COMMITTEE 5 REPORT

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AREA 051 FUELS

Coal, Petroleum, Explosives, Petrochemicals and Lubricants

COAL

Coal research in Canada is extended over the whole field of contemporary coal science and technology. This width of coverage is essential to meet the immediate practical needs of the industry, and to provide some hope for improvement. The chemical research and development work related to coal (with which this survey is concerned) is a much narrower subject and excludes research effort in the fields of exploration, geology, mining, economics, transportation, and to a large extent, beneficiation.

As coal is a bulk commodity in a highly competitive market, the funds that are generated within the coal mining industry for progress have to be entirely spent to improve the mining, transportation or the quality of the coal by the elimination of mineral matter and by screening to achieve the required

size distribution. For this reason, chemical research and development on coal is almost exclusively carried out by government agencies that are concerned with the development of the country's mineral resources. This state of affairs is not peculiar to Canada, but exists all over the world. It is unlikely that any great change in this set of circumstances will take place in the next five-year period in Canada, though the demand in North America for distillate fuels is increasing at such a rapid rate that the major oil companies have become much more interested in securing coal reserves as a potential source of synthetic liquid fuel. This may bring about some change in the traditional pattern of research on coal in the United States; however,in Canada within this period of time, it is not expected that Canadian oil companies will be interested in coal from this point of view--rather, coal lands will be purchased as potential sources of coking coal for the Japanese market.

In Canada, the government agencies concerned with chemical research and development work on coal, are: the Alberta Research Council in Edmonton, the Fuels Research Centre of the Mines Branch, Department of Energy, Mines and Resources in Ottawa and the Nova Scotia Research Foundation in Halifax. Each agency has retained full and exclusive control over its programming, and the development of problems selected by it for investigation.

There is, however, broad co-ordination and effective effort to minimize duplication, as well as to dovetail the programs to yield the greatest benefit through the Canadian Advisory Committee on Coal Research.

It is somewhat difficult to estimate exactly the amount of money spent per annum on chemical research and development on coal, as some of the facilities are shared with oil; however, it is less than $600,000 per year, or under one per cent of the dollar value of annual sales.

The distribution of personnel working on chemical research and development projects related to coal is shown in the following table.

	Alberta Research Council	Western Regional Lab, EMR	Fuels Research Centre, EMR	Nova Scotia Research Foundation
Professionals	8	1	11	1
Technicians	4	1	16	
Administrative Support	3		3	

Comparatively large groups of experts are required to undertake research and development on coal, because it is a very complex substance of variable composition. The equipment required by this variety of experts is expensive, so that this type of research can only be conducted in or near a major centre. It is the realization of this fact that has led the Canadian steel

companies and several coal companies, as well as, a tar processor, to combine to form the Canadian Carbonization Research Association. This organization undertakes research on coal as related to the metallurgical industry at the Fuels Research Centre in Ottawa. This type of collective action has been encouraged by the Mines Branch as a sound approach for a small country in areas where there is an acute shortage of skilled specialists.

In concluding these general remarks on coal research, it is important to emphasize that in spite of the activities of the Canadian Advisory Committee on Coal Research, the Canadian Carbonization Research Association, the Research Council of Alberta and the Fuels Research Centre, there is no room for complacency. Coal research in general and chemical research on coal, in particular, may well suffer a severe blow with the disappearance of the Dominion Coal Board. This organization gave financial support to universities and provincial agencies to pursue research designed to assist the coal industry.

The Coal Board also was empowered to conduct special studies and retain consultants to secure cost estimates of specific metallurgical operations that might benefit coal.

Unless some other agency can be found to carry out this portion of the activities of the Coal Board, the void thus created will have serious repercussions on coal research. Without modest sustained research funds, it would be impossible to

interest Canadian universities, and it will be increasingly difficult to staff the existing research organizations with Canadian personnel. It follows that the progress made, as indicated by the following review of current research and development work on coal, will fall into decline.

RECOMMENDATIONS

1. In the light of the proposed dissolution of the Dominion Coal Board, it is recommended that the Department of Energy, Mines and Resources assumes those responsibilities and powers essential to conduct the research and development functions formerly exercised by the Coal Board.

2. To maintain an acceptable level of coal expertise in Canada, related to coal processing for the metallurgical industry, it is recommended that an endowed chair at the University of Alberta be considered in the field of fuel technology. This would fall most logically into the chemical engineering department, and could be linked with the coal science undertaken at the Research Council of Alberta.

3. At the federal level, equipment and expert personnel must be maintained to insure that a satisfactory dialogue can be continued with the Japanese. This is essential if the present export market for coking coal to Japan is to be kept up and expanded.

