753	1,211	77,058	142,022	1,650	2,223
1953	143,693	63,910	1,299	79,909	145,118	3,083	2,275
1954	161,279	65,823	1,486	91,410	158,719	1,584	2,595
1955	174,928	65,954	1,452	106,473	173,879	2,103	5,020
1956	178,515	70,715	1,767	104,356	176,838	2,554	5,545
1957	187,958	73,694	1,706	103,258	178,658	2,092	4,532
1958	139,559	67,659	1,393	85,168	154,220	2,155	4,099
1959	186,555	65,657	4,157	102,111	171,925	1,857	4,059
1960	214,506	73,910	13,257	108,350	195,517	1,762	4,861
1961	232,991	92,938	18,021	133,504	244,463	4,304	4,935
1962	232,242	77,410	11,120	121,712	210,242	7,494	5,322
1963	217,030	83,392	15,208	109,156	207,756	10,973	5,869
1964	228,496	74,766	35,800	128,330	238,896	10,444	6,899
1965	259,182	82,327	40,956	135,197	258,480	12,172	8,924
1966P	234,061	83,586	33,631	132,712	249,929	28,916	..

Source: Dominion Bureau of Statistics.

[1] First year of recorded production.

[2] Refined metal and nickel in oxide and salts produced plus recoverable nickel in matte or speiss and in ores and concentrates exported.

[3] Exports are for calendar years 1890 to 1966.

[4] Imports for fiscal years 1890 to 1910 incl. and calendar years 1911 to 1966 incl. Imports consist of nickel in bars, rods, strips, sheets and wire; nickel and nickel-silver in ingots; nickel-chromium in bars.

[5] To 1959, producers' domestic shipments of refined metal; subsequent to 1959, consumption of nickel, all forms, (refined metal, oxide and salts) as reported by consumers.

– Nil; .. Not available; P Preliminary.

VI

BETWEEN THE WORLD WARS

The years between World War I and World War II saw significant technological changes involving the gradual demise of the electric arc process and the rise of synthesic nitrogen (fertilizer) production. Amid these substitutions the importance of prime Canadian natural resources shifted, as did their methods of production. Research interests in Canada altered appropriately, appearing to rise to new challenges. However, although the NRC's operations reflected an avid interest in in such changes its role remained the same. As the organization grew its researches expanded and gained more importance. Its early affinity to the military only appeared to wither as Canada and Britain ceased active war involvement and political interest in the growth of Canada's science institutions lost intensity. ~~In the early 1930's satisfaction was gained by carrying out~~ established plans to expand research facilities and to train more scientists at Canadian universities.

The principle technological change in Canada after the Armistice was the introduction of a method for the synthetic production of nitrogen. Originated in Germany before World War I, the Haber-Bosch process, as it was named, was the key innovation because its successful operation, aside from being financially feasible, obliterated the absolute limits to production existing with the use of organic nitrogen products. As nitrogen products, the method of both fertilizer and explosives production altered considerably. The possibility of increased production soared. While Germany was the only country to gain from the Haber-Bosch process in WWI, the Allies realized that if they were to be prepared for another extensive war they must also have the Haber-Bosch process, or at least have the power to prevent extensive stock-piling of resulting nitrogen supplies in any country. To this end Germany was made to export large quantities of synthetic nitrogen annually to France as part of the terms of the Versailles Treaty.[1]

One result of this process was the growth of international cartels which limited the export of nitrogen and its industrial by-products. After 1920 most Canadian producers were associated with the British Sulphate of Ammonia Federation, Ltd., London, which was in turn affiliated with the German led DEN (Deutschland-England-Norway) group.[2] These organizations made trade agreements which were necessary to ensure that prices remained stable and supplies proportionally distributed among nations. In this way, cartels were used to limit rearmament.

A shift in plant location also resulted from this revolution in production. For, while cyanamide production was based on the electric arc process and water power, as was the Hybinette process used in refining nickel, the use of hydrogen was basic to the Haber-Bosch process. Though electrolytic hydrogen could be made with water power this was not necessary. Coke-oven or natural gas were just as effective.[3] Thus, in 1930 the Consolidated Mining and Smelting Company began the manufacture of fertilizers at Trail, British Columbia, using sulphuric acid which was a by-product of the sulphur ores from the Sullivan Mine at Kimberley. Alberta Nitrogen Products, Ltd. also built a plant in Calgary. Here hydrogen was produced from a reaction between methane, a natural gas, and steam.[4]

The NRC had followed all of these technological changes, though its posture reflected an industrially protective rather than a pure research attitude. For instance, the manufacture of fertilizers by the Consolidated Mining and Smelting Co. at Trail, B.C. resulted in the unwanted by-product of sulphur pollution. Scientists at the NRC studied the effects of this noxious gas with some alarm for many years. Though no effective method of curtailing this pollution was found, neither the NRC nor the federal government were willing to curtail production at the plant because its industrial and potential military value were so great.[5] The science policy in this case placed ecological concerns behind the priority of the development of industry in Canada.

Association of the NRC with the military aspect of the industrial production had also been revealed in Dr. J.C. McLennan's proposal in 1917, "to prohibit the export of nitrogenous fertilizing products from Canada and to have the Dominion government take over and operate existing plants". His dictum that, "As electrical power is developed...all spare power should be used in the manufacture of nitrogenous products" reveals the extent to which military considerations ruled his science activities.[6]

The Associate Committee of Nitrogen Fixation, of which McLennan was an active member, was maintained until the spring of 1931.[7] As a research committee its purpose had been fulfilled in 1930 when the Consolidated Mining and Smelting Company has gone into nitrogen production using a variation of the Haber-Bosch process. This new industrial technique constituted the necessary replacement to the out-moded cyanamide production located in Niagara Falls.

A secondary reason for the cessation of these formal investigations of the development of nitrogen production was the depressed condition of agriculture throughout the world. Farmers, the members of the committee reported, found little benefit from the use of fertilizers since prices for agricultural produce had dropped to ruinous levels. Nevertheless these members advocated fertilizer use with the reasoning that increased yield per area at the same operating cost would lower overall costs and thus benefit the farmer.[8] To this end Canadian fertilizer was distributed without charge to demonstration farms on the prairie by prospective producers.[9] Set up originally by the Commission of Conservation, these farms were used to 'educate' farmers in the latest scientific advances, and in this instance, as a persuasive means of advertisement by manufacturers. Canada's producers of nitrogen had one other motivation for increasing fertilizer sales. They had to maintain their fertilizer markets in order to finance their recent expansion into synthetic fertilizer production. In the event of another world war this production would be easily changed to that of synthetic nitrogen. As such this product was crucial to the country. The use of the government's experimental farms as a vehicle for advertisement is therefore not surprising.

Emphasis on fertilizer use was little more than a placebo for agricultural producers in the prairies during the thirties. At most this nitrogenous material, both organic and inorganic, was a temporary crutch which even when combined with NRC research on wheat hybrids, field crop diseases, and cereal rust was insufficient to alter the infertility of prairie soil. For, the latter was caused by a semi-arid climate and abusive agricultural techniques the uses of which the federal government had encouraged during WWI. Neglect of dry farming, the government's encouragement of this practice, and the use of poor soil on which wheat was planted were in turn a result of the orientation towards foreign markets.

Canada's earth resources were often used in attempts to exploit foreign market demands. This occurred agriculturally with the wheat staple, with water-power energy, and the mining of nickel and other metals. In some cases the gain was financially advantageous; often, as in WWI, politicians and producers said the continued development was necessary to satisfy 'duties' towards the United Kingdom, mother of the British Commonwealth. Always, the products from agricultural lands, forests, waterfalls, and mineral deposits remained geared to the large international markets. In order to remain competitive with other countries new technological applications resulting from increased scientific research were introduced in Canada and the material wealth of the country was exchanged for financial riches, though these tended to disappear into the coffers of foreign-owned companies.

# # # # # # #

The NRC continued to expand throughout the twenties and thirties despite the financial deterrent posed by the Depression. Large research laboratories which had received financial sanction in 1928 (the result of requests begun in 1919) were erected early in the next decade, and graduate science programs in universities grew with increased grants. A large portion of these graduates made their way into the NR laboratories, often labouring for meagre or at least relatively low wages. This rise in trained scientific manpower at the NRC was accompanied by more research publications. The greatest innovation in this area was the founding of the Canadian Journal of Research in 1929, with issues that became more frequent as the years passed. As with the staple and natural resource product orientation towards foreign markets the dissemination of results from scientific research in the NRC periodical was dependent upon basic research from the international arena. The aim of the government was first to maintain and then to improve the lot of Canadian citizens by offering them the products of scientific research. Thus advanced technology applied to natural resources was expected to result in a new prosperity.

In actual fact, while a large, central scientific institution had been built and research facilities expanded, the administration and organization managed only to keep pace (at a relative distance) with the scientific organizations of other major industrial countries. Canadians may have felt they had come into their own and had begun the long process of maturation as a rich industrial nation which was only involved in the British Commonwealth by independent choice. But this was not the case. Instead research was continued which followed a scientific and industrial track but which also helped to keep the country entrenched in the old patterns of dependence on staple and natural resource products for export to foreign markets. The importance of wheat had declined to be replaced at the end of the war by cheap hydro power which was often used in connection with the refining of Canadian ores and the fixating of nitrogen. By 1930 natural and coke oven gas as a means of producing synthetic nitrogen had begun to erode, though not eradicate, the industrial importance of hydro power. Also, once WWII began nickel and associated metals were surpassed in importance by uranium. Not only was one of the world's two largest supplies of uranium located in Canada, as well as the only refinery in North America, but also the scientists working at the NRC conducted important basic pioneering research on this metal in its application to atomic fission. With this research and the supply of the indispensable uranium Canadians, and specifically the NRC aided the Imperial and Allied war cause by becoming involved not only in production of natural resources for export but also in their specific application to munition purposes.

Scientific research was used to aid industrial development and the achievements in this field were in turn put to military use. As has been shown, munitions production can never be separated from industrial production. Since the principal goal of Canada's major science institution was the increased use of the country's natural resources in industrial production, its affiliation with industrial and military interests was inevitable.

VII

GEARING UP THE ADMINISTRATIVE MACHINERY, 1935-1945

By the end of World War II the NRC had become the one principal government science organization in Canada. National science policy as a coherent plan of the federal government was effected both through and by this medium. The government policy for science that had established an environment fostering research activities had matured since its inception in 1916. In place of the mere trickel of Canadian-trained university science students graduating annually at that time, numbers swelled by 1936. At the end of March, 685 scholarships had been awarded to 385 people. They had a total value of nearly $600,000.[1] General fiscal expenditures had risen from a low of $50,000 in 1917 to 1918 to well over $650,000 in 1935 to 1936. A large, though monolithic, science laboratory had been built on Sussex Street in 1932 and this building along with a converted mill near the Rideau River served as the official homes of the federally supported scientific research organization.[2] The only retardant of growth to the federal government's national policy for science was a restricted, though not reduced, budget. This was largely a result of the economically paralysing Depression.

This restriction was minimized in mid-1935. On the first of June, General Andrew George Latta McNaughton, former Chief of General Staff, was appointed President of the NRC by

Prime Minister R.B. Bennett. The assignment of this office to a high-ranking soldier marked the intensification of liaison between Canada's national science organization and the federal departments concerned with military defence.

Many reasons can be found to explain the rationale behind the appointment: most published accounts rest on etiquette or political expediency. Eggleston remarks on "the discourtesy to Dr. Tory" and the latter's biographer, E.A. Corbett, vehemently condemns the shabby treatment of such a valuable civil servant. To Corbett, the fact that R.B. Hanson, Minister of Trade and Commerce, waited until May 29, 1935 to inform Tory that there would be no extension beyond the June first expiration date, "surely constitutes an unforgivable departure from ordinary amenities and official procedure."[3]

McNaughton tended to emphasize the political expediency of his appointment saying that it was a direct result of the unpopularity of the work camps which he had set up in 1932 for destitute victims of the Depression. These 'slave camps' were bound to be a black mark against the Bennett government in the upcoming election. Consequently, McNaughton was not completely surprised when Bennett summoned him on May 25, 1935 and said,

> Andy, I'm very fond of you. I've been pleased to be associated with you, but if you think that I'm going to go and meet the public in a general election with you still in the office of Chief of General Staff, you better think it over again. I've made up my mind...that you will vacate that appointment. I now address you as President of the National Research Council. [4]

McNaughton, however, balked at this dictatorial announcement.

