Report of Committee 14

High Pressure and High Temperature Chemistry, etc.

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SUMMARY REPORT

Committee No. 14

High Pressure and High Temperature Chemistry, etc.

The work of this committee has covered the following fields:

2700	Flames and Explosives	(I.R. Cameron)
2701	Fused Salts	(J.A. Plambeck)
2703	High Pressure Chemistry	(R.A. Stager)
2704	High Temperature Chemistry	(R.R. Finlay)
2707	Low Temperature Studies	(B.E. Conway and G.R. Finlay)

Definition of Fields of Survey

2700 Flames and Explosives

In Canada the study of the field of flames and explosives has been nearly totally contained in university and government laboratories; there is practically no industrial component. Included in the survey have been the following:

the chemistry of low and high pressure flames

the chemistry of explosives detonation

reactions in shock tubes

The chemistry of the formation of explosives and purely physical studies in shock tubes belong in the purview of other committees. No work is now being done in the area of explosive reactions which may occur between molten metals and water, though this is a hazard involved in current metallurgical operations.

2702 Fused Salts

Fused salt chemistry is a study of the chemical reactions involving, or taking place in the liquid state of materials which (a) have a significant degree of ionic character and (b) are solid at room temperature. The temperature range of this field is defined by the melting point of the fused salt used; the common range is from 150° to 1500°C. Virtually every type of measurement made in aqueous solution may also be carried out in fused salt media but the most common techniques are electrochemical or spectrophotometric.

2703 High Pressure Chemistry

High pressure chemistry is here defined as chemistry studied under pressures great enough to cause significant changes in materials and processes.

The gas phase only requires pressures slightly above atmospheric, the liquid phase greater than 30 atmospheres, and solids 1000 atmospheres or more.

Several of those interviewed complained that "high pressure" was not a "field" but a "technique".

2704 High Temperature Chemistry

High temperature chemistry is defined quite arbitrarily as chemistry at or above "red-heat" which amounts to above 1000°K. Included are most metallurgical operations as well as the chemistries involved with glass, ceramics, cement, calcined lime and magnesite, kilns, heat treatments, most combustions and the whole field of electrothermics. In this field there is inevitable overlap with other committees such as inorganic chemistry.

2707 Low Temperature Studies

Low temperature chemistry is here considered to be the chemistry of all reactions occuring below 0°C, which takes it outside of nearly all ordinary laboratory chemistry. Included are the whole field of cryogenics, the condensed phases of the noble gases, gas distillation and the chemistry associated with super-conductivity. This field considerably overlaps with Physics, and generally speaking, the physicists control and operate the equipment for producing very low temperatures.

Economic Importance of These Fields of Research

It is not readily possible to evaluate the productive potential of the fields covered by this survey.

The nearest relevant classification in the D.B.S. statistics refers to the manufacture of "non-metallic mineral products". This does not include all of the area considered but does include quite a few products not related to committee 14. For 1965 the non-metallic mineral classification production was valued at $1,038 million. Just over half of this amount represented value added. Annual growth in this field over the decade 1956-65 was 4.3%, just under the average. The sales of companies with R & D expenses in this field were $503 million for 1965.

The total value of clay products produced in 1965 is listed as $43.5 million. There are 71 brick and tile plants with a total annual capacity of 900 million brick.

Cement production in 1965 was valued at $144.6 million (8,400,000 T).

Electric steel in 1965 amounted to 11% of the total production, which was valued at $1,190 million. Assuming an average price per ton, this electrothermic production would be worth at least $131 million.

For the abrasive industry 1965 production was $59.15 million of which $36.1 million represented exports. Crude abrasives (which are an electrothermic product) were valued at $33.6 million.

Titania slag, again an electrothermic product, was valued at $22.4 million for 1965.

Lime production for 1965 was worth $18 million.

There are fifteen glass-melting plants now active in Canada and one glass fabricating plant, (Ford at Niagara Falls, Ontario). The estimated total capacity of these plants is 400,000 tons of glass per year. The 1964 consumption of silica sand for glass manufacture was 347,000 tons. Glass production in 1961 was valued at $113.3 million.

