CHEMICAL INSTITUTE OF CANADA

Survey of Chemical Research and Development

on behalf of the Science Secretariat

Science Council of Canada

RESEARCH IN CHEMICAL ENGINEERING IN CANADA

Committee 18

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1. Introduction

It is not easy to define what is meant by "chemical engineering research", and indeed, no unique or unambiguous definition seems to exist. Therefore, the committee adopted a viewpoint which appeared to it to be best suited to the purposes of this survey. "Chemical engineering research" was defined as all research in the chemical, process or resource industries which was of an applied nature. In this context, "applied" was taken to mean the kind of research required to develop successful bench scale laboratory experiments into commercial end products or process

With this approach, it was necessary to be concerned not only with applied research or development work accomplished by task forces designated for this purpose, but with engineering innovation and investigations resulting from other engineering groups, including the efforts made in the areas of economic or market studies.

While this viewpoint represents a very wide spectrum of industries, and of activities within these industries, we felt that it was better to set the boundaries perhaps too widely, rather than to omit any significant areas of engineering research or development in the chemical and process industries.

The committee devoted itself to gathering opinions, and a certain amount of factual information, by the use of personal interviews with research directors, faculty members, or others engaged directly in research direction or administration. A list of interviews conducted is attached as Appendix 1.

2. Functions of Chemical Engineers in Research and Development

Broadly speaking, chemical engineers are used in two ways in industrial research. For research organized on a project basis (as is true for a majority of applied research), the chemical engineer may enter the scene at any point, although usually not until a basic idea is undergoing initial development. As the project team expands with further development, chemical engineering participation increases through the stages of laboratory testing to pilot plant to feasibility studies to final utilization. In industrial research centers, the chemical engineering staff usually varies from 15% to 50% of the professional personnel, with the balance being chemists, mainly. Many research centers in Canada, however, maintain relatively little in the way of staff or facilities for larger pilot plant scale work, one of the principal areas for chemical engineering research employment. Such work is done either on a temporary basis, is contracted out, or is done by the parent organization.

An increasing number of chemical engineers, particularly in larger companies, are being organized in engineering divisions, process studies divisions, or some comparable arrangement. A minor but important fraction of the work done by such groups can be properly called engineering development. As some of these groups are now quite large, with a high percentage of chemical engineers in their complement, this contribution to chemical engineering research in Canada is not negligible, and is a rapidly growing one.

Chemical engineers employed in universities or government laboratories tend to work largely in basic engineering studies, sometimes in small scale pilot plants. With one or two exceptions, chemical engineers represent only a very small fraction of research personnel in government laboratories, by far the largest proportions being chemists or other pure scientists.

3. Numbers of Chemical Engineers

No information appears to exist as to the total number of chemical engineers employed in Canada. An estimate can be made from various sources that the total is in the neighbourhood of 5,000. Of this total it is fairly certain that at least 50% have graduated in the last ten years, so that the total group is a relatively youthful one.

Better statistics exist with respect to numbers of chemical engineers employed in research and development, because such statistics have been collected periodically by the Dominion Bureau of Statistics, and more recently by the Chemical Institute of Canada as a part of this survey. Tables 1 and 2 give numbers of chemical engineers, chemists and metallurgists employed in R. and D. for 1965 as reported by the Dominion Bureau of Statistics, and Table 1 also for 1966 as reported in the C.I.C. survey of industrial research in chemistry and chemical engineering.

Table 3 gives the number of academic staff in universities actually directing research, as best they can be determined from NRC publications, data from professional societies, etc. If postdoctoral fellows were included in these numbers (no exact count is available), there would be about a 15% increase. The great majority of those included in the statistics making up Table 3 have doctoral degrees.

4. Industrial Applied Research and Development

In a sense, all industrial research and development is "applied" in that it is oriented towards the needs of a particular industry. However, we have tried to exclude basic scientific work of an exploratory nature--even though it may be narrowly based--from our general comments.

Industrial research in Canada has shown a considerable increase in the

Table 1

Professional Personnel Engaged in Research and Development in Industry*

	1965			1966		
	Bachelors	Masters	Ph.D.	Bachelors	Masters	Ph.D.
Chemical Engineers	583	109	69	446	100	76
Metallurgists	198	44	39	112	38	39
Chemists	812	146	353	803	164	445

*1965 - Dominion Bureau of Statistics, "Industrial Research & Development Expenditures in Canada, 1965", Cat.No.13-527,Tabl
1966 - C.I.C. Survey of Chemistry Research in Canada, 1966, Table 27, Section 18

Table 2

Professional Personnel Engaged in Research and Development

in Federal and Provincial Laboratories*(1)

	1965		
	Bachelors	Masters	Ph.D.
Chemical Engineers	109	26	19
Metallurgists	55	20	29
Chemists	174	81	300

*1965 - Dominion Bureau of Statistics, "Federal Government Expenditures on Scientific Activities" 1964-65, Cat. No. 13-401, Table 12

Table 3

Personnel Directing Research in Universities*

	1965	1966	1967
Chemical Engineers	105	119	131
Metallurgists	53	73	98
Chemists	418	518	653

*Does not include postdoctoral fellows. Actual professional personnel - not full time equivalents. Data from various sources. Does not include graduate students working towards advanced degrees.

(1) Professional personnel in Provincial Laboratories from total figures given in Dominion Bureau of Statistics Cat. No. 13-527, distribution assumed same as for Federal Laboratories.

past few years, due largely to federal tax incentives and direct government aid programs. It has not been a regular growth pattern, and the effect of the government incentive programs begun in 1962 show up clearly as illustrated in Figure 1. (Numbers from DBS for self consistency.*) The accelerated pace of research spending from 1962-1965, in the neighbourhood of 20-30% increase per year, seems to be decreasing now to about 10% growth rate per year. This latter figure appears to be about the maximum growth rate that most directors of industrial research feel can be efficiently handled.

Results from the C.I.C. survey (see Table 24, Section 18) indicate that a growth rate to 1970 of 3-5% per year in research expenditures is forecast. In contrast to this figure, most directors of research when interviewed personally felt that the engineering content of their programs would increase by 6-10% per year over the next five years, a considerably higher rate of growth than the average forecast. The reason for this difference apparently arises from the expectation that much of the new basic work undertaken since 1963 will require increasing investment in applied research as it matures. Many of the newer research establishments have not as yet built up the developmental areas of their programs, and foresee this occurring over the next five years. The outlook for employment of chemical engineers in industrial applied research and development is good, therefore, and many new graduates will be required. On the average, a higher proportion of chemical engineers employed for R. and D.

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*"Industrial Research and Development Expenditures in Canada", Dominion Bureau of Statistics, Cat. No. 13-524 (1963), Cat. No. 13-527 (1965).