4. As there is no training available in coal science in Canada, it is recommended that training positions be established for coal research at the Fuels Research Centre. For example, the establishment of the following suggested positions would give very material support to current research programs:

Two summer student positions at the university level.

Two positions that could be used with the sandwich courses presently established at Waterloo University.

Two positions for training students at the technical institute level.

One position that could be used for training the permanent staff at the Fuels Research Centre. This would permit a member of the staff to be sent to the International Flame Research Laboratory at Ijmuiden, Holland, as well as to the British Coal Utilization Research Association, the Coal Tar Research Association, and other institutes of international standing.

5. New and more flexible financial arrangements should be examined that would permit national laboratories, such as, the Fuels Research Centre, to give more effective training and technical aid to industry.

PETROLEUM, PETROCHEMICALS AND LUBRICANTS

The chemical research and development activities in the field of petroleum are very largely carried out in Canada by companies that are owned by international oil companies that have diversified interests and extensive research and development programs. The Canadian companies can draw, to a considerable extent, on the expertise of the parent organization to select processes and operations that will be profitable in the Canadian environment. Relatively minor amounts of research, in terms of financial expenditures, are conducted in the laboratories of government agencies and those of the universities. The types of research in industry, government and university differ, and this will be brought out when considering each area.

In Canada, during 1965, there were reported to be thirty companies conducting chemical research and development in this particular area to establish new processes or improve versions of established processes for the Canadian market. (1)

The main concern of the petroleum industry is to establish and maintain profitable operations. It is quite understandable that Canadian petroleum companies associated with international companies would attempt to apply and adapt the technology already developed by the parent company to Canadian

(1) DBS Industrial R & D Expenditures in Canada 1965, Cat. #13-527

conditions. In this particular industry, this has been done in the past, and is being done at present to Canada's advantage. This is brought out by the statistical data of the Dominion Bureau of Statistics. What is not brought out by this information is that the oil companies in Canada are diversifying their interest into petrochemicals and metallurgy in a manner that shows considerable imagination. It is to be hoped that the economic climate will encourage this healthy trend.

STATISTICAL INFORMATION

As the petroleum industry is composed of competing private companies whose relative competitive position is dependent upon their research activities, it is quite evident that the nature of the research effort cannot be discussed in more detail than is available in tables supplied by the Dominion Bureau of Statistics. This data is composed of information supplied by thirty companies in the petroleum or petrochemical business. The latest year for which the tabular data is complete is 1965; consequently, this is the year to which the following remarks apply.

The total* expenditures for intra-mural research were $22,726,000. These were met from ~~$17,767,000~~ $17,919,000 derived from Canadian sources and $4,807,000 from foreign. This intra-mural research effort was augmented by $3,133,000 of extra-mural research. This additional research was largely conducted by

* Current + Capital

Canadian subsidiary companies 66.3%, Canadian consultants 16.4%, provincial research councils 9.3%, universities 6.85% and a small residue of other educational institutions and federal government laboratories.

During the year 1965, the payments of royalties on patents, licences, and technical know-how by the reporting companies was $2,581,000; whereas, there was no revenue derived by these companies from their own patents, licences, and technical know-how.

The distribution of current funds spent on intra-mural research and development shows that out of a total of $11,715,000, $2,374,000 were spent on research related to refining processes; $85,000 were spent on instrument development; $1,579,000 on petrochemical products, and $7,626,000 on the improvement of fuels, lubricants, asphalts, and other products.

To physically carry out these programs, a total technical labour force of 273 engineers and scientists was employed--of this, the largest single group was composed of 165 chemical engineers and chemists.

As mentioned earlier, the dominant emphasis is upon application and development. This is brought out in the statistical information on the current intra-mural research and development expenditures by type of activity, which shows that

$335,000 were spent on basic research, $8,625,000 on applied research, and $2,755,000 on development work. The number of scientists and engineers engaged in each of these activities is also shown, so that it is possible to calculate the amount of the expenditure in each area per professional scientist.

Type of Activity	Fundamental	Applied	Development
Current Intra-mural Expenditure Thousands of $	335	8,625	2,755
Number of Scientists	9	178	86
Expenditure per Scientist Thousands of $	37.2	48.5	32

(D.B.S. Industrial R & D Expenditures in Canada 1965, Cat. 13-527, Page 32, Table 14) Page 40, Table 28

A similar type of approach was used to relate the current expenditures for intra-mural research and development in a given field of science to the number of scientists in that field. That data yielded such wide fluctuations in the average current research and development expenditure per scientist in the various disciplines that it is clear that a much more detailed examination of the circumstances causing these fluctuations is required to extract any genuine meaning.