On May 27 Bennett again sent for McNaughton. Still he was unwilling, explaining that he preferred to remain as CGS because he believed that in that position he could be "of greater service to the state".[5] When the Prime Minister promised that he would be seconded from the post of CGS, as the Minister of National Defence, Hon. Grote Stirling, suggested on May 28, the General accepted. Only then was Tory given formal notice of his retirement.

The arguments for political expediency are valid. Aside from the work camps, strong evidence existed to indicate that the Bennett regime might lose the election. Provincial Conservative governments had been defeated in Nova Scotia, British Columbia, Ontario, Saskatchewan, and New Brunswick since 1933. Seven out of eight federal by-elections had been lost in the previous two years.[6] As for etiquette, Tory's treatment was certainly regrettable but the fact that Bennett had been seriously ill, not appearing in the House from late February to mid-May, aids in accounting for the late selection of a new President for the NRC.

Bennett's determination to replace Tory even at such a late date indicates the importance of his decision. Tory was over seventy years of age and his contract had expired: General McNaughton was politically unpopular but as an outstanding electrical engineer and military administrator he was qualified to be President. The time to make a new appointment was ripe and the choice of McNaughton was advantageous to the Conservative government. However, more fundamental considerations were involved. According to General McNaughton, Bennett had decided in early 1935 that the Hitler regime would not be checked and war would result. Further,

> ...he was concerned...that the National Research Council should be put in shape by association with the armed forces and by association in their problems and in the problems of industrial mobilization...that this vital contribution to the welfare of the Country in its defense or in its industrial field could be made by the Council.[7]

McNaughton was of a similar mind, having made a fairly accurate prediction in 1918 when he learned of the Armistice. "Bloody fools. We have them on the run. That means that we shall have to do it all over again in another twenty-five years."[8] When Bennett faced McNaughton with this proposal to link science and defence, an aim for which the General was well trained, his obstinacy melted. For, he was allowed to keep his army attachments by being seconded, he could advance the mechanization of war (the desirability of which he had commended[9]) and he could play a key role in preparing Canada for a war which seemed inevitable.

The drawback that McNaughton faced in instituting government policy and effectively preparing the NRC for war lay in the fact that there were no written orders outlining his purpose, or making it official.[10] Further, he could not announce to the Council that he had come to prepare Canada scientifically and industrially for war.[11] Despite these circumstances his hands were not tied.

In June, McNaughton presented the financial needs of the Army and Air Force to the Cabinet, his final duty as CGS. About to leave the room, Prime Minister Bennett called the General back to present the estimates for the NRC. McNaughton returned, set down his bundle of black accounting books and launched into a speech which he termed "the most impassionate plea of scientific research...in Canada that I ever made in my life." At the end of it he requested two million dollars extra on top of the estimates, which Bennett and his colleagues promised immediately. McNaughton claimed that this money "made all the difference in the world to the National Research organization".[12] And indeed this large sum towered beside the $658,326.93 regular revenue of the NRC for the 1935 to 1936 fiscal year.[13]

Never did this Cabinet contribution appear on the official financial records of the Council. Similar contributions from industries in Canada also went officially unacknowledged. For some time the NRC had received a small annual stipend from various industries but after the outbreak of war, and especially after the ten weeks of invasion following Hitler's attacks on Norway and Denmark, the donations of 'private money' mushroomed to over one million dollars. By September, 1940 the following grants had been made:

T. Eaton Company	$250,000
CPR and Consolidated Mining and Smelting Co.	300,000
Bronfman Bros.	250,000
International Nickel Co.	250,000

[14]

These donations came at a time when the Treasury Board was still maintaining a tight grip on money and they were, of course, a response to the shocking events of Europe. Certainly patriotism may have been one reason behind the giving of this money. However, to describe some contributors, the American International Nickel Co. for instance, as "public-spirited Canadians" as is done by W.E.K. Middleton, is an inaccurate assessment.[15]

Nevertheless, this money, referred to as the Santa Claus fund, was originally donated simply to help with Canada's war effort. There were no strings attached. J.S. Duncan, acting deputy minister of National Defence for Air, had proposed that it be used for specific war projects. To this end he had invited various people to a meeting in July, 1940 in order that suggestions could be made. McNaughton having resumed his army career, the Acting President of the Council, Dr. C.J. Mackenzie, won the support of both the government members and industrialists present by outlining some of the war projects which were underway.[16] These included construction of the Aeronautical Building and wind tunnel, equipping and staffing a laboratory for the certification of munition gauges, preparation for the manufacture of optical glass, operation of chemical warfare laboratories, expansion of the Radio (Radar) laboratory, research on the building of wooden airplanes, and on many types of ballistics equipment.[17]

Mackenzie's presentation had been ultimately persuasive not only for the sudden importance to the Allied defence effort of the war-geared projects but because they had been undertaken early enough to be of use within a short period of time. For this he could thank Bennett's foresight, McNaughton's skill, and the independent administrative structure of the NRC.

This latter factor was the most important because without it McNaughton would have been deprived of the latitude to assert the war geared science policy which Bennett had promoted. These two men found it possible to steer the Council over many constitutional areas for which the federal government normally lacked jurisdiction. For instance, laboratories were staffed by scientists who had received aid from the NRC to further their basic university education. Though education was constitutionally an inviolable provincial responsibility the practice of awarding grants to individuals rather than universities, which had been carried on since 1917, enabled the federal government to promote expansion of post-graduate science programs. This success was in direct contrast to the problems which McNaughton, as CGS, had encountered over objections to the Royal Military College at Kingston being operated by the Department of National Defense.[18]

Though originated in the early 1920's, Associate Committees were a uniquely Canadian organizational device that gained increasing usage as preparations for another international war intensified. They resembled the Special Committees of the federal government in the way that they were removed from public scrutiny. In this case however the effect was doubled since the Committees were private meetings arranged within the NRC, an organization which was in turn outside direct responsibility to a federal government minister and the general public.

Dr. C.J. Mackenzie described the method by which these Committees operated and were used to effect results. The Research Council, he said, "had the power to bring people together,...pay the expenses of the meeting". It stood alone. "No other government department had this authority." Thus, "the Research Council could approach a large project and bring people together who were the most knowledgeable in their occupations...and discuss general questions." Not only did such a committee allow an eclectic group of industrialists, scientists from universities and government services, and members of government to collaborate. It also allowed them to decide informally and quickly on any particular policy to be adopted. Although, "no decisions were ever reached, because they had no executive authority,...they would go back then and in their executive authority they would put into effect,...the results of their discussions in their particular fields."[19]

Originally this Associate Committee mechanism had been designed to allow centralized coordination of the pursuit of pure science in the universities, the private affairs of industrialists, and the research interests of public institutions such as government departments. Instead, the Associate Committee came to be used for national problems which were of interest to these diverse communities.[20] Predictably, during war, concerns over defence and military products became the focus of Canada's science effort.

Another factor which gave the Council even more independence from public scrutiny was the fact that the Sub-Committee of the

Privy Council on Scientific and Industrial Research rarely met. In fact, once the research laboratories were established in the early thirties, this committee never convened at all. This had the effect of giving the Administrative Chairman and President complete control.[21] Thus, just before Canada became officially at war, McNaughton was able to take representatives of the Canadian Manufacturers Association on a mission to England to unite research with industry.[22] Though only the unofficial leader his presence in the entourage was crucial. The Canadian manufacturers wanted war orders for munitions products. However, the British Supply Departments could not give technical drawings or other relevant examples of war materials to private companies. As a government official from Canada, and especially as President of the NRC, McNaughton was able to act as a liaison between the British government and private industry in Canada. He introduced members of the Admiralty, the Air Ministry, and the War Office to Canadian businessmen and became the custodian of a great deal of military research material.[23] McNaughton represented the dual role of Canadian science policy both symbolically, as soldier and engineer, and literally, as intermediary between the industrialists of Canada and the various British war departments.

The policies of centralization and preparation for war that R.B. Bennett had supported continued unabated despite the cautious stance towards rearmament taken during the 'twilight war' by the Mackenzie King government.[24] The independence of war-related researches allowed the making of science policy by the key administrators of the NRC that was an important difference from World War I when science policy was made through the establishment of the sub-Committee of the Privy Council on Scientific and Industrial Research.

VIII

MILITARY RESEARCHES IN WORLD WAR II

As President of the NRC, McNaughton began to prepare that organization for war soon after he took office in 1935. Working singlehandedly and under the politically cautious stance of the Mackenzie King government, including its budget restrictions, the General was able to institute his military policy only on a limited basis. This preliminary work was significant but was overshadowed by the sharp swing towards specific war researches initiated after Canada declared war and, most notably, following the 'twilight war'. As the Acting President, Dean C.J. Mackenzie wrote in May of 1940 that "eighty per cent of our activities have a war bearing."[1] At this time the mature NRC organization was finally fully staffed with competent science personnel, laboratories were well equipped, and previously restricted (official) budgets ballooned to finance the high-priority war researches. McNaughton had been instrumental in building up the Council's staff, furnishing the laboratories with the requisites for these investigations, and forming committees prepared to handle administratively certain key areas of research. With these stipulations in mind the contention that the NRC took a major shift into defence research during WWII may be accepted.[2]

More than ever before, the outcome of war depended upon scientific research and its technological application. In all areas from military usage on land, in sea, and in air, to basic food supplies for civilians, the inroads made by science were important, indeed crucial. People from all segments of the nation, as well as from Britain and the United States, grasped this fact. Yet the ability of each group to affect the advance of war science research varied widely. The average working person had to be content to fight in the war with or without the aid of new scientific apparatuses. Farmers, as an alternative, could force all their efforts towards increasing agricultural production by straining the capacities of land and animals: urban labourers could, at most, construct the improved war appliances. On another level, federal politicians were able to organize the country for war. This they achieved by mobilizing many industries for peak production of war items, by deploying Canadian troops for combat in Europe and along Canada's shores, and by increasing budgets for federal government activity.

Except for this last point much of this new activity was delegated from Parliament at the outset to specific Government departments, especially those concerned with defence. Though many departments had their own research laboratories most of this work was reassigned to the laboratories of the NRC. There were three main reasons for the switch. The Council, having been recently outfitted, possessed better equipment and a larger, higher quality staff than did the separate departments. Also, as a national institution, the NRC held greater potential for complete co-ordination of science activities in Canada and with Allied countries. As Dr. C.J. Mackenzie told a meeting of the Royal Canadian Institute, "It was early apparent that...we must start on every problem with the full knowledge available to our Allies; and further, that we must work co-operatively on common problems."[3] Collaboration between the industrial production of war apparatuses with the results of scientific military research was also paramount and the administrative structure of the NRC was best suited to accomplishing this task. Indeed it had been formed to co-ordinate industry and science although at first only on an advisory level.

President McNaughton was fond of noting that,

> The Council is not part of a Government department; it is a corporate body capable of acquiring and holding money and property and of administering trusts related to science and research.[4]

This status rendered it independent of ministerial control. According to the Act passed in 1924 the Council had charge of all matters related to scientific and industrial research in Canada which the sub-Committee of the Privy Council chose to assign.[5] Most significantly, the Council was required to engage in researches on problems referred from other Government departments.[6] In compliance with this function a flexible structure had been prescribed in order that collaboration and co-ordination between the Council, Government departments and their separate science services could be attained.[7] For all of these reasons the NRC was unavoidably receptive to the military demands from other departments.

By the late 1930's this pliant structure was readily being used to form Associate Committees the majority of which were concerned with war-related investigations. By 1940 the NR Laboratories were so totally inundated with war researches that only very basic civil researches were maintained. Thus, though no coherent plan or specific legislation was approved for the science institution, its activities were overtaken by a war cause and followed what amounted to a very consistent military-based policy. One reason for this was, most definitely, the unrelenting barrage of requests by various Government departments to the NRC to conduct research investigation which would help these departments to prepare for war. The force and direction of these requests was of primary importance because the Privy Council Committee on Scientific and Industrial Research by this time never met and thus was unable to affect the policy course of the research and advisory activities of the Council. Its silence amounted to an approving nod towards these activities. The abandonment of this Committee was an early abdication of the only body set up to provide official guidance as well as to receive advice from the executives of the NRC and other science organizations.