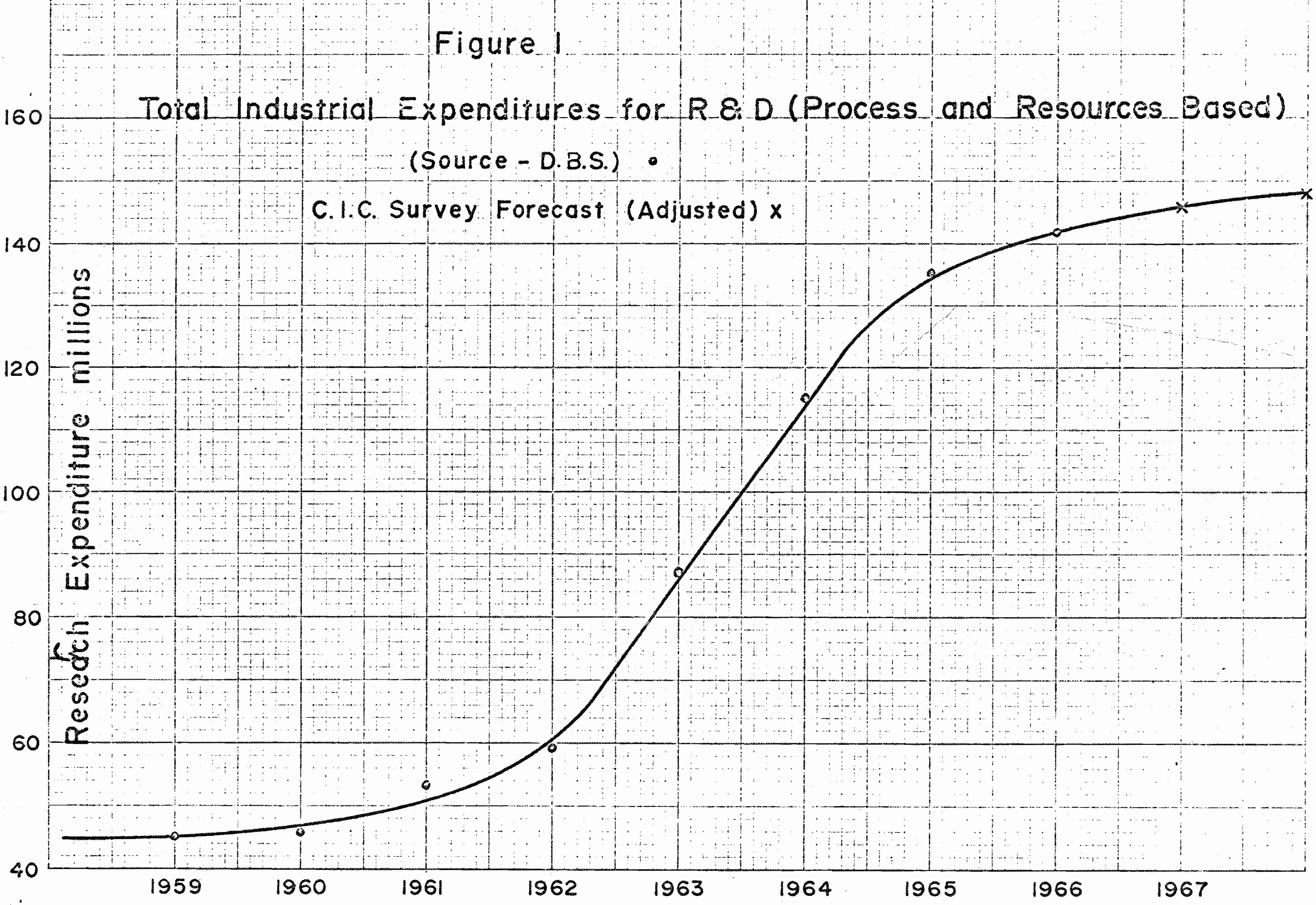

Figure 1

Total Industrial Expenditures for R & D (Process and Resources Based) are expected to have more advanced degrees than in the past, although many companies also claim that they foresee no need for any increase in the proportion of advanced engineering degrees in R. and D. Requirements vary a good deal among companies, but a significant number of companies now desire a certain proportion of Ph.D. chemical engineers. Only a few expect to have difficulty in recruiting the necessary staff for an accelerated rate of engineering research.

The nature of the engineering research and development programs presently existing in Canadian chemical and process industries has been in the past and is now heavily influenced by a number of basic factors. Among the more significant of these may be listed government policies with regard to taxes, grants and tariffs, whether or not companies are foreign subsidiaries, whether a company operates primarily as a producer of raw material or as a processing or refining company, and the basic nature and size of the market available to the present and potential future products of a company.

The research necessary to obtain engineering information, operating experience, trial production lots, etc. increases in cost very rapidly as a development moves towards commercial realization. A much larger project team with a wider spectrum of specializations is required, together with a greater degree of experience and maturity. Capital investment also increases by orders of magnitude. It has been said that for every basic researcher, ten will be required for the pilot plant stage, and a hundred to produce the basis of a commercial design or to justify a full scale production facility.

The effects of Federal policies on industrial R. and D. (discussed in more detail later) may be summarized at this point by stating that it is a common opinion that present tax incentives favour the new research group over the established one, and thus penalize those companies with larger and more stable research programs; that tariff concessions are likely to favour the importation of new products rather than their development and manufacture in Canada; and that the grants program, while commendable, lacks clear objectives and coordination. Federal policies, in general, while conceded to be much more helpful than a decade ago, are considered by most research directors in industry to be incomplete, or haphazard, or lacking in clear purpose. In short, there is a generally unanimous concensus that a good deal of room for improvement exists. Some such possible improvements suggested by industrial researchers are discussed later.

If a company operates primarily in Canada, or is Canadian owned, then it must do its own developmental work or purchase its technology from others. There are a number of instances in Canadian industry where the former is being done very successfully, but the majority of new technology installed in Canada by these primarily "Canadian" companies is obtained from abroad, whether it is for the purpose of producing new products or is for improved processing. It is an interesting fringe benefit, that those companies engaged successfully in both basic and developmental research had no difficulty in recruiting professional staff at any level, and without any regard to geographic location. However, a large number of companies manufacturing in Canada are subsidiaries of parent organizations which possess extensive central research facilities for pilot plant or development studies. Because of the high cost, and the relatively small volume generated from the Canadian operations, this type of work tends to be carried out in the laboratories of the parent. It is interesting to note, however, that the research costs reported as having been incurred because of payments for work done outside Canada have stayed relatively constant for several years. If these statistics are indeed real then an increasing number of subsidiaries must be carrying out their own development work in Canada.

A clear distinction should be made between the importation of technology developed by a parent organization, which is to be expected, and indeed, which is usually economically highly beneficial from the viewpoint of the Canadian operation, and payment for development work done by a parent organization to produce technology required by the Canadian operation. There is undoubtedly a strong trend towards having research and development work of primary concern to the Canadian operation done in Canada, and this trend is endorsed and promoted by most directors of industrial research. A frequent comment made by many research workers in government, universities and many industries was that many Canadian managements in a variety of companies are not sufficiently aggressive in pursuing this trend, either because of ignorance of research possibilities or because of a historical "branch plant" way of thinking. The lack of management appreciation of the place of research seems in some cases to be due to the fact that many smaller companies have only recently grown to a point where a research program might be feasible, and in others to the relatively unsophisticated processing or limited product range of many larger companies. It was also stated that in most subsidiary companies experience showed that a good deal of autonomy would usually result if Canadian management wishes to pursue research and development programs, and could produce the necessary economic justification.