On the average, the current research and development expenditure per year per engineer was $32,800 and per scientist, it was found to be $50,000.

It may be worth noting here, for future reference, that forty scientists and engineers were reported, in 1965, as being employed in the area of petroleum and natural gas production. Of this number, ~~fourteen~~ eighteen were listed as being chemists and chemical engineers. This technical group will almost certainly have grown substantially in the last three years, and in view of the Middle East situation, the growth may be expected to accelerate.

RESEARCH ON PETROLEUM AND RELATED TOPICS IN THE UNIVERSITIES

It may appear somewhat odd that petroleum, which gives rise to so much chemistry in its refining and utilization, is not itself studied in Canadian universities. This is because it is a natural degradation product containing countless compounds. The study of its composition involves formidable separation problems that are not considered to be of much educational value, and require complex analytical facilities to make any appreciable progress.

It is noteworthy that at this stage in the development of the oil industry, there is no organo-geochemistry taught in any of the universities in Canada. A better understanding of the genesis of oil might well enable large areas of sedimentary

rocks to be ruled out as potential sources of oil, and thus avoid unnecessary drilling and exploration.

Canadian universities are the recipients of numerous grants from the Petroleum Research Fund of the American Petroleum Institute, administered by the American Chemical Society. (2) Out of a total of approximately six hundred such grants made to universities in the United States and throughout the Western world, Canadian universities received seventeen in 1966. This fund was established in October of 1944, and the amounts of money paid out annually as grants have increased from $164,367 to $3,014,697 in 1966. The type of work supported by these funds covers an extremely wide range of subjects from the constitution of asphalts to porphyrin chemistry. The research to qualify for a grant must be of a fundamental nature and must enhance the teaching and training of students. An estimate of the total annual value of these grants to Canadian universities would be of the order of $136,000.

One of the problems of securing a meaningful indication of the current research effort related to petroleum, is that it would rarely be listed under petroleum or fuel. Suffice it to say that comparatively little research activity related to petroleum is taking place in Canadian universities.

A somewhat different situation exists in the area of the production of petroleum. In the Fall of 1964, the Technical

(2) 11th Annual Report on Research, Under Sponsorship of The Petroleum Research Fund, Administered by The American Chemical Society, Period Ending August 31, 1966

Advisory Committee of the Research Council of Alberta recommended that the Province of Alberta should be making a substantially larger contribution in aid of fundamental research directed toward increasing the recovery from the ground of oil and natural gas. The Alberta government agreed to support the plan on a continuing basis at a level of about $100,000 per year, provided similar support was offered by industry. This support was granted, and the Petroleum Recovery Research Institute was formed and established in the Engineering Building of the University of Calgary. The operating and capital expenditures of this Institute were 20 and 90 thousand dollars respectively for 1966.

RESEARCH ON PETROLEUM AND RELATED TOPICS IN THE FEDERAL GOVERNMENT

A large proportion of the chemical research and development related to petroleum is performed in two federal government agencies: the Mines Branch of the Department of Energy, Mines and Resources, and the National Research Council.

The Mines Branch program is directed toward gaining a clearer understanding of the fundamental chemical structure of Canada's low-grade petroleum resources to provide a better basis for the development of improved processes for treating this class of crude oil.

Research on the physical and chemical structure of petroleum is conducted because of the fundamental importance of understanding the behaviour of the high-molecular weight fractions of petroleum in many applications.

A limited amount of organo-geochemical research is undertaken at the Mines Branch to assist the Geological Survey of Canada in the proper classification of naturally occurring hydrocarbons, as well as to give an indication of the extent of the metamorphic transformations that have taken place in these substances. This type of information is helpful in assessing the possibilities of finding petroleum in a given formation.

The applied research program is designed to find improved techniques of refining Canadian low-grade crude oils by hydrogenation. This involves the development of better catalysts and improved processes.

In the field of petroleum combustion, research and development work is conducted at the Mines Branch to develop suitable additives that will remove the sulphur trioxide produced when sulphur containing fuels are burnt. The removal of this constituent from stack gases greatly reduces the corrosion resulting from the formation of sulphuric acid in the cooler parts of boilers. The elimination of the sulphur trioxide also eliminates the acid-smut problem, which is troublesome from the point of view of atmospheric pollution.

The research program of the Fuels and Lubricants Laboratory of the National Research Council is directed toward gaining a clear insight into the performance of a wide range of fuels and lubricants. The performance characteristics may

be associated with new products designed for special service requirements, or the examination of products that are known to give rise to operating problems. Here the objective is to gain some fundamental chemical appreciation of the causes of these difficulties, and to develop new solutions to these problems. As a rule, the problems arising in fuels and lubricants are not independent of the mechanical system in which they are used, so that this environment must also be studied in considerable depth.