Wilfrid Eggleston has pointed out that the link with the Department of Trade and Commerce had lost all relevance because the NRC engaged in activities affecting many different Government departments and branches.[8] This was a situation which though most obvious to Eggleston only after WWII had roots stretching back to the inception of the NRC in the First World War. Then the Departments of Agriculture, Education, and the Interior (viz. mines, fisheries, forests) as well as the Department of Trade and Commerce had all been affected by the activities of Canada's main national science organization.

The undertaking of such diffuse responsibilities can be directly correlated to the position of the Commission of Conservation. Such activities were cited as reason for abolishing the Commission, while the NRC was allowed to thrive and expand upon its activities. Eggleston's postulated irrelevance of the Department of Trade and Commerce to the NRC is thus more apparent than actual. For, after all, the aim of the Council was to increase natural resource and industrial development in order that expanded exports for international trade could be produced thus improving the commercial status of the country in a highly competitive world system. In the same way, with much the same purposes, the Commission of Conservation had produced an inventory of natural resources and begun defining some basic problems hindering industrial development.[9] The loss of the close connection with the Department of Trade and Commerce which had been maintained by men such as George Foster in WWI, the silence of the Privy Council Committee on Scientific and Industrial Research, and the 1924 mandate to accept research responsibilities from other Government departments were not representations of a loss of control over the NRC which allowed it to be accidentally turned into a military operation. The former two circumstances were simply evidence of maturation, a shedding of old, tight skins. Presentation of estimates to Parliament was not enough to keep an organization with such necessarily varied interests attached to the Department of Trade and Commerce even if the minister headed the sub-committee of the Privy Council. As was shown previously this Council had little industrial representation and consisted of a rather sterile group of federal ministers and academic scientists. Such a composition was inadequate to guide the very wide area of scientific and industrial research. It was innefective. Associate Committees and liaisons with other Government departments proved to be much more efficient vehicles for the broad government expectations for basic and industrially applied scientific research.

With the appointment of McNaughton as President the emphasis of dependence on other Government departments for research project suggestions increased. This was partially due to the recently augmented capacity for laboratory research but was also a result of the fear of impending war and the concommitant need for peak industrial efficiency and production. Basic to this efficiency, of course, were the results of contemporary scientific research. At this point a brief review of certain key researches and a description of their affiliation with industry and Government defence departments is necessary for illustrative purposes. Excluded from this discussion is atomic research which has been reserved for a separate chapter.

In September of 1937 an Associate Committee on Metallic Magnesium was formed to investigate the possible methods by which this metal could be produced in Canada. Members came from the Department of National Defence, the Department of Mines and Resources and the NRC. Even at this early date, Defence had become involved, indeed instigated the formation of this Committee, because supplies of metallic magnesium would be crucial in a war.[10] Magnesia was used for refractories to be employed in metallurgical industries,[11] and metallic magnesium was used to build small, light airplane parts.[12] In 1937 one half of the small 27,000 ton annual world production of magnesium came from Germany,[13] while the mining of a pure carbon magnesite was limited to Austria, Greece, India, and Turkey.[14] None of these sources could be reliably secured by any countries in the western world during a war emergency. Magnesite to be used to line steel furnaces for refining metals and obtaining nitrogenough and other by-products, was vital to Britain, Canada, and the United States. Magnesium could be extracted from magnesite, carnallite, and dolomite.[15] The latter was found in Canada and needed only a process by which the magnesite could be extracted. Scientists at the NRC duly developed the Pidgeon process and a group of private industrialists formed Dominion Magnesium Limited in late 1940. The United States adopted this process in January of 1942 and in April of that year Canada's private producer was taken over by the Wartime Metals Corporation, a crown company established by the Department of Munitions and Supply.[16]

The fact that the Associate Committee on Metallic Magnesium was ultimately turned to use by a Government department concerned with munitions production was less than unique. However, turning to a simplistic condemnation (or adulation) of these departments because of these occurrences, or making these occurrences seem inevitable would leave an inadequate understanding of circumstances. The NRC was never an independent body, cut off from other Government departments or their accompanying policies, the pulses of industrial production and technology, nor the pressure of international relations. Equally, this major science organization was not a pliant toy to be shaped by the whim of various departments. The paths of its research, as much as the types of industrial produce in Canada, were shaped by the very basic attitudes towards natural resources and economic development which had first given rise to the formation of the Commission of Conservation in the very peaceful year of 1090. With these attitudes, or values, the path of scientific research in Canada was left open to exploitation in time of war or peace. The science policy contained no restraints nor any discrimination against the development of natural resources for industrial use.

Work which was undertaken during peacetime was adapted to war use. This was the case with the Associate Committee on Survey Work which had been formed in early 1933 and carried out research on mapping methods, photography, and development of precise survey instruments. Though it became inactive early in the war, continued inquiries into aerial photography were undertaken jointly by the Optics Laboratory of the Division of Physics and Electrical Engineering and the Photographic Section of the R.C.A.F.. Work on survey instruments was adjusted by the Metrology Laboratories to new precision military instruments such as range finders, position finders, and clinometers.[17]

Other new precision military instruments, developed by the Associate Committee on Radio Research, included cathode ray direction finders and cathode ray air compasses.[18] These were used in battle to find the opponent's position. Major-General A.G.L. McNaughton and Colonel W.A. Steel had patented the method of using a cathode-ray oscilloscope for direction-finding as early as 1926. It was this work that Dr. Henderson and his associates furthered, first with the collaboration of the Air Ministry in Britain on March, 1939 and then in September at the request of the Army and the Chief of Staff of the Department of National Defence.[19]

The culminating research on RDF (Radio Direction Finding) or as it is now commonly called, radar, was top secret. After a preliminary dispute between the scientists, Sir Henry Tizard and E.A. Lindemann in Britain, the high priority of radar research was established.[20] While the Tizard Commission had no financial restraints, Canada's federal government refused the NRC the necessary extra funding for over a year.[21] However, by October of 1940, only six months after this funding was granted, the decision was made to begin production of RDF equipment at the recently created crown corporation, Research Enterprises Limited.[22]

A great deal more work was undertaken involving munitions projects. It included explosives, the most important of which was cyclonite or RDX (Research Department Explosives) a new synthesis which was developed by Dr. J.H. Ross at McGill University and financed by the NRC. Both Britain and the United States wanted to use this newly available explosive and large-scale production began at Shawinigan Chemicals Limited in July of 1942.[23] Though an Associate Committee on Explosives was formed in 1942 there was little work for it to do[24] since an Advisory Committee of Industrial Chemists, formed in December of 1939 and headed by Dr. Otto Maas, had already co-ordinated most of the work. Indeed this committee had been preceded by a meeting of the heads of industrial chemical research organizations convened by the NRC to plan cooperation between government laboratories and industrial research.[25]

Other work centred on ballistics and fire control, including the testing of gauges, and the development of the proximity fuse (which was the most effective weapon in deflecting the V-I bombardment of London). Research on chemical warfare played a large role with a joint British-Canadian Experimental Station located in the vast, arid, unpopulated expanse of Suffield, Alberta. Only here could experimental gases be tested without danger of harming Allied civilians. Worth noting is the fact that this area had been homesteaded and put into wheat production two decades earlier. The land, however, had been abandoned when cereal crop failures occurred.[26] Defensive work was also undertaken against mines, magnetic and acoustic, against acoustic torpedoes, and also on a method of detecting the presence of submarines. Medical researchers worked on combatting decompression and motion sickness which had cut down the efficiency of air force pilots. While Dr. Frederick Banting is famed as a discoverer of insulin, his primary interest was medical aviation research. He was on a flight to England to discuss this subject when he died in an airplane crash.

Alexander Fleming, a cohort of Dr. Banting's, discovered penicillin while he was involved in medical research for war. The production of this drug was undertaken by the government after a recommendation by the NRC Sub-Committee on Infections in

January, 1943 and the first penicillin produced was used by the armed forces against staphylococcal infections.[27]

Like penicillin, synthetic rubber was a war commodity which continued to be extensively used afterwards. Canada's consumption of rubber had leapt forward with the outbreak of hostilities. Seventy-five per cent of this was used on military vehicles. The Japanese advance into south-east Asia effectively cut off the Allied supply of rubber. With this urgent situation a cooperative research group was formed in March, 1942 involving the NRC, the federal Department of Agriculture and the University of Toronto.[28]

Experiments showed that butadiene, derived from petroleum or alcohol, was a key ingredient in the production of synthetic rubber. And alcohol, in turn, could be derived from grain. Consequently, the Associate Committee on Grain Research, begun in 1940, became involved as did the University of Alberta.[29] After innumerable separate investigations scientists found that one bushel of wheat could be broken down into ten pounds of butylene glycol, six pounds of alcohol, and seventeen recoverable pounds of feed for livestock. The wheat necessary to this production was easily available since shipping shortages had resulted in a surplus.[30]

With these promising research results preparation for production was quickly made. Polymer Corporation Limited, a crown company under the aegis of the Department of Munitions and Supplies, was created in February of 1942. Its purpose — to construct and operate a synthetic rubber plant — was achieved by September, 1943 in Sarnia, Ontario.[31]

During this war, science resources were mobilized by various parties. Sometimes requests from the United States (to the Wartime Metals Corporation for instance) or Great Britain spurred on Canadian research activity in new areas. Sometimes the initiative came from the NRC, at others from the Department of National Defence. The specially created Department of Munitions and Supplies, as a co-ordinating agent, often saw the need for production of given items and then urged industry, the NRC, and universities to conduct the required preliminary investigations.[32] Another defence agency that attempted to centralize and co-ordinate specific researches was the Army Technical Development Board, formed in the spring of 1942 and headed by an industrialist, James E. Hahn. As he explained,

> Through the Board, the Army Directorates, the National Research Council and their Development Agencies, we organized and harnessed the entire engineering, industrial, research, and technical facilities of Canada from coast to coast to cooperate in the great task of providing our troops with new weapons and in reducing the disparity in equipment that existed at the outbreak of war between ourselves and our enemy.[33]

In his autobiography, Hahn refers to one project which involved the construction of landing fields of ice, each with its own refrigeration system. These lozenges of ice, as Churchill referred to them, were to be 5,000 feet by 2,000 feet bt 100 feet and were intended for use on the coast of Norway as fight covers, and also as landing fields for small aircraft. An official request to the Canadian Government from the British Government was made on January 11, 1943 for the undertaking of this project.[34] Canada was chosen solely for its northern climate, apparently under the assumption that engineers had merely to chop the specified areas of ice from large ice flows, just as a dressmaker cuts a pattern from cloth. This, of course, was not possible and despite continued pressure from Britain to keep the research on a top priority level, investigations ceased within a year.

The project was conceived by an eccentric English inventor named Geoffrey Pyke who obtained, first, Lord Mountbatten's and then Sir Winston Churchill's attention with his lengthy report on a scheme called Habakkuk. The name, ironically, was derived from the Old Testament book of Habakkuk i.5: For I will work a work in your days, which ye will not believe, though it be told you.[35] This description, though its use by Pyke was out of context, would have been more appropriate if attached to the feverish research on atomic fission.

IX

ATOMIC RESEARCH

Immediately after cessation of hostilities in 1945 the American, Canadian, and British, among others, began to discuss the need for international control of atomic weapons. Their aim was to ensure safety. To this end the Washington Declaration was signed on December 15, 1945 by President Truman, Prime Minister Attlee, and Prime Minister Mackenzie King. It led to the establishment of the United Nations Atomic Energy Commission.[1] The fear at this time centred on widespread use of atomic bombs in warfare. Attempts to arrest such a possibility came from scientists as well as politicians. Albert Einstein, for example, had organized the Emergency Committee of Atomic Scientists under which he campaigned for a one million dollar education fund, "to ensure that atomic energy will be used for the benefit of mankind and not for humanity's destruction." He said that international control of atomic energy and, ultimately, the elimination of war were the only sure methods of safeguarding civilization.[2]

To assume, or even to hope, that war could be eliminated with a quick education program (or controlled through international legislation) merely because of the existence of the atomic weapons indicates the general paucity of critical acumen regarding atomic energy developments. The trend of thought was: fear would lead to the elimination of war; atomic energy as a power source would benefit a peaceful, though energy-hungry, population.