In many of the large subsidiary companies, a very considerable degree of autonomy with regard to research and development does exist, and has for many years, and mutually beneficial cooperation in research is common between the parent and its Canadian operation. It is also true, however, that many large chemical and process companies have little or no Canadian research program, while many others have just begun research and have very limited capabilities in developmental work.

Another characteristic feature of Canadian industry is the number of large resource based companies who have little or no research effort, or who are just making a modest beginning. Ownership seems to bear little relation to the existence of a research program in these companies. What is abundantly clear is that in the major resource industries (that is, mining and metal production; wood, pulp and paper; food and agriculture) the average research effort in terms of the value of the industry has been only a fraction of one per cent of sales, a relative proportion many times less than in other industries. Of course, individual companies do exist which are exceptions, but the average low scale of performance in research and innovation of this sector of the manufacturing industries has been pointed out publicly many times in the last ten years. The most recent figures, obtained from the C.I.C. survey of industrial R. and D.

expenditures indicates that some $124 million was spent in research and development in 1966 by those companies classed as chemically based industries (see Table 25). Value of the sales of this group of companies in Canada in 1966 was about 14,000 millions giving a rate of expenditure on R. and D. for the Canadian chemical and process industries of about 0.9% of sales. The chemical industry (petrochemicals, synthetics, etc.) alone spends about 2.1% of sales on R. and D., and the resource based industries figure for R. and D. is around 0.6% of sales. By contrast the chemical and process industries in the United States spent about $2,815 million on R. and D. in 1966, for a rate of 2.3% of sales.

While it is true that the resource based industries in all countries invest in research at a lower rate than the chemical industry as such, in Canada these industries form the basis of our industrial economy. In other highly developed countries, for example, in the United States, this is not the case.

Canadian industry is, of course, unique also in that such a large proportion of its chemical industry is controlled by foreign corporations. Among chemical products over 80% of sales are accounted for by firms having more than 50% foreign ownership. The economic implications of this situation have been the subject of a recent government report.* Some of the consequences with respect to the kind of research carried out in Canada have been discussed earlier.

The most emphatic opinion, expressed with varying degrees of forcefulness by nearly all those interviewed, was that industrial research in Canada needed to be concentrated on those areas of unique concern to our economy, and that far too little of this kind of research was presently being done. Federal research expenditures, which are of the same magnitude as industrial expenditures, are not effective in promoting commercial development or exploitation of new products or processes. Industry could do a great deal in taking the lead in this kind of research, and subsidies should be available for development work in economically crucial areas. Government research should have more guidance and advice from industrial personnel, who are in a position to more accurately evaluate economic and market factors. Scientific research for prestige or for the training of scientists is now supported at an adequate level.

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*Foreign Ownership and the Structure of Canadian Industry", Report of the Task Force on the Structure of Canadian Industry, (M.H. Watkins, Chairman) for Privy Council of Canada, Queens Printer, Ottawa, Jan. 1968

Clear objectives and policies from government are now needed for development of a strong technology able to exploit the natural economic advantages of Canadian resources. Such policies have existed for many years for the fostering of an adequate level of achievement in the sciences, and the same action is many years overdue with respect to technological innovation.

5. Some Comments on Particular Industries

(i) Heavy Chemicals - Salts, acids, bases, fertilizers, etc. Process technology is largely international and purchased from contractor-designer. Applied research is largely short-range production problems, or product and market oriented. Transportation costs are a vital factor. Little basic research is done, or can be expected to be done in these industries. Process improvements and product development to suit Canadian conditions or needs is done to some degree by some companies.

(ii) Petrochemicals, fibres, plastics, etc. - Production technology is nearly all supplied from outside Canada. A limited Canadian market for these relatively sophisticated products cannot bear costs of new product or process development, e.g. average sales per manufacturing unit in the United States are about double those in Canada. Recent tariff agreements appear to discriminate especially against manufacture of synthetic fibres or plastic products in Canada. Development tends to be oriented to product improvement. Basic process research is carried out in this area by many companies, but major commercial development is nearly always transferred to facilities of parent company outside of Canada.

(iii) Extractive Metallurgy - Comments are also being made by another committee. Insufficient research in process development is carried out in Canada relative to the size and importance of the industry, but the investment in research has increased rapidly in recent years. Because a large number of smaller producers account for a good deal of mineral production, this leads to a considerable segment of the industry supporting little or no research. The recent increase in R. and D. has been entirely within the largest companies. Because the Canadian operations tend to be large, and autonomous, or the degree of foreign ownership is smaller, if research is done at all much of it is done in Canada. The volume of research as a per cent of sales is very low, probably around 0.5%. Those companies using metallurgists, chemical engineers and chemists have relatively little difficulty recruiting research personnel. The exchange of research information is quite unhampered in the metallurgical industries, and cooperative research ventures, such as institutes, etc. might well be very feasible.

(iv) Pulp and paper - A good deal of applied research is carried out by individual companies, and the only industry supported cooperative research institute in Canada exists as the Pulp and Paper Research Institute. Research expenditures are still less than 1% of sales, and are not increasing at a rate comparable to the national average. Much basic research and a good deal of product research is supported. The industry has contributed very little, however, to the development and manufacture of pulp and paper making machinery although it is the second largest world producer of pulp and paper. This is one example of a general apparent unwillingness on the part of Canadian producers to be the first to undertake the risks of manufacturing innovation.

(v) Food and Pharmaceuticals - In the food, beverage and detergent industries virtually no applied research or development has been carried on in Canada. A few companies are now making a beginning. Foreign ownership in industries is very high. Management in food and beverage industries, on the whole, is not research oriented nor able to appraise research needs or potential. From the viewpoint of national technological competence the food industry in particular is not in a very advanced state.

The pharmaceutical industry, on the other hand, serves a small but highly sophisticated market and invests heavily in chemical research. Engineering research and development is of very minor concern, pilot plants being operated primarily to produce test quantities of new products.

(vi) Process Equipment Manufacturing - The manufacture of process equipment is a highly competitive field, but one which can pay very substantial dividends in founding secondary engineering industries. Insofar as the supplying of special machinery for chemical processes, the industry is virtually non-existent in Canada. In the areas where engineering industries might be expected to have developed, namely the metallurgical or mineral industry and in pulp and paper, very limited manufacturing or development occurs. Even technological innovations developed by Canadian industry are marketed in Canada by foreign engineering firms. This specialized hardware represents a substantial fraction of all capital investment in the chemical industries, but this investment has produced only a minimal return in the form of development of secondary industry. Clearly, the economic climate in the past has not favoured such development in Canada, and government assistance or incentives have not been effective.