STATISTICAL INFORMATION

Of the total operating expenditures of $24,523,000 $23,881,000 for the federal government intra-mural research and development during 1966, the amount spent on petroleum-oriented research is estimated to be of the order of $400,000, or approximately 2% of the total. (3) The total scientific and technical labour force to carry out these programs is estimated at 41 man-years. The Mines Branch programs involve 22 man-years, and the balance is associated with the research and development programs of the National Research Council. The Mines Branch expenditures are composed of $11,000 spent on basic research, $61,900 on applied research and the balance of $180,900 was used to carry out development programs. The distribution of expenditures for the National Research Council is not available at this time; however, by far the greater proportion would fall into the applied research category.

(3) C.I.C. Survey Chemistry Research in Canada 1966, Table 6

SURVEY OF LUBRICATION RESEARCH IN CANADA

Although there is no CIC specialty classification number for lubricants, it seemed too important a topic, from the Canadian point of view, to pass over without comment, particularly, as few countries possess such wide extremes in climatic conditions as Canada.

In the field of lubrication, friction, and wear, there is at present a very limited activity in Canada in fundamental research. The only substantial programs under way are at the University of British Columbia (Professor C. Brockley) and at the Fuels and Lubricants Laboratory of the National Research Council.

The importance of fundamental research in this field is obvious, since the life of all well-designed machinery is limited by wear; and friction in most cases produces undesired heat, as well as representing a loss in power. Thus, any improvement in lubrication can show a very considerable saving to the whole economy besides allowing new attitudes to machinery design.

The development work necessary in the formulation and application of new types of lubricants and additives is difficult in Canada, since the markets for advanced products is much smaller than the United States. For example, aircraft engine synthetic lubricants have been successfully developed

both in Britain and the United States--stimulated by the fact that advanced engines requiring these lubricants are developed in these countries. Only now has it become economically feasible for one company in Canada to produce synthetic lubricants, and this production is based entirely on British and United States research and technology. Additives for petroleum oils are also almost entirely developed elsewhere, although some of them are now manufactured in Canada, and some of the applications are novel in Canada.

As in the case of the fundamental research, much of the development work in the lubrication field is closely tied to mechanical engineering design, particularly, now that engineers have at last been driven to the conclusion that lubrication is an important aspect of the finished machine, and must be considered as part of the original design.

There is, however, a considerable amount of work done by the petroleum industry (by Imperial Oil, British American and to a smaller extent by Shell Canada) in the application of lubricants to existing machinery. This is a particularly difficult problem in the case of outdoor equipment imported from countries with warmer climates. In general, these problems are tackled by the oil company research departments if sales are likely to be high enough to justify the expense involved; otherwise, the work must be done by some of the government laboratories if of sufficient national or defence interest.

Many of the products involved are used only in comparatively small quantities in Canada, and in these cases it is obviously uneconomic to manufacture in this country, and this generally means, too, that no active development work on these products is undertaken in Canada. This applies to both mineral oil and synthetic-based aircraft-hydraulic fluids, most of the aircraft greases and similar products. Activity here is limited to solving of field problems which arise.

RECOMMENDATIONS

In the private sector of the petroleum and petrochemical industry, the problem is largely one of stimulating more research and development. This may be achieved by creating a favourable economic climate that will encourage the industry to search for new products and processes.

In every development there occurs the difficult period of reducing the process to practice. Government assistance and special tax concessions are desirable to encourage venture capital, and to reduce the severity of financial loss in the event of failure. It is not generally understood that the bench-scale research is one of the cheapest links in the innovation chain, amounting to possibly one-tenth of the whole cost of a successful innovation. It, therefore, is not wise to become involved in bench-scale investigations that will cost a hundred thousand dollars, unless there is a million dollars

available to undertake the prototype construction, production, market development, and sales. The risk of miscalculation and poor timing is considerable. Schemes of taxation, which allow rapid write-off of losses, are possibly the most equitable method of assisting industry whether large or small.

The present incentive schemes provided by the federal government, such as, IRDIA, PAIT, NRC and DRB industrial research grants are appreciated by industry. These incentive schemes which encourage the initiation of research are desirable to maintain Canada's competitive position; consequently, it is recommended that they be continued.

It is recommended that some collective attempt be made by the Canadian petroleum industry to extend the grants to Canadian universities made by the Petroleum Research Fund of the American Petroleum Institute, particularly, in the field of secondary recovery, chemical engineering and organo-geochemistry.