Of course, not everyone was so naive. A French physicist, Professor P. Auger, who worked in both Britain and Canada during WWII and who thus collaborated on the American bomb project, went on record after the war as saying:

> ...asking to outlaw the atomic weapon alone, and not outlaw at the same time the mass bombardments for instance has, in my opinion, no meaning at all. 3

His objection was a sound one for by it the ridiculousness of instituting control of atomic energy solely from fear of this powerful munitions product, rather than from an objection to the essence of the bomb as a weapon among others, is underscored. On the other hand, if Auger was sincere in his use of this pacifist argument his statement contains the seed of hypocrisy. For, since he had been deeply involved in aiding atomic research his actions lacked the crucial reinforcing pillar of moral responsibility. Auger was involved in research relating more to atomic power than atomic weapons but <u>all</u> research on atomic energy was potentially useful in the creation of atomic weapons. Thus, despite whether he (or anyone else) distinguished between the applications of atomic energy, finding one more legitimate than the other was immaterial.

No pretense of pacifism was made by the Canadian government. The official Canadian statement on atomic research and development was issued by the Honourable C.D. Howe, Minister of Munitions and Supply and Reconstruction, on August 13, 1945. He first acknowledged that the dropping of atomic bombs was the culmination of the most extensive financial and scientific effort ever directed towards the attainment of one new weapon. Next he proudly noted the role Canada had played through the organization of the NRC and the use of "basic materials, good water supplies, and isolated sites well suited to the work." He ended these remarks by concluding that due to this involvement Canada was now able to be a pioneer in an important new field of technology.[4] His focus rested on this point. The war was over. Canada was on the winning side both militarily and technologically. Qualitatively, atomic weapons and atomic power were equal. No difference existed between the desirability of their development so long as Canada was able to play a major role. In this sense, atomic power development was ranked along with penicillin and synthetic rubber, each of which began as Canadian produced war commodities but remained useful afterwards.

Unlike these latter two commodities, however, the pursuance of atomic technology led to the encroachment of the public sector on private industry. Due to the scientific sophistication and the secrecy involved in the research, key political officials lost some of their decision-making supremacy. Though science institutions had previously been given a high degree of administrative independence, it was atomic research which completely removed scientific research and development from parliamentary control.

Uranium, as an element with high radioactive properties, was the single most important raw material necessary for atomic research and weapon production. The major sources of uranium were in the Belgian Congo and Canada. In the early stages of experimentation, 1940 and 1941, only small amounts of uranium oxide were needed for research purposes. Consequently, there was little concern with future sources of supply. In Britain, the Maud Committee borrowed an adequate amount from an English firm of selling agents and Tube Alloys (Cavendish Laboratories) anonymously bought two tons of uranium oxide through the NRC in late 1941.[5] Dr. George C. Laurence, who began the first atomic researches in Canana at the NRC in March of 1940, required similar amounts. Both countries made their purchases from the Eldorado Mining and Refining Co. which was directed by Gilbert LaBine. Though the mining operations from Great Bear Lake had been shut down in July of 1940, a refinery at Port Hope, Ontario (the only one in North America) remained in operation. It was upon this stockpile that the British and Canadians depended.[6] However, by 1942 both the British and Americans realized that large supplies of uranium oxide would have to be secured if large-scale production of atomic weapons was to be undertaken.

At this point clashes between the two countries began over sources of supplies, in spite of earlier scientific collaboration. The chase for supplies soon came to Canada. After gaining control of numerous low-grade uranium mining properties in other countries, the British decided that their own demands could be met from Eldorado. Together the D.S.I.R., the Treasury, and Sir John Anderson's office of the Home Secretary decided that either control of this company or of its output and price should be gained.[7] In June of 1942 this suggestion was taken to Prime Minister Mackenzie King, who after consultation with

Dr. Mackenzie and C.D. Howe, agreed that Howe should quietly acquire the majority of shares. While no other people were to be told of the transaction, Mackenzie King did stipulate that the Americans should be advised in advance and informed that the action was in compliance with the wishes of the British Government.[8]

The Americans, who had cornered the supply of Eldorado's only major competitor, the Union Minière of the Belgian Congo, had meanwhile concluded that despite possession of these large quantities sixty tons of oxide should be ordered from Eldorado to ensure the reopening of the mine in 1942.[9] Difficulty in securing a majority of shares in Eldorado had brought Howe's efforts for government control to a temporary standstill.[10] The American order amounted to the total annual production of Eldorado. Thus, the British orders were not met, having been diverted to the Americans.

American attempts to corner the Canadian supply of a refined material necessary to the industrial production of an atomic weapon were repeated with deuterium oxide (D_2O), otherwise known as heavy water. Theoretically, this substance appeared to be a superior moderator to the pure calcined petroleum coke (a form of carbon used in the manufacture of graphite) which both the Canadians and Americans used in atomic piles. In the late 1930's, Norway had pioneered a modest production of heavy water. But this Norsk Hydro Electric plant had been in Nazi hands since mid-1940. As a result, the Americans looked to producing their own heavy water.

From a study conducted by Professor H.S. Taylor of

Princeton University in the summer of 1941, American eyes focused on the Consolidated Mining and Smelting Company of Trail, British Columbia for production of heavy water. This company was producing electrolytic hydrogen in the manufacture of ammonia and was North America's largest producer of such hydrogen. Professor Taylor's study proposed that the heavy water, which constituted 150 parts per million of the produced electrolytic hydrogen, could be extracted without substantially altering the rate of manufacture of ammonia. In June of 1942 a contract was duly negotiated between the American government and this private Canadian company. Dr. C.J. Mackenzie of the NRC accidentally learned of this transaction in late August, 1942. No American representative had given official notification of the Consolidated Mining contract to Ottawa despite the military importance of the transaction. Upon Mackenzie's discovery, such a representative was required to discuss patents of the proposed process with the Canadian government.[11] This act was only a curt nod by the American government to the formalities of Canadian law and the sovereignty of the country. Both the Canadian supply of uranium oxide and the new supply of heavy water became the exported property of the American government and were distributed at their discretion.

In the case of Eldorado, the company eventually was taken over as a crown corporation by the Department of Munitions and Supply. Though this was an emergency war act Prime Minister Mackenzie King indicated in his diary that he realized, "...it was important to keep anything of the kind away from the enemy in the post-war period."[12] This statement bespoke the effect that atomic developments were to have on the involved industries for years to come. No official cessation of war could dissolve government control. Originally the government control had come at British instigation and was a response to international hostilities as well as to international scientific and technological developments.

The takeover of Consolidated Mining and Smelting left the company's American contract intact and similar to that of Eldorado. The heavy water produced was potentially crucial to the outcome of war. Both the Canadian and British governments acknowledged that control of this product should therefore not fall to that of a foreign government or to private hands. Though Consolidated Mining and Smelting became a crown company, however, the American government continued to command the production output.

The very method of production of heavy water at Trail was built upon scientific and technological processes which were older than the atomic military technology. For here the Fauser (Italian) variation of the Haber-Bosch process was used to produce synthetic ammonia.[13] This production of synthetic fertilizers was, as earlier explained, an important technological development dating from 1913 and remained of great significance to potential munitions production. Without use of this electrolytic process in which quantities of hydrogen were produced, manufacture of heavy water would not have been possible. At the same time, the Canadian team of atomic scientists were in need of more heavy water in order to continue their purposeful theoretical, or basic, researches. Thus international technologies, theoretical scientific researches, and the competition of war all merged in an interdependence which resulted in the continuous government control of two previously privately owned companies.

The extension of public ownership culminated in the construction of a uranium-heavy water pilot plant near Chalk River by August 19, 1944. This project contained elements by now familiar to the course of government affiliated scientific and industrial development in Canada. Planning took place under the authority of the President of the NRC and the Minister of the Department of Munitions and Supply. Thus both the members of the major government science organization and military officials worked together. A key ingredient to the future development of atomic energy, both as a munitions commodity and a future source of power, this pilot plant was to house the newest and most important technology of the era. Of immediate import was the military use which held the interest of both the Americans and the British. The formal co-ordination between these countries for the development of the project placed international tensions and constraints upon it. During the war Canada was the least politically important country involved in the project, being included only because of geographic location which afforded a large supply of fresh water, low population level in the district selected, and equal proximity to the United States and to Britain. Finally, the intrusion of private industrial interests into the international political collaboration marred this Allied discourse and focused some attention on the grasping economic use to which the atomic research and technology would be harnessed at the end of the war.

Of the three countries involved, Canada was the most politically insignificant in the Allied atomic research effort. Co-ordination began with the transfer from Britain of the Cambridge heavy water team on September 24, 1942. Headed by Dr. Hans Halban, the team of scientists remained on the British payroll while working in an otherwise Canadian financed laboratory. Their Montreal location had been chosen only after proposals to locate the team in the United States had been turned down for political and security reasons. In fact, American scientists were consulted on the Tube Alloy transfer to Canada before Dr. Mackenzie and C.D. Howe.[14]

While Dr. Mackenzie expressed his enthusiasm at the technological opportunity which Canadian involvement in this 'heavy water' research would offer, C.D. Howe took the responsibility of assuring Gordon Munro, Deputy High Commissioner for the United Kingdom in Canada, that the government's approval would be given.[15] This approval was acquired but since Howe disapproved of telling his colleagues, political officials, including the Prime Minister, remained uninformed of the details and significance of this collaboration.

The following year Churchill and Roosevelt, as well as British and American Chiefs of Staff, met for the Quebec Conference from August 17 to 24. Just before the conference got underway a formal British and Canadian conference was held. "I shall have throughout", said Mackenzie King in anticipation, "to maintain with care and due deference our own position as a country in no way subordinate to Britain in any aspect of its domestic or foreign affairs."[16] Regarding atomic research, this aim was not realized. How could it be when the Canadian Prime Minister was so poorly informed about the nature and potential of atomic power that he found it analogous to William James' explanation of the power of the mind that comes from tapping deeper sources of energy? Instead of tri-partite negotiations on atomic research the Lord President of the Council of the United Kingdom Government, Sir John Anderson, told Mackenzie King on August 8, 1943 that an agreement had been reached which both Churchill and Roosevelt were expected to sign. Canada was made a party to this development simply because uranium and heavy water supplies were located here.[17] When Churchill met with Mackenzie King two days later and secured agreement to his proposal that C.D. Howe be the one Canadian member of a British, American and Canadian combined policy committee[18] the subordinate position of Canada to Britain and the United States was finalized. Little wonder should escape then at the exclusion of Canada from the Quebec Agreement of August 19, 1943 which governed collaboration between British and American authorities in the matter of Tube Alloys.[19]

The tenets of the Quebec Agreement contained two major stipulations: guarantees of allied secrecy regarding use of and information about atomic power were tabled first; recognition of the American claim to "any post-war advantages of an industrial or commercial character", except as conceded by the President of the United States to the Prime Minister of Britain followed the previous military considerations. Each stipulation was of great importance. While the military collaboration which ended with participation in Canada has been considered, the effects of industrial interests on atomic research developments were also of consequence and must be explored.