The size of the electrothermic industry in Ontario is best described in the Ontario Hydro's annual report of deliveries to direct customers. The 1965 data, which are the most recent available, show the following average monthly peak loads:

Steel and electrometallurgical customers	190 megawatt
Abrasives customers	90 "
Chemical, Electrochemical and Cyanamid	209 "

A fair estimate would be that 380 megawatts of this load is electrothermal and that at least a comparable quantity is consumed by the Quebec electrothermic industry.

History of These Fields in Canada and Current Status

Canadian investigators have taken an early lead in numerous developments in these fields but usually the follow-up and commercialization have occurred elsewhere. Many Canadian plants are branches depending on imported research and technology, either in whole or in part.

2700 (Flames and Explosives)

Combustion is a very old chemical process but understanding of it is coming very late. Improved high speed instrumentation, radiation theory and advances in our knowledge of atomic and molecular theory have enabled considerable advances.

During World War II, the National Research Council carried out extensive research on detonation phenomena and propellants particularly for cannon. Dr. G. Herzberg at University of Saskatchewan studied detonation by means of a high speed rotating mirror camera. Dr. C. Ouellet at Laval studied cool flames with a fast sampling mass spectrometer and Dr. K. Laidler at University of Ottawa contributed to the theoretical chemical kinetics of flames reactions. On the foundations laid by these workers some twenty years ago, numerous studies of flames, plasmas and shock waves are now in process. These have practical applications to forest fire control, aircraft, missiles, diesel and gasoline motors and shock tubes.

The current effort in this field is mainly in the Universities. At the present time, there are 27 professors, 27 masters students and 22 doctorate students working full or part time in the field of flames, explosives and plasmas. This is a large increase from 3 professors and 4 students in 1950.

There is also appreciable effort in this field in Government laboratories such as CARDE and National Research Council, but the current size and direction of this effort can't be clearly evaluated from the available information.

Queens University has an interest and projects in explosives as applied to mining but it was felt that this area was outside our frame of reference.

The Department of Chemical Engineering, University of Saskatchewan, has a continuing project on the use of cool flames in the partial oxidation of hydrocarbons as a means of commercial synthesis of oxygenated compounds.

There does not seem to be an industrial effort in this field in Canada.

2701 Fused Salts

The bulk of fused salt research in Canada is being carried on in academic institutions with no particular geographic concentration. The earliest group in the field was apparently at University of Manitoba under Prof.A.N. Campbell. Most of the groups are fairly recent, having originated in the past five years centering about a principal investigator who was trained in the U.K. or U.S. The research is being done mainly in departments of chemistry and metallurgy but there is also some in departments of geology and chemical engineering. One interesting project at the University of Toronto is concerned with molten salt solvents for cellulose.

There is a small but active group which studies fused fluorides and silicates at the Atlantic Regional Laboratory of N. R. C. in Halifax. Other Government laboratories involved in fused salts are the Mines Branch of the Department of Energy, Mines and Resources and the D.C. B.R.L. at Shirley Bay. The Mines Branch have been active in fused-salt research related to extractive metallurgy for more than ten years. The Shirley Bay group have been concerned with fused salts for fuel-cell applications. (This work will be reported by Committee 13.)

On the industrial side, Ferranti-Packard Electric Limited have been working on fused carbonate fuel cells.

Alcan naturally have an interest in, and an active group working on, fused salt electrolytic baths. (For both these industries see also committee 13.) Noranda Research Centre (Anion exchange in fused salts) and Stelco (steel-making slags) are both active in fused salt chemistry as applied to extractive metallurgy. Geo-Met. Reactors Limited of Ottawa in collaboration with Carleton University are working on the use of molten pyridinium chloride in the treatment of niobium ores such as pyrochlore.

<u>2703</u> High Pressure Chemistry.

The late E. H. Boomer did extensive work in Canada before 1939 on processes involved with natural gas and the coal and wood industries. By 1942 a Canadian laboratory was involved in directing the cooperative Bridgman project on diamond synthesis. (G. E. was later to carry this on and bring it to successful fruition, so that a synthetic diamond unit is now being set up in Canada with imported technology). Because of its interest in nuclear power, A.E.C.L. has been particularly active in the study of high pressure boiling of both natural and heavy water and has a large and active group working in this field. N.R.C. also has a large and well equipped high pressure laboratory and has done some outstanding work on ices.