In the federal government laboratories, the research on petroleum and related topics has been held at a modest level for many years, and in certain areas there have been reductions in the professional staff. The traditional role of the Mines Branch has been to assist the mineral industry by evaluating the resources and conducting pilot-plant investigations to give some sense of the economic merit of innovations. Certain aspects of petroleum research might be facilitated through closer association with the industry. It is recommended that the various means of doing this be explored.

It is specifically recommended that the facilities available in the federal government laboratories dealing with petroleum and fuel technology be used more effectively in the matter of training students of both the technical institutes and universities during the summer months. It is also important that provision be made for more liberal funds for this purpose. The present practice of grouping the funds available for summer student training with those for permanent employees will tend to eliminate the training of summer students completely. The professional staff who are interested in advancing their research projects as quickly as possible, will always choose a trained technician to work all year round, rather than a summer student who must first receive training and then has only a short time to advance the research before he returns to university.

In view of the urgency of training personnel in the field of combustion science, as it applies to air pollution, it is recommended that funds be set aside for post-graduate training at the Fuels Research Centre.

Lubrication is rather a neglected field for research activity in Canada for a variety of reasons, most of which are entirely outside the control of the petroleum industry. As our engineering industry expands on its own, rather than as a manufacturing adjunct to foreign parent companies, there will be a real necessity for advances in lubrication technology, and it

would be desirable that the research in both fields proceed together. The necessity for this is already becoming apparent in some instances. An excellent example being in the power saw and small two-stroke engine manufacture where the Fuels and Lubricants Laboratory were recently consulted.

One of the main handicaps to expansion of research work in the lubrication field is that it requires personnel with a knowledge covering many of the conventional branches of science, namely, engineering design, organic chemistry, physical chemistry, physics, rheology and metallurgy. It is extremely difficult for a person in Canada and elsewhere to obtain an education covering the relevant aspects of these subjects and the biggest advance which could be made is to increase output of the necessary personnel by encouraging one of the Canadian universities perhaps not to contemplate a complete degree course in lubrication enginering, but, at least, to try to make available some of the other subjects oriented towards lubrication, which would be useful to a student interested in this type of work. The University of British Columbia would be the logical choice for such a course, and projecting the needs of government and industrial research into the future, it certainly should present no difficulty to place about ten to twelve graduates per year in extremely useful employment.

RESEARCH ON EXPLOSIVE SUBSTANCES

This brief summary confines itself to the research and development associated with the production of explosive substances. The research on the various aspects of combustion and detonation of explosives falls in another area of this survey.

The companies engaged in the manufacture of explosives in Canada are, for the most part, subsidiaries of international companies who are in a position to draw on the technical experience of the parent firms. The research and development is, therefore, essentially directed to apply and extend this knowledge to meet Canadian conditions.

In 1966, Canada manufactured 300 million pounds of commercial explosives, excluding ammunition and other specialty items. This production had an estimated retail value of forty million dollars.

Quantitative information relating to Canadian explosives research operations are difficult to obtain, since the number of commercial companies participating in research on explosives is small, so statistics tend to disclose industrial confidences. Also, as in other countries, the amount of research on explosives carried out on behalf of the Department of National Defence is not completely available. A very rough estimate of the total Canadian scientific manpower engaged in this type of work is 75 Bachelors of Science and perhaps 40 scientists with higher degrees.

Most of the Bachelors of Science engaged in research and development on explosives have received their training in explosives technology within their company or institution. It is not possible for a person in Canada to obtain formal training at a university in this particular area of specialization. In general, companies build up teams of experts to cope with the diverse problems associated with explosives technology. The organic chemists look after the synthetic problems; the physical chemists deal with the problems of stability, the kinetics of the initiation and propagation reactions. Inorganic chemists are usually assigned the problems of making the oxidizing agents, and the thermodynamicists are concerned with the questions of performance.

RECOMMENDATIONS

The problems which occur in this particular area of specialization are typical of the difficulties encountered by scientists in small specialized areas in Canada. The problems of communication are probably best solved through the Chemical Institute of Canada or through attendance of meetings of the Combustion Institute.

It must also be pointed out that there exists a great lack of facilities for studying explosive phenomena. For many years the Canadian Explosives Research Laboratory has attempted to acquire a high speed framing camera to clarify many of the

obscure problems associated with the propagation of combustion and detonation in explosives, as well as, dangerous goods. To date, it has not been possible to obtain the necessary funds to purchase such a camera or to obtain the qualified personnel to operate it. At this stage in Canada's development, it would appear that a pooling of resources is required by interested parties.