A large flaw in the development of science policy and one which had a serious detrimental effect on collaboration with the Americans was the intrusion of private industry into the research, development, and production of atomic energy. Though the American government relied heavily on the American duPont to fill its needs in association with the atomic industry, it raised objections to the involvement of the British Chemical Industries (I.C.I.). For, the members of the Tube Alloys project, most of whom had been transferred to Canada, maintained strong connections with I.C.I. These connections thus reached deep within the Canadian atomic projects. Dr. Wallace Akers, former Research Director of I.C.I. headed the Tube Alloys project and was consequently the official liaison figure for the joint Anglo-American project. His assistant, Michael Perrin, was seconded from an I.C.I. position which had been of equivalent status. Dr. Hans Halban, a native of France who fled to Britain, headed the Montreal laboratory in 1943. He had set up such strong I.C.I. ties with Akers and other employed engineers that these men were kept posted on certain Canadian developments while the scientists at Montreal were left uninformed.[20] Also, in 1914 he had negotiated with I.C.I. to make use of his French patents on nuclear energy and had agreed to join the corporation. This proposition had been vetoed by the British Defence Panel in September of 1941 but the memory of cooperation remained.[21]

Development of the joint project to build an atomic bomb remained at a virtual standstill as the Montreal team stayed aimless even after the Quebec Conference. The Americans had surpassed the British and Canadian effort, to be sure, but this did not alone explain their reluctance to work with the conglomeration of Montreal scientists. Only on September 12, 1943, while on a visit to Washington, was it revealed to Dr. C.J. Mackenzie that the Americans objected to the extensive I.C.I. penetration of the British and Canadian teams.[22] General Lesley R. Groves, military director of the American atomic bomb project wrote that, "Akers might well be influenced by an undue regard for possible postwar commercial advantages for the British when speaking of interchange information."[23] Such were American concerns. Changes were quickly made to ease their fears, with Akers being replaced by Dr. James Chadwick and Halban's partisan and autocratic conduct being curbed through the operation of a Technical Committee of the Montreal Laboratories.

From this point collaboration progressed with decisions being taken regarding construction of the Chalk River facilities. Designed and built by Defense Industries Ltd., a government owned subsidiary of Canadian Industries Limited (C.I.L.), the key staff for the project were employees of this parent corporation.[24] C.I.L., however, was in turn a subsidiary of the British I.C.I.. The odd fact here is that though the link was well known no objection to the further involvement of this company was raised by the Americans. Perplexity tends to dissolve, however, once one learns that C.I.L. was also a subsidiary of duPont Limited.[25] Though the financial interest of duPont in this venture must remain conjectural the likelihood of conveniently combined interests in C.I.L. involvement in the Chalk River project should be considered. If this shoul prove to be true then some light may be shed on the factors which composed science policy in Canada. For not only in terms of a source of supplies, such as uranium oxide, heavy water, and quantities of fresh water, or convenient geographic location, or military alliance would Canada have been useful and would her involvement in scientific projects have been of use to certain other countries. As with the international flow of scientific information, of technological developments, and national hostilities, the international flow of business would have overtaken attempts by the Canadian government to shape a science policy regarding nuclear developments.

The exact manner in which business pervaded government policy appears oblique. For, in taking on contracts for the American heavy water and plutonium projects, duPont stated that no profits were desired and no patent rights were expected. All that was asked for was reimbursement of expenses.[26] Yet negotiations in the Quebec Agreement, the confession of General

Groves and the objection to Akers which Roosevelt related to Dr. Mackenzie all indicate that business interests played an important role in joint Anglo, American, and Canadian collaboration.[27] All of these attempts to safeguard American industry emanate from the government. This can only indicate that the military and political authorities in the United States were closely associated with industrial and business interests. Unfortunately one cannot deduce which first set out to court the other. Despite this shortcoming we can see that the military, political and business associations had their effect on the progress of the Canadian based project, just as did the similar British associations.

The conclusion that must be reached is that the government of Canada, as represented by the NRC and the Department of Munitions and Supply, through Dr. Mackenzie and C.D. Howe, became involved in atomic research in order that the country would be on the winning side militarily, technologically, and industrially. These aims were achieved but not by this country alone. In the process Canada, as a distinct national entity, was overrun politically and (in limited areas) geographically, as a source for specific raw and refined materials, and as a location for the pursuance of foreign business interests. The aim of advancing the level of scientific research and industrial development in Canada proved to be a science policy which also aided the military and technological interests of Britain and the United States.

X

CONCLUSION

The Lamontagne Commission's perplexity over the failure of the federal government to implement a co-ordinated science program to aid the national unity of the country begins to disperse as we emerge from this study. The internationality of political relations, the unrestrained pursuit of basic scientific research to develop natural resources, and the competition for the most advanced industrial processes to be used in the development of those resources were all combined in the formation of Canada's national science policy.

In the first period, 1910 to 1920, the determination of the founders of Canada's two national science organizations to "promote the economic utilization of resources" and to work towards "the conversion of our natural resources into developed wealth...through the application to them of science of the most highly advanced type" characterized the aim of national science policy. These aims, which were considered by Clifford Sifton to be "universally commended as essential to the highest degree of national welfare" were at times less than beneficial to the groups of affected citizens. As was shown, prairie farmers often experienced the loss of land and homes as bountiful crops failed to materialize. To these people, the inability to fill virtually insatiable market demands bespoke much more than the dry figures cited on financial loss. Though industry brought some employment, the residents of Sudbury, Ontario and Trail, British Columbia suffered from the noxious and unhealthy sulphur pollution which accompanied it.

During each of the two periods considered a world war shook the balance of the western world. In the First World War the realization by Britain and Canada that many supplies upon which they had come to depend would be unobtainable was a catalyst to the formation of science research organizations in the Commonwealth. Thus, in Britain the DSIR, and in Canada the NRC were formed. The first concern of the NRC was education of scientists in Canada to staff the organization and associated industries. Then came the construction of laboratories. These aims were compatible with the general policy to develop natural resources and to aid the growth of industry in Canada.

Despite the unity of aims between Canada's aspiration for development and the need for a science organization made evident by the First World War, a conceptual flaw marred the success of the science policy goals. The flaw was an over-simplification which was evident in the name of the Honorary Advisory Council for Scientific and Industrial Research. It was conspicuous in the inability of the Council to ingratiate industrial scientists with the academic members. This was the case in Britain as well as in Canada. For, rival industrial interests are not national in scope but international. Their business of profit-making knows no patriotism that is not financially, or at least technologically, advantageous. And, to them, whether products are for use in war or peace is irrelevant. Government sponsored science is an activity which is distinct from that of private industry. While one can easily see how industry would benefit from free access to the government's scientific research results, how government and citizens would benefit from this essentially international industry is much more difficult to understand. The flaw in the science policy is found in the assumption by the government that it could both direct and benefit from the industrial development which would be encouraged through its scientific aid.

The superficial thinking regarding the uniting of science and industry tended to be hidden by the rush of science activities precipitated by war. For, during hostilities, the concentrated effort towards mobilization of industry for munitions production tended towards the harmonious blending of government and industrial forces. In Niagara Falls, the American Cyanamid Company transferred to production of explosives in 1916. A new competitor, in the form of a company and an engineering process, appeared in the nickel industry when the British government gave financial support to the British American Nickel Corporation. The electric arc and the Hybinette processes, key technological advancements which allowed increased production, were the basis from which the demand for munitions permitted both this realization and the profit. Both the chemical and metallurgical industries enlarged their production capacity and financial value. Canada, on the other hand, had access to some of the technology and production capacities necessary to fighting a modern war.

Yet, even with the expansion of these industries the tension between the goals of government and industry persisted. International Nickel, perhaps because it was a foreign-owned company, refused to apply patriotic loyalties to the sale of its products. Though the refinery of its nickel was moved from New Jersey to Port Colborne the purpose of keeping ore mined in Canada within the country and under the control of Canadian authorities was not the reason for relocation. Rather, a technological advancement involving replacement of the Orford process for that of Hybinette's, which included the need for large quantities of cheap electric power, provided the motive. The development of Canadian hydro power became a natural resource crucial to other industries. Despite attempts by the Commission of Conservation to preserve this natural resource for use in Canada conditions necessary to the expedient production of munitions brought interference from the Solicitor-General. Hydro power was diverted for use in the United States. In each of the cases cited the pressures of war brought the expansion of industry in Canada but the inability of the government to control the use of each natural resource product was also evident.

The mechanisation of war was much more sophisticated by the Second World War. With the NR Laboratories now properly established and staffed by Canadian educated scientists federal government involvement in scientific research relevant to mobilization reached a new height. Products from synthetic rubber to magnesium, uranium, and heavy water came into manufacture. The extended web of government sponsored industrial production was responsible for a great deal of the development. It was also aided by the new administrative technique of Associate Committees which facilitated the direct though informal participation of industrial scientists and businessmen within Canada's national science organization. The fact that federal government scientists acted as direct liaisons to industrialists was aptly portrayed in President McNaughton's trip to Britain in 1939 with members of the Canadian Manufacturers Association.

The scientific development of certain major technologies during WWII necessitated the exclusion of related industries from private ownership. Thus, Consolidated Mining and Smelting, which produced heavy water, and Eldorado Mining, the extractor and refiner of uranium, became crown companies. The Chalk River plant, where Canada's first nuclear reactor was built and operated, was in government hands from the outset. But though the industries which used these advanced technologies and which produced the militarily valuable and potentially dangerous products came under the wing of the federal government the protective value of this officiator was, and is, dubious. For, as has been shown, the political control of natural resource industries has been minimal.

Beside Prime Minister Mackenzie King's very naive conception of atomic power were the virtually unregulated defence departments and the structurally independent NRC. Each of these was undeviatingly motivated towards further scientific and technological development as they related to munitions and natural resource industrial production. Munitions production in turn was closely influenced by international political relations and, to be efficient, had to keep abreast of all pertinent technological advances. Likewise, the scientific research conducted by the NRC for the express purpose of industrial development had to include the study of areas related to new technological processes. As we saw in the example of atomic research and technology, military and industrial interests cohabite within one technology.

The pursuit of scientific research is irredeemably connected to technology. In the periods studied, industrial manufacture and munitions production were both linked through technology. Since the means of relating government scientific research to industry had not been adequately considered in the original formation of national science policy political control was soon lost. Pressures of industrial competition over mass markets and demands for munition products in the face of international hostilities quickly relegated science researchers to servant status and wrenched all vestiges of political control over science policy from elected members of the federal government.

The several reasons which swept away the quandary over the cause of Canada's national science policy failure have left us with an even greater problem. How can we ever erect a sound science policy structure in Canada which gives Canadians political control over the various science related activities being carried out in Canada? Can it be done? The complex interweaving of the results of scientific research which are applied as technology to be used in industrial manufacture, possibly in the direct production of munition products, form a system of development which is international in scope. All of these pressures shape the effective science policy. Thus science activities in any country where natural resources are traded for developed wealth through the application of scientific research results must bow to the strength of international pressures involved in this production. Political control through formal legislation is only one element among many. This control is only the remains left over after science policy and activities have been buffeted by the storms of international hostilities, industrial competition for advanced engineering processes, and rivalry over the securing of markets. Suffering through this harsh climate, any political control remains stunted and weak. A strengthening of the political control over national science policy can only come about by the recognition of and removal of these adverse forces. This would involve deflecting Canadian science policy from the goal to develop our natural resources for industrial production aimed towards highly competitive international markets. Such a change would require a concerted effort by both the federal government and the people in Canada which would involve setting new priorities favourable to the continuous but conservative use of natural resources instead of their extremely rapid and excessive exploitation. The resulting emphasis on appropriate technology for limited consumption would include a withdrawal from the international arena. Admittedly, a reversal of science policy orientation of this magnitude is not easily achieved. However, if Canada would have political control of national science policy, nothing less is required.

FOOTNOTES

Chapter 1

[1]Maurice Lamontagne, A Science Policy for Canada Report of the Senate Special Comittee on Science Policy, V olume I, (Ottawa: Queen's Printers, 1970), p.3. This definition is quoted from Emmanuel G. Mesthane's, Technological Change, New American Library (New York, 1970), p.25.

Chapter II

[1]'National', in this thesis, denotes the all-encompassing territorial spread and juristiction of the policy. Consequently activities initiated by the federal government, rather than the provincial governments, dominate the political focus of this study.

[2]Wilfrid Eggleston, National Research in Canada (Toronto: Clarke, Irwin & Company Limited, 1978), p. 3.