High pressure technology (mainly imported) has become commonplace in the production of polyethylene (1500 atm) and ammonia (600 atm).

A Canadian development is the Sherritt Gordon pressure hydrometallurgy process for the recovery of nickel powder from ores. This employs pressures up to 250 psig and higher pressures have been proposed.

2704 High Temperature Chemistry

Canada got away to an early start in the high temperature industry. Glass was being made at St. Johns', P. Q. as early as 1845. One of the first successful safety glasses for windshields was developed in Canada, based on an acetal type insert from Shawinigan Chemicals.

Phosphorus was being produced in Buckingham, P. Q. from local apatite as early as 1896 and the electric furnaces there were subsequently applied to the manufacture of ferro-chrome (1898) and later to rock-wool, calcium phosphide, phosphorus sesqui-sulfide and ferro-phosphorus.

"Carbide" Willson after an initial success at Spray, N. C. returned to Canada to establish a calcium carbide plant in St. Catharines, Ontario (1896). Shawinigan started up carbide furnaces by 1904. By 1907 the Electrometallurgical Company was producing ferro-silicon alloys at Welland, Ontario. American Cyanamid came to Niagara Falls, Ontario for its initial plant in 1909 and numerous developments have followed this original fertilizer unit which made calcium cyanamide. Sodium cyanide was added as a product in 1916 and "water-glass" (sodium silicate) by 1933.

The Norton Company moved to Chippawa, Ontario in 1910 to commence production of silicon carbide and fused alumina in Canada and later broadened its line to include boron carbide and fused magnesia (ca. 1934).

About 1933, J. Powers came to Chippawa Laboratories of Norton Company as a new ceramic engineer graduate from Ohio State, bringing with him knowledge of powder metallurgy processes. This was promptly applied to the problem of fabricating boron carbide into sand-blast nozzles and other useful wear resistant articles and led to considerable advances in the art of hot pressing many refractory materials.

Whiteware manufacture in Canada began in Hamilton and by now there are more than two hundred ceramic plants scattered across Canada. Ceramic education also got away to a good start in Canada under W. G. Worcester at the University of Saskatchewan. Ceramic Engineering courses grew and flourished there and at Toronto and then died out due to a lack of students. There is now no undergraduate education in ceramic engineering except for a ceramic option at Toronto. McMaster University does provide an extension course leading to a certificate in ceramic technology.

Of 73 abstractors contributing to Ceramic Abstracts in 1967, there were nine Canadians (12% of total) which is an extraordinary showing for a country without a ceramic school.

Failures of concrete, due to particular Canadian conditions, impelled the Engineering Institute of Canada in 1920, to initiate studies under Dr. T. Thorvaldsen of University of Saskatchewan. These led to the development of "sulfate-resistant" cement and later "high early strength" cement as well as a thorough theoretical investigation which produced a number of classic papers.

Due originally to cheap hydro-electric power, the electrothermic industry has developed extensively in Canada. A list of Canadian firms making use of electric furnaces totals to fifty-two and some of these installations are very large, requiring as much as 50 megawatts for full capacity operation.

As a measure of Canada's world wide position in high temperature chemistry, the references cited in the I.U.P.A.C. Bibliography on the High Temperature Chemistry and Physics of Materials in the Condensed State were counted for the first three quarters of 1967. In these three-month periods, 1.8, 1.8 and 1.9% of the total papers were of Canadian origin. The similar compilation on the High Temperature Chemistry of Gases and Plasmas showed 2% Canadian content for the third quarter although the sample in this case was much smaller (4 out of 200). On a population basis, this is a very creditable showing. The field is very active in Russia and the U. S., stimulated by the extensive space research in both countries. Japan and the Netherlands are also active particularly in electronic areas of application.

Except for publications, the participation of Canadians in this field has not been great. Security and geography seem to be factors in the lack of Canadian participation in U.S. and world conferences on high temperature.

High temperature chemistry itself does not seem to be taught in any specific course, but is implicit in or ancillary to a wide variety of courses and disciplines. The Regina campus of the University of Saskatchewan is proposing a summer course in high temperature chemistry at the graduate level, which seems to be a forward step. Probably due to the lack of an undergraduate text dealing with the subject, there are amazing and amusing gaps in the information available. One of the U.S.

groups involved with an air heater for their wind tunnel recently complained that the refractories were absorbing oxygen from the air supply, since they found a loss of oxygen. Actually, the problem was due to the reaction of oxygen and nitrogen in the air heater and the equilibrium was quickly reversed as the air cooled. The simple explanation should have been part of any chemists or chemical engineers backgroundbut obviously isn't.