6. Chemical Engineering Research in Universities

Some statistics are given in Table 4 showing the numbers of chemical engineering departments, faculty, first degree and advanced degree students. Similar but less complete data for metallurgical engineering are recorded in Table 5. The most striking feature of these data is the tremendous growth in size and research activity of chemical engineering departments. In 1961/62, these departments averaged about four faculty members with less than two graduate students each. In 1966/67, only five years later, each department averaged nearly eight faculty members with about three graduate students each. In this time period, faculty numbers have doubled and graduate student numbers have tripled. A recent but considerable increase in the numbers of first degree students graduating has also occurred.

Departments of Metallurgy do not show the same high rate of growth as do chemical engineering departments. Metallurgy departments at present tend to be rather smaller than those of chemical engineering although the relative level of graduate work is about the same. However, ratios of graduate students to undergraduates and faculty to undergraduates are nearly twice as high for metallurgy as for chemical engineering.

This rather sudden growth in chemical engineering and metallurgy requires some explanation. It is certainly not to be found in a fostering of these areas by deliberate policies of either industry or government, for there is no evidence of any such national planning or foresight inherent in any Canadian policies dealing with technological areas.

Table 4

Personnel in University Departments of Chemical Engineering

(Directory of Chem. Eng. Research, Can. Soc. Ch. Eng., 6th Ed. 1966-67, I. G. Dalla Lana ed.)
(Engineering Journal)

	1961/62	1962/63	1963/64	1964/65	1965/66	1966/67
Total No. of Departments	16	16	17	17	18	18
Total Faculty	66	79	93	111	121	136
Total Faculty* Directing Research	--	--	--	--	--	119
Total Ph.D. Students	50	67	82	99	117	149
Total M.Sc. Students	62	81	119	137	174	195
Total Graduate Students	112	148	201	236	291	344
Total B.Sc. Graduates	--	--	--	265	268	353

*Postdoctoral Fellows not included (about 21 in 1966/67)

Table 5

Personnel in University Departments of Metallurgy

(NRC Statistical Summary of Graduate Students, 1966/67, Pub. 9341)
(Engineering Journal)

	1964/65	1965/66	1966/67
No. of Departments	10	10	11
Faculty Directing Research*	45	53	73
Total Ph.D. Students	--	75	78
Total M.Sc. Students	--	89	82
Total Graduate Students	116	164	160
Total B.Sc. Graduates	103	82	98

*Does not include Postdoctoral Fellows

In 1961, departments of chemical engineering were generally inadequately staffed, and were dealing with the end result of the slump in engineering enrollment in 1957. After 1958, however, many new departments came into existence (in 1955 there were only seven chemical engineering departments and in 1961 there were sixteen). With the new departments came a keener competition in graduate training and research. Demand from 1959 onward has exceeded the supply of graduates every year, and after 1962 the increased rate of industrial research spending opened a much greater market for those with advanced degrees. Hence, all the prerequisites for growth were present, and academic chemical engineers were quick to take advantage of the situation.

At the present time there are more holders of doctoral degrees in chemical engineering in Canadian universities than in all industry and government combined. Whatever this may imply with regard to the sophistication of the Canadian chemical industry, it does emphasize that a considerable pool of talent for applied research exists in the universities. It is of considerable interest to determine to what extent this talent is employed in conducting research purely for educational purposes, and to what extent innovation and invention (the so-called "spin-off" of research) are to be found.

For universities as a whole, and equally true for chemical engineering departments, funds for research come almost entirely from federal and provincial sources, with only about 4% of the total from industry. The support of research by provincial and federal governments has always been on the basis of a maximum of academic freedom to pursue any kind of work of a suitable intellectual level. Accomplishment is then measured by publication of results in reputable scientific journals, and hence financial support is obtained in direct proportion to a research worker's activity in research publication. In the engineering field, this creates a requirement that idealized minor problems be studied, because these lead directly to the most rapid and prolific publication. Real problems encountered in industrial practice tend to be complex and full of non-idealities, and even basic studies on systems of economic significance therefore often proceed slowly and with difficulty. Undoubtedly, the requirements of the sources of funds have dictated to a considerable degree the nature of the research carried out in universities. In Table 6 a summary is given of the actual topics being studied in 1966/67 in university departments of chemical engineering. Possibly 10% of the topics, certainly no more, have some direct relevance to problems of Canadian industries, or to the obtaining of information of direct usefulness to them. About 90% of all the work carried out is "academic" in nature, that is, its primary purpose is to train graduate students in research methods and as a secondary result, to add to the store of general knowledge of our physical world.

If industrial research and development in chemical engineering were carried out at a more advanced level in Canada, this state of affairs might be both expected and desirable, as it is in the United States. However, as pointed out previously, the amount of engineering research and developmental work done in Canada is limited by the facts of subsidiary status, reluctant management and small markets. It is probable that many Canadian companies, regardless of ownership, will be very slow to develop sophisticated product or process development capabilities even when the scale and nature of their operations might fully warrant such activity. However, there are still problems of engineering research to be solved if the fullest exploitation of our natural resources is to occur, or if we are to be able to cope with uniquely Canadian conditions.

The pool of engineering talent in Canadian universities could make a very considerable contribution towards providing solutions to these Canadian research problems, if research could be done with the advice and cooperation of industry. Funds for mission oriented research would have to be available to chemical engineers on university faculties, and the use of these funds would have to be assessed periodically, preferably by industrial researchers. Such suggestions were made with two exceptions by every Department of Chemical Engineering in Canada, and by many industrial research directors.

While chemical engineers in academic work do not wish or intend to surrender their freedom to pursue research for its own sake, most feel that adequate funds for these purposes exist at present. The great majority at all levels feel keenly that it is very difficult to carry out research on problems of economic significance without penalizing one's academic career. Almost without exception, chemical engineering faculty members feel that both "academic" and "oriented" applied science research in approximately equal amounts belongs in university departments.

Suggestions on ways of introducing closer ties between university and industry researchers, and for increasing the amount of oriented research, were remarkably in agreement. All agreed that the oriented research must be relevant to Canadian industry, and particularly to the utilization of natural resources. Most faculty members felt that any further increases in federal or provincial research support to universities (including increases which might otherwise go to the pure sciences) should be diverted into research having definite economic objectives. The present level of government research support for the pure sciences and for academic engineering studies was deemed to be more than adequate. Many were hesitant about creating a new government agency for the encouragement of mission oriented research in universities, but at the same time most doubted the ability of the National Research Council to create and administer this type of research policy. Failing a rather major change in objectives and attitudes on the part of the National Research Council, many felt that another body, possibly an Engineering Research Council, or an arm of the Department of Industry would be preferable. No one favoured the

Table 6

Analysis of Research Projects in University Departments of Chemical Engineering, 1966/67*

	Nature of Research	No. of Projects	%
1.	Basic Transport Phenomena in Physical or Chemical Systems (Fluid Mechanics, Heat and Mass Transfer, Reactor Design)	153	38.5
2.	Physical Chemistry (Chemical Kinetics, Thermodynamics, Catalysis, etc.)	131	32.9
3.	Simulation, Control, Optimization	49	12.3
4.	Pulp and Paper	20 (a)	5.0
5.	Plastics	20 (b)	5.0
6.	Nuclear and Radiochemistry	14 (c)	3.5
7.	Extractive Metallurgy	5	1.3
8.	Miscellaneous Process Studies	6	1.5
9.	Food and Drugs	0	0
		398	100

(a) Over one-half of these projects under one man.