[3]The following is a list of the original members of the NRC.
Dr, Frank Adams, Dean of Applied Science, McGill University,
Mr. T. Bienvenu, Vice-President and General Manager, La Banque Provinciale du Canada
Mr, R. Hobson, President, Steel Company of Canada
Dr, A.B.Macullum, Professor of Biochemistry, University of Toronto
Dr. A.S. Mackenzie, President, Dalhousie University
Dr. J.A. McLennan, Professor of Physics, University of Toronto
Dr. W.C. Murray, President, University of Saskatewan
Mr. R.A. Ross, Consulting Engineer, Montreal
Dr. R.F. Ruttan, Professor of Chemistry, McGill University

J.B. Challies of the Waterpower Branch in the Department of the Interior became the Secretary.

In the first year two additional members were appointed.
S.F. Kirkpatrick, Professor of Metallurgy, Queen's University
Arthur Surveyer, Consulting Engineer, Monteal

[4]S.A. Cudmore, "Reconstruction in Canada", Canada Year Book 1920, (Ottawa: King's Printers, 1921), p.53.

[5]Mel Thistle, The Inner Ring: The Early History of the National Research Council of Canada (Toronto: University of Toronto Press, 1966), p. 16. Thistle relates that members of the Advisory Council were already embroiled in disputes of where the national laboratories should be situated by 1917. Chairman Macallum backed Ottawa, while Dr. J.C. McLennan pushed for laboratories in Toronto, Winnipeg, and Montreal.

[6]C.J.S. Warrington and R.V.V. Nicholls, A History of Chemistry in Canada (Toronto: Sir Isaac Pitman and Sons, 1949), p. 395.

[7]D. Carnegie, The History of Munitions Supply in Canada, 1914-18 (Toronto: Longmans, Greene and Co., 1925).
This statistic on the number of workers in Canada for the Imperial Munitions Board is taken from M. Bliss, A Canadian Millionaire (Toronto: McLelland and Stewart, 1978), p.358.

[8]Mel Thistle, op. cit. p. 6. In January, 1916 Canadian universities received a circular from the Ministry of Munitions which invited research cooperation and suggested that university research activities be organized through a department of the Canadian federal government.

[9]Debates, House of Commons, Dominion of Canada, 5th Session, 1921, Volume IV, Conservation Act Repeal Bill, p. 358.

[10]Sir Clifford Sifton, Review of Work of the Commission of Conservation reprinted from the Eighth Annual Report of the Commission of Conservation, (Montreal: The Federated Press Limited, 1917), p. 4.

[11]See the front of the Dictionary of Altitudes in the Dominion of Canada James White, ed., Department Head and Assistant to Chairman (Ottawa: The Mortimer Press Co. Ltd., 1916) for a listing of the members.

[12]The Honorary Advisory Council gained administrative responsibilities on July 19, 1921 when the Research Council Act was constituted.

[13]Before this time the group of Ministers in the Sub-Committee of the Privy Council performed this function for the NRC.

[14]See Debates of the Senate, pp. 462-463 and Debates of the House of Commons, 5th Session, 1921, Volume IV, p. 3959.

[15]Hon. H.S. Béland, member of the Commission of Conservation, Debates of the House of Commons, May 13, 1921, Volume IV, p. 3966.

[16]Hon. H.A. Meighen, Debates of the House of Commons, 1921, Volume IV, p. 3959.

[17]Hon. Mr. Fielding, Debates of the House of Commons, May 13, 1921, Volume IV, p. 3970.

[18]W.J. Dick, "Carbonizing and Briquetting of Lignites: Economic Possibilities" (Ottawa: Commission of Conservation, 1917).

[19]NRC, Synopsis of Organizational Activities, 1917-1926 p. 20.

[20]Sir Clifford Sifton, reprint of Eight Annual Report, op. cit. p. 6.

[21]Ibid. p. 5.

[22]NRC, Synopsis of Organizational Activities, 1917-1926 pp. 21-22.

[23]Mel Thistle, op. cit. p. 16. Taken originally from Min. 34, Proceedings, 2nd Meeting, NRC, Jan. 5, 1917.

[24] Ibid. p. 17. Taken originally from Min. 20 and 21, Proceedings, 2nd Meeting, NRC, Jan. 5., 1917.

[25] The International Joint Commission consisted of three Canadians and three Americans, a majority of which has the right to render a decision which is binding on both countries. For a brief history see, G.V. LaForest, "Boundary Water Problems in the East", Canada-United States Treaty Relations D.R. Deener, ed., (Durham: Duke University Press, 1963), pp.32 to 35.

[26] H.V. Nelles says in, The Politics of Development: Forests Mines & Hydro-electric Power in Ontario, 1849-1941 (Toronto: Macmillan of Canada, 1975), pp. 367-368, that a munitions supplier in New York state announced in 1917 that it was unable to complete orders for the British government due to an insufficient supply of Canadian hydro power. This report touched off a discussion of the entire export question and included the intervention of Joseph Flavelle, head of the Imperial Munitions Board. The Aluminum Company, or one of its associated branches, was probably the munitions supplier in question.

[27] See pages 450 to 455 of John W. Dafoe's, Clifford Sifton in Relation to his Times (Toronto: The Macmillan Company of Canada Limited, 1931) for a more extensive discussion of the Long Sault debate.

[28] The argument that the Commission of Conservation was marked for removal due to a personal or political vendetta was advanced by the Acting Chairman, the Honorable Mr. Edwards, in the Senate Debate of May 19, 1921, p. 511. He claimed that two civil servants from the Ministry of the Interior were responsible for the repeal agitation. (Sifton had been Minister of the Interior until 1905 when he split with Prime Minister Laurier.) However, W. Eggleston notes on p. 36 of National Research in Canada that President Tory, of the NRC, also had a confrontation with a "wrecking crew" which consisted of some civil servants and a secretary. Thus, such a vendetta, if it did exist, could hardly have had a purely personal motivation, and a political motivation is virtually impossible to establish. At any rate this crew disbanded in 1923, according to H.M. Tory.

Chapter III

[1]E.K. Andrews and Roy MacLeod, "The Origins of the DSIR: Reflections on Ideas and Men, 1915-1916", Public Administration 1970, p. 37.

[2]Mel Thistle, The Inner Ring: The Early History of the National Research Council of Canada (Toronto: University of Toronto Press, 1966), p. 8. Quoted from a letter by Sir George Foster to J.C. McLennan, May 26, 1916, Foster Papers, Volume 18, P.A.C.

The recipient of this letter, J.C. McLennan was a professor of physics at the University of Toronto, vice-president of the Royal Canadian Society, and a member of the British Honorary Advisory Council. At that time he was working on anti-submarine measures. He became one of the original members of the Canadian Honorary Advisory Council and within this organization was keenly interested in nitrogen-related research. After the Great War he was scientific advisor for the British navy. Are these the qualifications which Foster believed constituted a man "of a practical turn"? If so, the phrase 'militarily practical' as opposed to 'industrially practical' seems to describe the specific qualification that Foster had in mind.

[3]The original members of the DSIR were,
Sir George Beilby, Chairman of the Royal Technical Institute, Glasgow
Raphael Meldola, chemist and former head of Finsbury Technical College
Sir Richard Threlfall, consulting engineer and manufacturing chemist
(NOTE: The above men were all industrial chemists.)
W. Dudell, consulting engineer
Bertram Hopkinson, Professor of Mechanics at Cambridge
Lord Rayleigh, key member of the Aeronautics Committee of the National Physical Laboratory
J.C. McLennan, Professor of Physics at Toronto, Canada

This list is taken from E.K. Andrews' and Roy MacLeod's, "The Origins of the DSIR", p. 40.

[4]Ibid. p. 41.

[5]Ibid., p. 42, Quoted from Ed.24/1580, Max Muspratt, United Alkali Company to Walter Runciman, 27 July, 1915.

[6]Hon. Mr. Thompson, Debates of the House of Commons, Research Council Act Amendment, 2nd Reading, April 28, 1921, p. 2701.

[7]Cronyn Committee, Interim Report read to the House of Commons on July 1, 1919. See p. 4376ff, Hansard, Volume V.

[8]Hon. Hume Cronyn, Chairman of "Special Committee of the House of Commons Appointed to Consider the Matter of the Development in Canada of Scientific Research, Debates, House of Commons, July 3, 1919, p.4457.

[9]Hon. Sir Sam Hughes, Debates, House of Commons, July 3, 1919, p.4461.

[10]Ibid., p.4461.

[11]Cronyn Committee, Final Report, issued on April 27, 1920, (Ottawa, King's Printer, 1922), p.5.

[12]Hon. Mr. Thompson, Debates, House of Commons, July 3, 1919, Volume V, p. 4463; Hon. Mr. McMaster, Debates, House of Commons, 1919, Volume II, p.1372.

[13]National Research Council, Synopsis of Organizational Activities, 1917-1926,"The Value of Scientific Research", Appendix M.

[14]Hon. Peter McGibbon, Debates, House of Commons, 1919, Volume II, p.1371.

Chapter IV

[1]Sir Clifford Sifton, Chairman, Review Work of the Commission of Conservation, reprinted from the Eight Annual Report of the Commission of Conservation, (Montreal: The Federated Press, 1917), p.5.

[2]John H. Thompson, "Permanently Wasteful but Immediately Profitable: Prairie Agriculture and the Great War", Canadian Historical Association, 1976, p.193.

[3]The Canada Year Book, 1920, (Ottawa: F.A. Acland, 1921), p.31.

[4]D.A. McGibbon, The Canadian Grain Trade, (Toronto: The Macmillan Company of Canada Limited, 1932), p.31.

[5]Ibid., see page 8 and page 30 for examples.; see also John W. Bennett's Northern Plainsmen, edited by Walter Goldschmidt, (Illinios: AHM Publishing Corporation, 1969), p.235. Bennett states that,

> The homestead influx in 1910 coincided with a wet period, and the myth of a permanent change in the weather was born at that time. After the droughts of the late teens and 20's, the conviction of drought as an abnormal condition did not die, but after the decade of the 1930's, the violent swings in mood had ceased.

[6]John H. Thompson, Op. Cit., p.198; For an historically contemporary writing on the method of dry farming see F.J. Harrison, "The Science of Crop Rotation", Farmer's Advocate, March 15, 1916.

[7]Edward Hyams, Soil and Civilization, (London, Jarrold and Sons Limited, 1952), p.244.

[8]Ibid., p.198-199.

[9]Ibid., p.199.

[10]J.H. Thompson, Op. Cit., p.200 and p.201.

[11]C.J.S. Warrington, A History of Chemistry in Canada, (Toronto, Sir Isaac Pitman and Sons, 1949), p.69.

[12]D.A. McGibbon, Op. Cit., p.41.

[13]Ibid., p.432.

[14]National Research Council, Synopsis of Organizational Activities, 1919-1926, p.11.

[15]J.H. Thompson, Op. Cit., p.199.

[16]Mel Thistle, The Inner Ring: The Early History of the National Research Council of Canada, (Toronto: University of Toronto Press, 1966), p.70.

[17]Wilfrid Eggleston, National Research in Canada, (Toronto: Clarke, Irwin & Company Limited, 1978), p.30.

[18]Bruce MaCallum, Environmentally Appropriate Technology, (Ottawa: Offices of the Science Advisor, Department of the Environment, 1975), p.134.

[19]See the Annual Report of the National Council for 1932-33 for a further discussion of this research development.

[20]Report of the Royal Commission on Dominion-Provincial Relations, Book I, (Ottawa: King's Printers, 1940), p.121.

[21]D.A. McGibbon, Op. Cit., p.55.

[22]See page 82 of V.C. Fowke's National Policy and the Wheat Economy, (Toronto: University of Toronto Press, 1957). Fowkes refers to these new resources but considers them in terms of "investment frontiers", thus paving the way for their later consideration in purely financial terms.

[23]Ibid., p.134.

Chapter V

[1]See chart #98 on p. 226 of C.P. Stacey ed., Historical Documents of Canada: Volume V, The Arts of War and Peace, 1914-1945, (New York: St. Martin's Press, 1972).

[2]The Canada Year Book, (Ottawa: F.A. Acland, 1921, 1921), p.7.

[3]Ibid., p.7.