A comparatively recent development is the setting up of materials groups at Universities. Toronto, Waterloo and Western Ontario have all set up Departments of Materials Science, while McMaster has established a Materials Research Unit. Such departments will probably fill the needs formerly supplied by courses in ceramic engineering and electrochemical engineering.

2707 - Low Temperature Studies. -

Low temperature chemistry in Canada dates from the work of E. A. Lesueur at Sault Ste.Marie in 1900. His basic patents on oxygen liquefaction were useful in founding La Societe L'Air Liquide in Montreal in 1910. A Claude Nitrogen plant was built in 1914 to supply nitrogen for the production of cyanamid from calcium carbide at Niagara Falls, Ontario. For some time this was the world's largest installation. Due to World War I requirements, a helium separation plant was set up in Hamilton in 1917. The Liquid Carbonic Corporation began bottling carbon dioxide in 1930. The first pipe-line for oxygen was built at Dosco (Sydney, N.S.) in 1938.

At the present time, cryogenics is still the major industrial application of low temperature in Canada, largely for fractional distillation and purification of air and other gases.

In the range of the first 150°C below zero, there is considerable work at N.R. C. Several projects at the University of Ottawa also involve this range and there is work at D.C.B.R. L. on low temperature batteries suitable for arctic or space conditions. Outside the capital, there are isolated projects, such as the organic chemistry of frozen solutions at U.B.C., frost durability studies on concrete at Windsor and Queens, infra-red spectroscopy at University of Montreal and various hail studies.

In the range up to 50°K there is a lot of activity, mainly in physics departments or in association with them in the fields of super-conductivity, super-fluidity, magnetic cooling, and with the use of various low temperature lattices (frozen rare gases, zeolites, etc.) for ESR or EPR studies.

No work involving liquid ammonia or other low temperature non-aqueous solvents was found active in Canada, nor did there seem to be much activity in the range 50-125°K.

There is now a liquefied natural gas plant in operation at Richmond, B. C., and, of course, there are numerous installations involving liquid propane.

Although Canadians were involved early and of necessity in the problem of frozen foods, no great advances in this field seem to have been made in Canada. Freeze-drying and its applications to food, biologicals, and medicine seem to depend on imported technology, aside from a little work on food storage and spoilage. Refrigerators and freezers also seem to have depended on imported information and systems, including coolants, with the partial exception of some of the development work on the Frigistor, a thermo-electric cooling device which was not commercially viable.

N.R.C. has contributed to basic studies on ice, as noted previously in the high pressure section, but has also been involved with the very practical problems of de-icing for aircraft and for the windshields of both aircraft and automobiles.

Some of the hail research has been encouraging and control or prevention is not impossible according to more or less parallel Russian studies. Large economic benefits could result from preventing hail in some wheat-growing areas of western Canada.

Summary of Investigators
carrying out Research and Development in
areas covered by Committee 14

Area	Academic			Government & Inst.		Industrial	
	Prof. & P.D.F.	PhD Candidate	Masters Candidate	PhD	Aux.	PhD	Aux.
2700	27	22	27	Several	?	nil	nil
2701	15	5	11	12	?	10	?
2703	21	16	20	5 +	?	1	?
2704	33	24	28	34	14	19	27
2707	19	11	10	?	?	?	?
Total	115	78	96	51 +	14	30	27

Overall Totals Academic	289
Government & Institutes	65
Industrial	57
GRAND TOTAL	411

		Totals
2700	Flames and Explosives	76
2701	Fused Salts	53
2703	High Pressure Chemistry	63
2704	High Temperature Chemistry	179
2707	Low Temperature Studies	40
		411

Discussion of available statistics

The C.I.C. statistical survey shows a much smaller effort than we believe to be realistic, for the fields of Committee 14. This is true for all three sponsors of research, Government, industry and universities. The only explanation we can offer is that those answering questionnaires used much narrower definitions than did the committee. This would result in work being reported under physical or inorganic chemistry or being rejected to the fields of physics, metallurgy, ceramics, mechanical engineering, etc.