(b) Mainly basic studies of polymerization kinetics.

(c) One group only.

*Source - Directory of Chem. Eng. Research, C.S.Ch.E., 6th Ed., 1966-67

possibility of each government research agency promoting mission oriented research in their own areas.

In summary, chemical engineers in universities recognize that much applied research needs to be done in areas of economic concern to Canada, and the great majority wish to participate to some degree in such research problems. No source of funds exists at present to support developmental work of an engineering nature. A positive national policy on the support of mission oriented research in universities or institutes would be welcomed. Large numbers of competent researchers and well equipped laboratories exist at present, and these researchers are spending a very small fraction of their research talent on problems likely to be of economic benefit to Canadian industry. As long as university engineering research tends to be divorced from economically significant problems, no real cooperation or collaboration between university and industry can be expected to result.

7. Government Laboratories

(i) Federal Research Establishments

It is difficult to get precise figures on the extent of chemical or process engineering R. and D. in government establishments. However, as shown in Table 7, an attempt has been made to estimate the extent of Federal support of this type of work.

First, althoughthe Federal government spends large sums on engineering R. and D., these figures do not represent a balanced effort. Some 35% of all Federal current R. and D. funds go to engineering, but of this sum about 75% is spent on Atomic Energy or National Defense, neither of whom engage to any significant degree in what we have defined as chemical, process or metallurgical R. and D. Of Federal R. and D. funds for engineering placed in industrial research organizations, about 83% goes to the aircraft or electronics industry. Finally, by considering reported Federal engineering R. and D. expenditures for fisheries, forest products and minerals and estimating the National Research Council share for chemical or metallurgical process studies, figures were estimated for the percentage of Federal expenditures going into these areas of engineering research (items 11 and 12 Table 7). Only about 3% of all Federal R. and D. expenditure appears to fall within the broad definitions used here. About 1.4% of the total Federal R. and D. expenditure goes for "in-house" research in this area of engineering R. and D. and this represents only about 6% of the Federal "in house" engineering research program. For chemical engineering alone (excluding metallurgy and specific process studies), the Federal government allots only 3.0% of its current "in-house" engineering R. and D. budget. By contrast, in 1965, industry spent in comparable categories (current intra-mural R. and D. for engineering) 12.9% of its budget on chemical engineering projects.

Table 7

Federal Current R. and D. Expenditures (Millions)

(D.B.S. 13-401, 1964-65, Table numbers shown in brackets)

Item	1964/65	1965/66
1. Total Federal (4)	240.7	294.0
2. Federal-Engineering (9A, 9B)	101.6	129.5
3. Federal-In House-Engineering (7A, 7B)	59.0	61.8
4. Federal-Engineering-Atomic Energy and Natl. Defense (9A, 9B)	62.4	80.8
5. Federal-In House-Engineering Atomic Energy and Natl. Defense (7A, 7B)	43.9	45.5
6. Total Federal to Industry (4)	45.0	69.7
7. Federal Engineering R. and D. to Industry, excluding Aircraft and Electronics	6.8	15.0
8. Federal-Engineering as % of Total Federal (Items 2,1)	42.2%	44.1%
9. Atomic Energy and Natl. Defense--In House-Engineering as % of Federal-In House-Engineering (Items 5, 3)	74.4%	73.5%
10. Atomic Energy and Natl. Defense -Engineering as % of Federal Engineering (Items 4, 2)	61.4%	62.4%
11. Estimated % of Total Federal R. and D. to Chemical, Process and Metallurgical Engineering R. and D. (Item 1, 9A, 9B)(See P. 18)	2.5%	3.3%
12. Estimated % of Total Federal R. and D. to In-House, Chemical, Process and Metallurgical Engineering R.and D. (Item 1, 7A, 7B)(See P. 18)	1.4%	1.3%
13. Chemical Engineering only In-House R. and D. as % of Federal-In-House-Engineering (11, Item 3)	3.1%	3.0%

Some comments would seem to be in order on the results of the C.I.C. survey of basic, applied and development work in government laboratories (see Table 11A). It would appear from the responses in various areas that many research personnel in government laboratories use definitions of "applied" and "development" work which seem to refer to the maturity of a project rather than its objectives. In the sense used by this committee, research and development is "applied" only if it has a definite economic objective clearly related to industrial problems, products or processes.

Using the C.I.C. government questionnaire results for 1966 shows that the total research operating expenditure for in-house research in the chemically oriented areas is \$24.3 million (about 10% of the Federal total expenditure for R. and D.). Of this total, by selecting sums given for applied and development work in areas which might conceivably involve some engineering research (e.g. excluding analytical chemistry, pharmaceuticals, biochemistry, agricultural chemistry, theoretical chemistry, etc.) one arrives at a figure of 7.1% of the total in-house chemical expenditure for applied research and 8.4% for development. Both estimates must include some very questionable definitions. About 13.0% of the professional manpower is estimated to be chemical engineers, or other engineers. These estimates therefore agree fairly well with those made from D.B.S. figures shown in Table 7.

Clearly, engineering research and development for the benefit of the chemical, extractive metallurgical, pulp and paper or other resource based industries (except atomic power) is only a very incidental and minor portion of Federal research expenditures. By contrast, in 1965 industry spent about 20% of all R. and D. funds in these areas of engineering (about 27% after allowing for Federal support of R. and D. in the aircraft and electronics industry), or in terms of actual expenditures, about 4.5 times as much as the Federal government although industrial R. and D. spending was only two-thirds of the Federal total. A substantial portion of

Federal R. and D. spending for chemical and metallurgical engineering arises from the university grants program, which,as shown in Table 6,mainly supports projects which are rather remote from potential industrial utilization.

Interviews by committee members with industrial research directors showed that this small and haphazard involvement of government research in areas of concern to them was common knowledge. A great deal of harsh criticism arose from this state of affairs, perhaps some of the most severe being reserved for government "in-house" research policies and activities. One need only read the replies to Item 10 of the C.I.C. companies questionnaire to gain an idea of current opinion among industrial researchers. Undoubtedly, many Federal agencies are doing much of their research in areas of little direct relevance to Canadian industry or to the problems of the Canadian economy.