"Values of Munitions and Materials Exported from Canada"

Year	$$
1914	28,164,000
1915	57,213,688,000
1916	296,505,257,000
1917	388,213,553,000
1918	260,711,751,000

[4]D. Carnegie, History of Munitions Supply in Canada, 1914-1918, (Toronto: Longmans, Greene and Co., 1925), p.282.

[5]Ibid., p. 285.

[6]H.C. Engelbrecht and F.C. Hanighen, Merchants of Death: A Study of the International Armament Industry, (New York: Garland Publishing, Inc., 1972), p.253.

[7]Warrington, C.J.S. and R.V.V. Nicholls, A History of Chemistry in Canada, (Toronto, SIR ISAAC Pitman and Sons Limited, 1949), p.187-188.

[8]M. Lamer, The World Fertilizer Economy, (Stanford: Stanford University Press, 1957), p. 168.

[9]From 1914 to 1915 the Hydro-Electric Power Company increased its load by 35 per cent. It distributed 167,000 horsepower in 1916 and by 1918 this amount had catapulted to 333,000 horsepower. In all, service tripled over three years. (See A History of Chemistry in Canada, p. 185-186.) See Appendix A for statistics on nickel production and trade. (This is reproduced from B.W. Mackenzie, Nickel- Canada and the World, (The Department of Energy, Mines and Resources, Ottawa, 1968), p.161-162.

[10]H.V. Nelles, The Politics of Development: Forests, Mines & Hydro-Electric Power in Ontario, 1849-1941, (Toronto: Macmillan of Canada, 1974), p.365-367.

[11]Ibid., p.367.

[12]O.W. Main, The Canadian Nickel Industry, (Toronto: University of Toronto Press, 1955), p71.

[13]Ibid., p.72.

[14]D.M. Le Bourdais, Sudbury Basin: The Story of Nickel, (Toronto: The Ryerson Press, 1953), p.127.

[15]B.W. Mackenzie, Nickel - Canada and the World, (Ottawa: Department of Energy, Mines and Resources, Queen's Printer, 1968, p.64.

[16]H.C. Engelbrecht, op. cit., p.167.

[17]O.W. Main, op. cit., p.85.

[18]H.V. Nelles, op. cit., p.358, p.356.

[19]Ibid., p.358.

[20]National Research Council Act, section 10. c.iii.

[21]C.J.S. Warrington, op. cit., p.58.

[22]The Canada Yearbook, 1916-1917, (Ottawa: F.A. Acland, 1918), p.44. C.J.S.,Warrington, op. cit., p.10.

[23]Report of the Administrative Chairman of the Honorary Advisory Council for Scientific and Industrial Research in Canada, for the year endig March 31, 1918, (Ottawa: King's Printer, 1918), p.3o, 31, 32.

[24]Hon. Mr. Edwards, Debates of the Senate, Dominion of Canada, 1921, Conservation Act Repeal Bill, considered in committee, p.512.

[25]D. Carnegie, op. cit., See pages 193 to 202 for a more complete description of the use of British Columbia timber by the Imperial Munitions Board.

[26]Debates of the House of Commons, Dominion of Canada, 1921, Conservation Act Repeal Bill second reading, p.3958. (P.M.Meighen)

[27]Innis, H.A., Problems of Staple Production in Canada, (Toronto, The Ryerson Press, 1933,), p.78.

Chapter VI

[1]M. Lamer, The World Fertilizer Economy, (Stanford: Stanford University Press, 1957), p.169.

The following amounts of ammonium sulphate were sent to France (in metric tons).

1920 to September 1924	184,000
1925	138,000
1928	200,000
1929	123,000
1930	50,000

[2]Ibid., p.171, p.174.

[3]Annual Report of the National Council, 1928-29, p.51. By 1929, Norway had turned 140,000 kilowatts produced from its might water power to production of electrolytic hydrogen. This power had previously been used in the arc process of nitrogen fixation.

[4]M. Lamer, op. cit., p.225-226. See p. 45 of the Annual Report of the NRC for 1920-193- for more detail on this methane and steam process. NRC interest in these gas processes is reflected in the fact that an Associate Committee on Gas Research was formed in 1920 and was still in existence in 1935.

[5] See the Annual Reports of the National Research Council from 1934 to 1940 for brief discussions of this pollution.

[6]Mel Thistle, The Inner Ring: The Early History of the National Research Council of Canada, (Toronto: University of Toronto Press, 1966), p.17. This quote is originally taken from the Agenda Papers of the NRC, 2nd Meeting, January 5, 1917, items 4 and 9.

[7]See the Annual Reports of the NRC for a summary of the work of the Associate Committee on Nitrogen Fixation.

[8]Annual Report of the NRC, 1930-31, p.85.

[9]Annual Report of the NRC, 1928-29, p.51.

Chapter VII

[1] Annual Report of the National Research Council, 1935-36, p.17.

[2] The Sussex Street building was monolithic becauase rather than meeting the specifications of a science laboratory it matched the aesthetics of architects and urban planners. When General McNaughton proposed ripping out a floor in order to house transformers for researchin highvoltage electrical transmissions he was met by the opposition of horrified politicians. As a result this research was moved th laboratories located in the countryside. (See Eggleston, National Research in Canada, pp.110-111 and the CBC interview of McNaughton and Mackenzie from 1965.)

[3] SeeW. Eggleston, National Research in Canada: The NRC 1916-1966, (Toronto: Clarke, Irwin & Company Limited, 1978), p.87 and Corbett, E.A., Henry Marshall Tory: Beloved Canadian, (Toronto: The Ryerson Press, 1954), p.179.

The manner in which Tory was retired and McNaughton hired results in a great deal of resentment from both Liberal and Conservative M.P.'s. This matter was taken up in the House of Commons on June 11 and 19, 1935. See pages 3505 and pp. 3788-89 of Hansard, 1935.

[4] CBC Interview of General McNaughton and Dr. Mackenzie, January 5, 1966, Reel I, p.3.

[5] Swettenham, op. cit., p.315. The original source is a memorandum dated May 28, 1935, "Correspondence, Rt. Hon. R.B. Bennett, "McNaughton Papers."

[6] J.M. Beck, Pendulum of Power: Canada's Federal Elections, (Toronto: Prentice-Hill of Canada, Ltd., 1968), p.207.

[7] CBC Interview, op. cit., Reel 1A, pp. 2-3.

[8] J. Swettenham, McNaughton, Volume I, 1887-1939, (Toronto: The Ryerson Press, 1968), p.168. The author of this volume derived this fact from the McNaughton Papers, "Department of Communications".

[9] CBC Interview, op. cit., Reel I, p.4.

[10] Ibid., Reel 2, p. 5.

[11] Swettenham, op. cit., p.326.

[12] CBC Interview, op. cit., Reel IA, p. 3-4.

[13] See Annual Report of the National Research Council, 1935-1936, p.20.

[14] M. Thistle, The Mackenzie-McNaughton Wartime Letters, with introduction and epilogue by C.J. Mackenzie, (Toronto: University of Toronto Press, 1975), Mackenzie to McNaughton on September 28, 1940, p.47.

[15] W.F.K. Middleton, Physics at the National Research Council of Canada, 1929-1952, (Waterloo: Wilfrid Laurier University Press, 1979), p.84.

[16] Ibid., Mackenzie to McNaughton, July 25, 1940, p. 42.

[17] For more detail see Dr. F.T. Rosser's, Sir Frederick Banting Fund, (NRC pamphlet), Ottawa, 1960.

[18] CBC Interview, op. cit., Reel 2, p. 2.

[19] Ibid., Reel 4, p.2.

[20] M. Thistle, The Inner Ring: The Early History of the National Research Council of Canada, (Toronto: University of Toronto Press, 1966), p.333.

[21] Ibid., p. 330.

[22] CBC Interview, op. cit., Reel 2, p. 5., Reel 4A, p. 2.

[23] Swettenham, op. cit., p.339-340. The original source is the CBC interview referred to above. (This source has been used since the entirety of the tape has seemingly not survived for public use.)

[24] See Fayrs, J., In Defence of Canada: Appeasement and Rearmament, (Toronto, University of Toronto Press, 1965), pp.115 to 126 for an elaboration of Mackenzie King's attitude and policy.

Chapter VIII

[1] M. Thistle, The Mackenzie-McNaughton Wartime Letters, (Toronto: University of Toronto Press, 1975), Mackenzie to McNaughton on May 4, 1940, p. 34.

[2] E. Regeher, Making a Killing: Canada's Arms Industry, (Toronto: McClelland and Stewart Limited, 1975), p.71.

[3] W. Eggleston, Scientists at War, (Toronto: Oxford University Press, 1950), p.3.

[4] Annual Report of the National Research Council, 1937-38, p.8.

[5] Annual Report of the National Research Council, 1936-37, p.14.

[6] Annual Report of the National Research Council, 1937-38, p.8.

[7] Annual Report of the National Research Council, 1937-38, p.8.

[8] W. Eggleston, National Research in Canada, (Toronto: Clarke, Irwin & Company Limited, 1978), p.374.

[9] See Doern, G.B., Science and Politics in Canada, (Montreal: McGill-Queen's University Press, 1972), P.3 regarding the Commission of Conservation.

Some of these problems had included investigation of the cause of forest fires which it was found were ignited by sparks from passing trains, the setting up of Experimental Farms which were subsequently taken over by the Departments of Agriculture and used to teach farmers new techniques, and calling attention to the problem of colour loss of canned lobster.

[10] War History of the Associate Committees of the National Research Council, p.66.

[11] War History of Division of Chemistry, p.17.

[12] Morgan, G.T., and D.D. Pratt, British Chemical Industry: Its Rise and Development, (London: E. Arnold & Co., 1938), p.125. Kennedy, J. De. N., History of the Department of Munitions and Supply, Volume I, (Ottawa: King's Printer, 1950), p.507.

[13] War History of Division of Chemistry, p.19.

[14] Morgan and Pratt, op. cit., p.126.

[15] Ibid., p.125.

[16]War History of the Division of Chemistry, p.22.

[17]War History of the Associate Committees of the National Research Council, p.110.

[18]Ibid., p.100.

[19]W. Eggleston, Scientists at War, (Toronto: Oxford University Press, 1950), p.28-9, p.33.

[20]See C.P. Snow's, Science and Government, (Cambridge, Massachusetts: Harvard University Press, 1961), for a full discussion of the progress of radar research in Britain. It is especially noteworthy that Churchill, always backing E.A. Lindermann or as he was also called, Lord Cherwell, put more faith in stategic or obliteration bombing and felt that this should be reflected in research priorities.

[21]See W. Eggleston's, National Research in Canada, (Toronto: Clarke, Irwin & Company Limited, 1978), p. 149 to p. 151.

McNaughton and Henderson had requested extra funds as early as April 26, 1939, but were refused money until April, 1940. Work was possible in the meantime only because McNaughton diverted $3,000 from his budget and the Department of National Defence made over $1o,ooo in equipment and supplies available.

[22]J. de N. Kennedy, op. cit., p.423.

[23]Scientists at War, op. cit., p.74, p.79.

[24]War History of the Associate Committee of the National Research Council, p.9.

[25]Scientists at War, op. cit., p.75.

[26]Ibid., p.103.

[27]Ibid., p.233,234.

[28]Ibid., p.194.

[29]See pages 22 to 64 of the War History ofthe Associate Committees of the National Research Council for a detailed history of this Associate Committee and pages 72 to 92 of the War History of the Division of Biology for a detailed history of experiments on resin-rubber from Canadian grown plants and the production of alcohol from wheat.

[30]Scientists at War, op. cit., p.199, p.196.

[31]Kennedy, op. cit., p.395.

[32]On January 22, 1940, the War Supply Board was created to assure production and adaquete supplies of war materials. It was superseded on April 9 of the same year by the new Department of Munitions and Supplies, headed by C.D.Howe, with, as he said, the purpose of " knitting together this vast web of enterprise... to meet the unprecedented demands of the greatest war in history." (p.v., J. de N. Kennedy) Responsible for mobilizing, conserving and coordinationg both the economic and industrial facilities of Canada for the prosecution of war, this department was soon of prime importance since its administrators were given the power to control the production and use of materials necessary to war. This function was effected via direct Control liegislation established by orders-in-council, through coordination of branches of private industries of munitions production to avoid unnecessary competition for supplies of raw materials, equipment and labour, and through the establishment of an eventual 28 Crown companies both to produce specific articles and to dispense certain supervisory, administrative and purchasing functions.

[33]J.E. Hahn, For Action: The Autobiography of a Canadian Industrialist, (Toronto: Clarke, Irwin & Company Limited, 1954), p.179.

[34]W. Eggleston, National Research in Canada, (Toronto: Clarke, Irwin & Company Limited, 1978), p.221, p.227.

[35]Scientists at War, op. cit., p.154-155.

Chapter IX

[1]G.C. Laurence, "Canada's Participation in Atomic Energy Development", in Bulletin of the Atomic Scientists, November 1, 1947, p.328.

[2]A. Einstein, Bulletin of the Atomic Scientists, June, 1947, p. 136.

[3]P. Auger, "Professor Auger on I.S. Control Plan", Bulletin of the Atomic Scientists, September 1, 1946, p.17.

[4]"Canadian Information Service Statement, August 13, 1945", in Smyth, H.D., Atomic Energy for Military Purposes: The Official Report on the Development of the Atomic Bomb under the Auspices of the United States Government, 1940-1945, (Princeton: Princeton University Press, 1947), p. 288.

[5]M. Gowing, Britain and Atomic Energy, 1939-1945, (London: Macmillan &Company, Ltd., 1965), p. 179.
Note that Tube Alloys was the code name for the atomic physicists working at the Cavendish Labouratories towards the production of an atomic bomb.

[6]W. Eggleston, Canada's Nuclear Story, (Toronto: Clarke, Irwin & Company Limited, 1965), p.41-43.

[7]M. Gowing, op. cit., p.180, p.182.

[8]J.W. Pickergill, The Mackenzie King Record, Volume 1, 1939-1944, (Toronto: University of Toronto Press, 1960), pp. 413-4

[9]M. Gowing, op. cit., p. 181.

[10]Ibid., p. 183.

[11]W. Eggleston, op. cit., p.49.

[12]J.W. Pickersgill, op. cit., p.414.

[13]M. Lamer, The World Fertilizer Economy, (Stanford: Stanford University Press, 1957), p.103.

[14]W. Eggleston, op. cit., p.52,53, p.50.

[15]Ibid., p.51-52.

[16]J.S. Pickersgill, op. cit., p.531.

[17]J.W. Pickersgill, _op. cit._, p.532.

[18]_Ibid_., p.536.

[19]See Appendix on Quebec Agreement, August 19, 1943.

[20]W. Eggleston, _op. cit._, p.39, p.91.

[21] M. Gowing, _op. cit._, See pages 75 to 76 and page 109 for greater detail of this transaction.

[22]W. Eggleston, _op. cit._, p. 92.

[23]L.R. Groves, _Now it Can Be Told: The Story of the Manhatten Project_, (New York: Harper & Row, 1964), p.129.

[24]M. Gowing, _op. cit._, p.278.

[25]M. Lamer, p.178. Lamer notes that at this time Dupont and I.C.I. each owned 42% of the commonstock of C.I.L.

[26]L.R. Groves, _op. cit._, p.58.

[27]On page 172 of _Britain and Atomic Energy_, Margaret Gowing indicates that it was the leading American scientist and government advisory, Dr. Vannevar Bush, who had Roosevelt relate that Akers was "_persona non grata_" to the Americans on account of his industrial connections with I.C.I."

III

BIBLIOGRAPHY

1. Primary Sources

Articles

Auger, P. "Prof. Auger on I.S. Control Plan" Bulletin of the Atomic Scientists, September 1, 1946, p.17.

Cudmore, S.A. "Reconstruction in Canada", Canada Year Book, 1920, Ottawa: King's Printers, 1921.

Einstein, A. Bulletin of the Atomic Scientists, June, 1947, p. 136.

Harrison, T.J. "The Science of Crop Rotation", Farmer's Advocate, March 15, 1916.

Howe, C.D. "Canadian Information Service Statement, August 13, 1945", in H.D. Smyth's, Atomic Energy for Military Purposes: The Official Report on the Development of the Atomic Bomb under the Auspices of the United States Government, 1940 to 1945, Princeton: Princeton University Press, 1947.

Laurence, G.C. "Canada's Participation in Atomic Energy Development", Bulletin of the Atomic Scientists, November 1, 1947, p. 328.

1. Primary Sources

Books and Pamphlets

Cronyn, H. Cronyn Committee: Final Report. [issued on April 27], 1920. Ottawa: King's Printer, 1922.

Canada Year Book, 1920. Ottawa: F.A. Acland, 1921.

Canada Year Book, 1916 to 1917. Ottawa: F.A. Acland, 1918.

Dick, W.J. Carbonizing and Briquetting of Lignites: Economic Possibilities. Ottawa: Commission of Conservation, 1917.

Lamontagne, M. A Science Policy for Canada: Report of the Senate Special Committee on Science Policy, Volume I. Ottawa: Queen's Printers, 1970.

National Research Council. Synopsis of Organizational Activities, 1917 to 1926.

--------. The Annual Reports of the National Research Council. 1928 to 1929, 1930 to 1931, 1932 to 1933, and 1934 to 1935 to 1938 to 1940 inclusive.

--------. National Research Council Act, 1924.

--------. War History of the Associate Committees of the National Research Council.

--------. War History of the Division of Chemistry.

Report of the Administrative Chairman of the Honorary Advisory Council for Scientific and Industrial Research in Canada, for the year ending March 31, 1918. Ottawa: King's Printer, 1918.

Report of the Royal Commission on Dominion-Provincial Relations, Book I, Ottawa: King's Printers, 1940.

Rosser, Dr. F.T. Sir Frederick Banting Fund. [NRC pamphlet], Ottawa, 1960.

Sifton, Sir C. Review of Work of the Commission of Conservation. reprinted from the Eighth Annual Report of the Commission of Conservation. Montreal: The Federated Press Limited, 1917.

Thistle, M. The Inner Ring: The Early History of the National Research Council of Canada. Toronto: University of Toronto Press, 1966.

Thistle, M. The Mackenzie - McNaughton Wartime Letters. With introduction and epilogue by C.J. Mackenzie. Toronto: University of Toronto Press, 1975.

White, J. Dictionary of Altitudes in the Dominion of Canada. Ottawa: The Mortimer Press Co. Ltd., 1916.

1. Primary Sources

Debates

Debates of the House of Commons, Dominion of Canada. 1919, Volume II, Hon. Peter McGibbon. p. 1371.

--------. 1919, Hon. Mr. McMaster. p. 1372.

--------. Cronyn Committee, Interim Report. July 1, 1919, Volume V, Hon. Hume Cronyn. p. 4376.

--------. 1919, Hon. Hume Cronyn. p. 4457.

--------. 1919, Hon. Sir Sam Hughes. p. 4461.

--------. 1919, Hon. Mr. Thompson. p. 4463.

--------. 1921, Conservation Act Repeal Bill. p. 358.

--------. 1921, Hon. Mr. Thompson. p. 2701.

--------. 1921, Prime Minister Meighen. pp. 3958, 3959.

--------. 1921, Hon. H.S. Beland. p. 3966.

--------. 1921, Hon. Mr. Fielding. p. 3970.

Debates of the Senate, Dominion of Canada. 1921, p.462 to 463.

--------. 1921, Hon. Mr. Edwards. p. 511.

--------. 1921, Hon. Mr. Edwards. p. 512.

Miscellaneous

CBC Interview of General McNaughton and Dr. C.J.. Mackenzie, January 5, 1966.

2. Secondary Sources

Articles

Andrews, E.K. and MacLeod, R. "The Origins of the DSIR: Reflections on Ideas and Men, 1915 to 1916", Public Administration, 1970.

LaForest, G.V. "Boundary Water Problems in the East", Canada-United States Treaty Regulations, edited by D.R. Deener, Durham: Duke University Press, 1963.

Thompson, J.H. "Permanently Wasteful but Immediately Profitable: Prairie Agriculture and the Great War", Canadian Historical Association, 1976.

2. Secondary Sources

Books and Pamphlets

Beck, J.M. Pendulum of Power: Canada's Federal Elections. Toronto: Prentice-Hall of Canada, Ltd., 1968.

Bennett, J.W. Northern Plainsmen. Edited by W. Goldschmidt. Illinois: AHM Publishing Corporation, 1969.

Bliss, M. A Canadian Millionaire. Toronto:Macmillan and Company, 1978.

Carnegie, D. The History of Munitions Supply in Canada, 1914 to 1918. Toronto: Longmans, Greene and Co., 1925.

Corbett, E.A. Henry Marshall Tory: Beloved Canadian. Toronto: The Ryerson Press, 1954.

Dafoe, J.W. Clifford Sifton in Relation to his Times. Toronto: The Macmillan Company of Canada Limited, 1931.

Doern, G.B. Science and Politics in Canada. Montreal: McGill-Queen's University Press, 1972.

Eayrs, J. In Defence of Canada: Appeasement and Rearmament. Toronto: University of Toronto Press, 1965.

Eggleston, W. Canada's Nuclear Story. Toronto: Clarke, Irwin & Company Limited, 1965.

---------. National Research in Canada. Toronto: Clarke, Irwin & Company Limited, 1978.

---------. Scientists at War. Toronto: Oxford University Press, 1950.

Engelbrecht, H.C. and Hanighen, F.C. Merchants of Death: A Study of the International Armament Industry. New York: Garland Publishing, Inc., 1972.

Fowkes, V.C. National Policy and the Wheat Economy. Toronto: University of Toronto Press, 1957.

Gowing, M. Britain and Atomic Energy, 1939 to 1945. London: Macmillan & Co. Ltd., 1965.

Groves, L.R. Now It Can Be Told: The Story of the Manhattan Project. New York: Harper & Row, 1964.

Hyams, E. Soil and Civilization. London: Jarrold and Sons Limited, 1952.

Hahn, J.E. For Action: The Autobiography of a Canadian Industrialist. Toronto: Clarke, Irwin & Company Limited, 1954.

Innis, H.A. Problems if Staple Production in Canada. Toronto: The Ryerson Press, 1933.

Kennedy, J. de N. History of the Department of Munitions and Supply, Volume I. Ottawa: King's Printer, 1950.

Lamer, M. The World Fertilizer Economy. Stanford: Stanford University Press, 1957.

LeBourdais, D.M. Sudbury Basin: The Story of Nickel. Toronto: The Ryerson Press, 1953.

Mackenzie, B.W. Nickel - Canada and the World. Ottawa: The Department of Energy, Mines and Resources, 1968.

Main, O.W. The Canadian Nickel Industry. Toronto: University of Toronto Press, 1955.

McCallum, B. Environmentally Appropriate Technology. Ottawa: Office of the Science Advisor, Department of the Environment, 1975.

McGibbon, D.A. The Canadian Grain Trade, Toronto: The Macmillan Company of Canada Limited, 1932.

Middleton, W.E.K. Physics at the National Research Council of Canada, 1929 to 1952. Waterloo: Wilfred Laurier University Press, 1979.

Morgan, G.T. and Pratt, D.D. British Chemical Industry; Its Rise and Development. London: E. Arnold & Co., 1938.

Nelles, H.V. The Politics of Development: Forests, Mines & Hydro-electric Power in Ontario, 1849 to 1941. Toronto: Macmillan Company of Canada Limited, 1975.

Pickersgill, J.W. The Mackenzie King Record, Volume I, 1939 to 1944. Toronto: University of Toronto Press, 1960.

Regehr, E. Making a Killing: Canada's Arms Industry. Toronto: McClelland and Stewart Limited, 1975.

Snow, C.P. Science and Government. Cambridge, Massachusetts: Harvard University Press, 1961.

Stacey, C.P., editor. Historical Documents of Canada: Volume V, The Arts of War and Peace, 1914 to 1945. New York: St. Martin's Press, 1972.

Swettenham, J. McNaughton, Volume I, 1887 to 1939. Toronto: The Ryerson Press, 1968.

Warrington, C.J.S. and Nicholls, R.V.V. A History of Chemistry in Canada. Toronto: Sir Isaac Pitman and Sons, 1949.