The most common suggestion made was that much, much more applied research and development needed to be done, and much of the current Federal expenditure on R. and D. could be better used to this end. A majority of those interviewed did not feel that government agencies themselves could profitably engage in applied R. and D., at least, not with their present organization, personnel and attitudes. It was suggested that possibly with the assistance of industrial supervisory and advisory councils some improvement might be possible. A point made repeatedly was that only through industrial expertise could applied research be kept relevant to economic and market limitations. Therefore, an economically meaningful program of applied R. and D. must include some form of industrial participation. Many of those interviewed favoured much greater government expenditures for mission oriented contract research, which could be placed with industry, institutes, universities, wherever it might best be done. The decision as to those areas justifying research expenditure was felt to be a government responsibility, and it was assumed that the advice of the Science Council would be a major factor in such decisions. Not only should proposed work be supported by contracts if it was felt to be an economically sensitive area, but these areas should be identified and proposals for research sought by the government.

The subject of invention and innovation in Canada has come in for recent analysis (J.J.Brown, "Ideas in Exile", McClelland and Stewart, Toronto, (1967)) undoubtedly because one might assume that Federal expenditures on research (which have always exceeded industrial expenditures) should generate a good deal of patent activity on the part of Federal agencies or universities. As is well known, this is very far from being the case. Table 8 reproduces statistics with respect to patents, as reported by the Organization for Economic Co-operation and Development (The Research and Development Effort in Western Europe, North America and the Soviet Union, 1962).

This table shows clearly that very few patents issued in Canada originate in Canada. Canada issues only a fraction of the number of patents issued in the United States, and 94% of these are to foreign applicants. In this respect, no industrial nation in the world shows even closely comparable statistics. The conclusions are inescapable--either Canadian research spending does not result in useful end products, or useful results found in Canada tend to be developed to the patentable stage outside the country. The first reason would seem to be clearly applicable to government research, and the second to industrial research. Probably the industrial research situation with respect to development work leading to patents is complex. However, there seems to be no apparent reason why a conscious policy on the part of government to finance a far greater amount of economically useful research should not improve the rate of invention greatly.

(ii) Applied Research in Institutes

At present only three institutes exist for research and development in specific industrial areas, namely, the Pulp and Paper Research Institute, the Alberta Sulfur Research Institute and the Petroleum Recovery Research Institute. All obtain support from both industry and government; the contribution of the former amounting to about 0.05% or less of industry sales in each case. The latter two are recent creations, and have had little time to realize their potential. The total funds expended in these industry-oriented research institutes is of the order of 1% of the Federal total research spending.

One impression received during interviews by this Committee was that many Canadian industrial managements have not yet really considered the possibilities of cooperative research institutes or the potential benefits of cooperative research. Certainly, not all spheres of industry have the proper set of circumstances to warrant such cooperative institutes, but probably more could usefully exist than do at present.

All institute personnel commented on the fact that when an institute project approaches a development stage, further work is difficult. The higher cost of development apparently deters companies from assuming the risk of introducing major new technology into Canadian operations.

In summary, many researchers in government, industry and universities feel that more scope exists for industry-oriented institute research, particularly for applied and developmental work. A majority believe that the leadership for creating such institutes must come from government, apparently because of the question as to whether or not Canadian managements, particularly in the small resource industries, are able to provide at the present time the required degree of research leadership necessary for the establishment of effective cooperative institutes.

Recently, the Department of Industry has financed the establishment for a three year period of a number of Industrial Research Institutes in Universities across Canada. These Institutes are intended to render technical or research services to industries in their geographic areas, and are not oriented to any particular kind of research or development work. Obviously, their success will depend on their acceptance by industry as agencies capable of rendering research or development assistance with industrial problems. At present, none of these institutes has existed for a long enough period to allow any conclusions to be drawn from their experiences.

Table 8

Patent Statistics

	Total Number of Patents Taken Out		Percentage Taken Out by Foreign Applicants		Percentage Taken Out by USA Applicants		Percentage of Total Taken Out in USA	
	1952-56	1957-61	1952-56	1957-61	1952-56	1957-61	1952-56	1957-61
Belgium	45,406	57,904	81.2	85.1	15.0	17.2	0.2	0.2[1]
France	142,300	157,700	48.3	59.4	11.0	17.1	1.4	1.7
Germany	126,342	103,076	22.4	32.4	5.8	11.5	2.0	4.2
Netherlands	14,620	16,352	68.9	74.5	16.4	17.7	0.8	0.8
United Kingdom[2]	184,095	218,995	41.7	47.0	16.5	18.4	3.7	3.6
Total "Western Europe"	513,363	554,027	43.0	52.6	12.2	16.7	8.1	10.5
Canada	56,969	100,133	94.2	94.7	65.6	69.4	1.1	1.2
Austria	20,183	29,680	60.5	75.9	5.6	6.8	0.1	0.2
Denmark	9,090	9,735	72.0	79.3	10.6	12.3	0.1	0.1
Ireland	2,130[3]	4,361	81.0[3]	87.5	13.4[3]	16.0	(x)	(x)
Italy	85,400	77,698	55.0	62.7[4]	11.4	17.0[4]	0.3	0.5
Norway	8,985	10,676	71.3	80.0[5]	12.4	14.0[5]	0.1	0.1
Sweden	22,978	20,344	64.2	68.8[6]	17.3	16.6[6]	0.8	0.8
Switzerland	38,285	41,050	56.8	64.8	8.7	11.9	1.1	1.2

1. 1958-61 only.
2. Applications only.
3. 1954-56 only.
4. 1957-60 only.
5. 1957, 1958, 1959 and 1961 only.
6. 1957 and 1958 only.

Source: Journal of the Patent Office Society, February 1964, Washington.

(iii) Provincial Research Centers

A number of provincial research councils exist, of widely different sizes and ranges of activity. In general, however, they all exist to serve provincially based industries by scientific and engineering assistance, and to a more widely varying degree, to carry out applied research of direct relevance to the provincial economy. Total R. and D. expenditures are of the order of 3.0% of total Federal research expenditures (D.B.S.) with about two-thirds of this coming from provincial governments. Of the total operating expenditures about 90% goes for applied research and development in the process or resource based industries.

The net result of these figures is that with less than 3% of the Federal research budget, provincial councils spend a nearly equal sum of money on applied research directly relevant to resource development (see Table 7, line 11). In the course of interviews, this conclusion was reinforced by observing the nature of research in the provincial councils. This committee concludes that insofar as the Canadian process and resource industries are concerned as much benefit is derived from the very modest total sums spent by provincial research councils as they do from the more than thirty-fold greater total expenditure for all purposes in Federal laboratories.

Research workers in provincial research councils are very conscious of a need to engage in R. and D. of value to the provincial and Canadian economy. Without exception, all maintain close liaison with industry. Without exception, all feel that not nearly enough effort in applied research is being made, and that the Federal government and provincial governments both could demonstrate more leadership in this area. Views were expressed that some research must be done in the same geographic areas as those in which resource based industries are found, otherwise no competent professional team will exist which can bring secondary industries into being when these are justified, or who can develop the technology for secondary processing operations.

At present, except in a few designated areas (e.g. weather research) there is limited cooperation between federal and provincial research laboratories.

Some federal facilities that apparently might be useful to provincial councils, e.g. Canadian Patents and Development Corp., are not considered to be adequate by the provincial agencies, who in at least one case assign all patent development to an American corporation. The only meaningful cooperation between federal and provincial bodies appears to be in the area of scientific information dissemination.

Several of the provincial research councils appeared to the committee to be performing a much needed task in the area of applied research and development, for all the process and resource industries, but especially for the newer or smaller manufacturing firms. Some noteworthy technological advances have resulted from their efforts in the last ten years. The work of these councils shows clearly that technology pertinent to Canadian problems and resources can be developed by government research groups cognizant of the economic problems, and having as their objective this kind of oriented research carried out in close cooperation with industry. The present system of provincial research councils appears to be a very good one, and much greater expenditures by these councils for applied research in their respective economic sectors would be desirable, because they would be likely to yield higher dividends than might be expected from the present programs of any other presently existing government organization.

8. The Role of Government Support of Applied Research and Development

We have enquired specifically into the opinions of industrial, government and university personnel concerning the role of the various governments in support of applied research and development. Obviously, the federal government, because of its taxing authority and much greater financial resources, was most frequently discussed. Making the most of manufacturing operations in Canada was recognized as a problem of the national economy, and therefore a primary responsibility of the federal government.

First, we would like to re-emphasize the overwhelming majority opinion among those interviewed that not enough applied research and development work relevant to Canadian problems of the chemical and process industries was being carried out in any sphere of activity. Secondly, we also emphasize the belief of this majority that such work can only be successful if carried out either by, or in close liaison with industry, or by those with industrial experience, or under some form of supervision or advisement from industry. Finally, we point out that the opinion is held by many in research that, in some sectors of the Canadian process industry, the expertise at senior management level to actually fulfill this industrial function does not exist to the same degree as does competence in research, with the result that industrial participation, particularly in development work, is left to others, or is not pursued diligently.

Generally speaking there are four ways in which a federal government may encourage, support, or subsidize applied research and development, that is, by taxation, by contracts, by subsidies and grants, and by direct services. Taxes most frequently discussed fall into two categories, those related to income and those related to tariffs. With respect to the latter, the chemical industry generally fears that the latest "Kennedy round" of tariff reductions will greatly discourage the development and manufacture of new products in Canada, particularly in the synthetic field, as distinct from products based on natural resources. Much has been written on this complex subject, and we can only draw attention to this as a very major factor which will determine for some chemical industries both the amount and nature of their R. and D. work.*

Beginning in 1962, the federal government made extraordinary allowances for industrial research costs, and revised this plan in 1966. Current tax incentives (IRDIA) apply now only to the increases in research costs incurred over a base of the

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*See "Chemistry in Canada" July, 1967, p. 57
Also "Brief to Standing Committee of the House of Commons on Finance, Trade and Economic Affairs" by Canadian Chemical Producers Association Commerce House, Montreal, January, 1968

previous five years, apparently in an attempt to encourage new research enterprises. However, an established research program, whose growth rate might normally be only 10%-15% per year, gains very little from the present regulations. While there is general agreement that new research enterprises are needed, these incentives should be extended to all research. It is argued that many of the existing research groups are doing the most productive work, and if this is the kind of activity required in the national interest, then these groups must share in the tax incentive program. In some industries, because of the lack of top management experience with research or a lack of complete autonomy in making management decisions about research, some industrial research enterprises tend to need all the arguments they can find if they are to sell research projects they believe to be meritorious to management. Comments have also been made with respect to tax incentives for the introduction into production of new technology. If industry were allowed to carry research incentives to the level of introduction of new technology into production (assuming this technology is original and has been developed in Canada) it might do much to encourage management to accept the higher risk inherent in the first commercial application of new technology.

With respect to contracts for government-specified mission oriented research, those in industrial, university, provincial or institute research groups would welcome such a mechanism. While such federal contracts have been commonplace for some time in defense areas, or atomic energy research, they are almost unknown in the chemical or resource based industries. This fact is also evident from the figures on federal spending in industry given in Table 7. Apparently, the federal government has not been prepared to allow federal agencies (other than for national defense or atomic energy) to make policy decisions regarding areas of industrial research which should be strengthened. Possibly, the federal agencies have not always considered this to be one of their responsibilities, and little activity has resulted in this sphere from lack of leadership.

The subsidized development programs, such as PAIT, in which the initiative comes from industry, received rather mixed praise. In general, the equally-shared cost aspect of such schemes was felt to be desirable, so that proposals for development would be responsible ones. At present, the PAIT scheme requires manufacture arising from the development to be conducted in Canada. Many in the process industries felt that the program would be improved if this requirement were dropped and the export of technology allowed, providing that it was paid for at an adequate return. In the chemical industries, very few companies controlled outside of Canada have participated in PAIT. In the resource industries, where the choices of processing alternatives are more limited, ownership has less influence on company participation in government programs. In summary, government subsidized or supported development programs, are welcomed and praised by those companies not subjected to external constraints. One interesting feature we found was that research directors in companies which did not participate in PAIT were largely ignorant of the details of the program. One shortcoming of the PAIT program also pointed out is that it requires a present manufacturing capability, and thus eliminates support for new enterprises regardless of their technical merit or economic promise.

Grants are presently made by the National Research Council to industry in support of personnel for basic oriented research studies, as well as the university research grant program. The latter represents over 90% of all external research funds available to universities. In an industrial atmosphere, basic research is not regarded with the same priority as applied work, and this was reflected in the attitude of industrial researchers to the NRC grant program. The program was welcomed, and many companies took advantage of it to support two or three professionals (a surprising number of such NRC supported positions were vacant), but it was a common opinion that much more urgently required support programs were needed in applied research and development.

The grants-in-aid program to the universities by the federal government through the National Research Council is the major reason for the high level of both quality and activity in scientific research in many of these institutions. In the past, as discussed in an earlier part of this report, the nature of these funds tended to promote the more academic and theoretical research over the shorter-range applied problem, particularly in engineering departments. Federal support in universities of both basic and industrially oriented applied research was felt (nearly unanimously) to be appropriate. Direct government contracts for mission oriented work were not felt to be out of place in engineering departments, and such contracts already exist with crown companies such as Atomic Energy of Canada and the Defense Research Board. Mission oriented contracts imply evaluation of research progress by the sponsor. University engineering staff recognize and agree fully with this principle. However, no government department or agency has yet attempted on a planned basis critical evaluation of research programs in universities.

In the area of services to industry, such as making available scientific information, the federal government has and is rendering a necessary service, which is recognized and used widely. Some comments indicated that additional services in economic or market statistics would be useful.

9. Recommendations

We have attempted to summarize in the foregoing sections the information and opinions gained through interviews with others, and through our own studies. On the basis of this body of information, we feel that certain recommendations should be made.

1. The federal government must increase greatly its support of applied research and development in areas of national economic significance through tax incentives, research contracts and research grants. However, this increase should not occur in federal government laboratories but primarily in industrial research

centers, or in provincial research councils, institutes and university departments in association with industry. This increased support is long overdue, and to an important degree the future strength of the national economy may rest on the success of such a program. Immediate decisions are needed as to objectives of such a policy, and quick effective action to implement these policies fully.

2. The present research tax incentive program (IRDIA) should be altered, or a supplementary new program implemented, which subsidizes functioning industrial research laboratories at their present level, that is, does not support only incremental research expenditures. This subsidy should not support the entire cost of industrial research, but should be only partial support, preferably for specified activities. For example, a subsidy of a certain amount per research worker, but not sufficient to pay the entire cost of a worker, would guarantee company responsibility, while at the same time giving the research director external funds, and therefore some independence and freedom of action from a management which may frequently not be fully conversant with research priorities.

3. Development subsidization programs should be altered to permit support of developments leading to new processing industries, or to processing in areas new to a company, whether a manufacturing capability presently exists or not. Similarly, export of technology developed within a government subsidized program should be permitted without penalty, providing a fair return on development cost can be demonstrated.

4. Development subsidization programs should be extended so that the government shares with industry the increased risk associated with the first commercial application of new technology, developed in Canada, to a Canadian manufacturing process or product. This objective could be attained equally well through a tax incentive program, in the form of inflated or accelerated depreciation rates, or some similar device, for plant representing original technology.

5. The federal government should develop objectives and policies which will allow it to undertake fully-funded mission-oriented contract work in those areas which are of greatest economic importance and urgency to the national welfare. These contracts should be placed with industry or with institutes, universities or provincial research councils which maintain close collaboration with industry, or have a development capability in their own organization. The government should have advisory committees with a strong industrial representation to aid in determining the areas of economic significance.

6. Any federal government program for the purpose of increasing applied research and development in areas of national concern should not be implemented through the National Research Council or any other existing federal research agency having their own laboratories and research staff. A separate body for this purpose should be constituted, and it should be allowed to operate with a minimum of political control. One suggestion which appears practicable is to constitute such a body as a crown company, possibly answerable to the Minister of Industry.

7. The present National Research Council support of basic research in industry and in the universities should be continued, although no requirement for an increased scale of operations beyond normal growth rates seems to be justified at present.

8. The balance between basic, applied research and development work carried out in federal laboratories should be re-examined in the light of the total government research support program. In particular, the needs of the process industries based on natural resources should be considered, and their advice should be sought.

9. Tariff structure should bear some relationship to the economic factors such as markets, transportation, raw materials, etc. under which the chemical and process industries must operate in Canada. These factors favour expansion of certain

industries, and tariff regulations should act to promote the growth of those industries with the greatest economic potential.

10. Patent services and patent regulations should be improved. The reasons for the very low rate of invention and innovation in Canada bear serious investigation, and could well be the subject of a special enquiry by the Science Council of Canada.

D. S. Scott/js
March 4, 1968

Appendix I

Companies and Institutions Interviewed Personally by Committee 18

Companies

Abitibi Pulp and Paper
Dunlop Rubber Co.
International Nickel Co. Ltd.
Sherritt-Gordon Ltd.
Canadian Industries Limited
Noranda Ltd.
Dupont of Canada Ltd.
Procter and Gamble Ltd.
General Foods Ltd.
Lever Bros. of Canada Ltd.
Chemcell Ltd.
Polymer Corp.
Imperial Oil Ltd.
Dow Chemical (Canada) Ltd.
British American Oil Co. Ltd.
Union Carbide of Canada Ltd.
Ayerst Laboratories Ltd.
Peace River Mining and Smelting Ltd.
Cyanamid of Canada Ltd.

Institutes, Research Councils

Pulp and Paper Research Institute of Canada
Research Council of Alberta
Ontario Research Foundation
New Brunswick Research and Productivity Council
Alberta Sulfur Research Institute
Petroleum Recovery Research Institute
Mines Branch, Dept. of Energy, Mines and Resources
Dept. of Industry

Universities

University of Alberta
University of Calgary
Ecole Polytechnique
Université Laval
McGill University
McMaster University
University of New Brunswick
Nova Scotia Technical College
Queen's University
University of Ottawa
University of Toronto
University of Waterloo
University of Windsor

ADDENDUM

One of Committee 18, (J.M.H.) wished to emphasize or qualify certain conclusions in their report as follows:

This is not a minority report in the usual sense because we do need in Canada - (1) more research and development (2) more industrially oriented research at universities (3) more industrial direction in federal government research spending in the chemical process industries.

May I outline my reasoning on the basis of the following points.

1. The most obvious piece of data on research in Canada is the rapid growth in research in industry since 1962. This came about because government provided a business oriented reward system (however imperfect) for good research. Within this environment, business was able to identify those research areas that would best yield to research effort. My conclusion is that business (industry) will respond to economic incentives to do research. Without special consideration by the government of the status of research expenditures, there is little economic incentive for most industries in the Canadian business climate to engage in large amounts of research with the accompanying risk.

2. Establishing such a climate for research by industry does not mean that national objectives cannot be established for research priorities. Thus we can control research objectives by the tax or other economic incentives used and by the controls on the total business climate of each particular industry (tariffs, depletion allowance, etc.)

3. The best way to involve research and industry for the benefit of Canada is for the industry to have a potential profit commensurate with the cost and risk. It is already clear that we have, or will have, manpower certainly adequate to handle a large increase in Canadian research activities. To utilize this manpower profitably, industry must be able to see a potential for investment of money and effort in research.

4. Research directed towards real economic goals must continually be under business review to establish priorities in research effort and to move the project along as required by the changing business circumstance. This detailed evaluation and study of research objectives is really only possible within specific corporate business situations where actual knowledge of changing market volumes, pricing and changing business conditions, other than the technology, that may affect the worth of this research are continually available. One of the basic factors in commercializing such research is that the total corporation must become committed to developing a commercial utilization. To do this, it is a requirement that knowledgeable research people inside the corporation be available to promote this change.

5. It is my belief that it is on a large base of industrial research carried out with specific corporate economic objectives, that one builds a system of grants for universities and government laboratories. These grants form a part of the fabric of a good industrial research society. We need to utilize the talents available in our universities and we need to train the required people in actual commercial type research. Furthermore, the grant system provides an important function to assist small businesses to move in a research area. But I emphasize that all of this will be unrewarding unless we effectively get research and development into industry and under commercial surveillance.

There is one other area in which I believe we do not agree. This is subsiduaries and their effect on Canadian research. It seems to me that none of the data we have presented here shows that the subsidiaries status of a number of Canadian corporations in any way has inhibited research in Canada. Indeed I believe that research would be at a much lower level were it not for the subsidiary being in a position to support a portion of research in Canada even though the economic climate to date has not encouraged technological development within the Canadian business. There may be other political and social arguments on the effect of subsidiaries but there has as yet been no definitive study on their effect on research and development. Certainly there is nothing that says the "average" subsidiary is any different from the Canadian corporation in research and development.