Committee 14, however, felt that it should examine any project having chemical or chemical engineering research content and found many such projects outside the nominal university or Government department which might be expected to be involved. In support of this position the committee has submitted a "head-count" list on Page 11, which is known to be incomplete, but does represent a lower limit of those known to be working in the assigned fields of this survey. We have also prepared a list of graduate students based on the annual NRC summary for 1967-68, selecting the students by thesis title as related to the fields of Committee 14 as defined in this report.(Students for whom no thesis title was listed were not counted, regardless of their professors field of interest). This type of survey gives even larger numbers of people involved in the field than any other measure. It must be admitted that it includes quite a bit of work going on in Departments of Metallurgy, or Mechanical Engineering. However, it is not possible to distinguish the thesis subjects from Chemistry or Chemical Engineering in these cases.

There does seem to be a special shortage of qualified graduate students in the areas of fused salts and of high pressure chemistry.

Universities Research

In the areas of Committee 14 the reported effort of the universities and institutes is listed as follows:

Basic	$ 74,600
Applied	20,800
Development	1,500
Total	$ 97,000

which represents 1% of the funds available for R & D in universities and institutes.

The following staff is listed:

Academic	-	12
Post Doctorate Fellows	-	3
Graduate Students	-	29
Technicians	-	9
Total	-	53

(References: CIC Section No. 18, Tables 38 & 39)

Government Research

In the C.I.C. statistical survey only one government Project fell within the purlieu of Committee No. 14. This was a federal government project in the field of high pressure. (Reference C.I.C. Section 18, Table No. 8, Item 2703). This is the sole government project listed out of a total of 577 (See Table 9)

This project is readily identifiable as NRC's high pressure group working with Dr. Whalley. It involves an average level of staffing of 6 PhD's and 4 technicians.(See Table 16)

The project involved $188,000 in operating funds and was judged to be arbitrarily distributed as 40% basic, 40% applied and 20% development. Evidently this is one of the larger Government projects of the 577 listed since it consumed 0.8% of the total funds available and employed 1.3% of the total PhDs and 0.5% of the technicia staff. (References Tables 11, 13 and 13a).

Three other government projects possibly relate to the field of Committee 14, although they were not so identified in the survey. These are listed under the industrial classifications. (References Tables 10 and 12)

Operating Expenses R & D

1784	Electronic Products	-	$ 18,000	
1788	Other Ceramic Products	-	164,000	
1780	Total Ceramics	-	182,000	Sub total
1790	Other non-metallic mineral products	-	372,000	
1700	Total non-metallic mineral products	-	554,000	Total

The electronic products project is surprisingly small. (We submit that it may be ineffectual unless extremely specific). The two larger projects have not been identified. The total of 3 projects is a small fraction (0.6%) of the 473 Government projects classified by indústry and is certainly not proportional to the importance of non-metallic mineral products in the Canadian economy.

Neglected areas in Government Research are listed in C.I.C. Section 18, Table No. 21. In 577 reports 216 neglected areas were noted. The area of Flames and Explosives (2700) was noted four times, while Fused Salts (2701) was mentioned once. Both of these were noted as lacks in the Federal government programs. With only 2% of the total neglected area we must assume that most respondents are satisfied with the status quo. The Committee respectfully submits that they may not know what they're missing!

Industrial Research

The C.I.C. survey reports the 1966 research operating expenditures of industry in the areas of Committee 14, as follows:

Basic	-	$ 22,000
Applied	-	156,100
Development	-	39,300
Total	-	$ 217,300

This represents 0.2% of the total Canadian effort in industrial chemical research - a rather small contribution.

The nearest general classificaion in D.B.S. reports (DBS - Industrial R & D in Canada (1965) (Cat No. 13 - 257) is that of "Non-metallic Mineral Products" In this area the statistics for 1965 show:

R. & D. Operating Expenses

Basic	-	$ 255,000
Applied	-	659,000
Development	-	870,000
Total	-	$ 1,784,000

(1966 - $ 2,100,000)

This is 0.8% of the total R & D expenses for all industry. Further, it is less than 0.2% of the annual sales of this segment of the economy.

(Note that the D.B.S. statistics are for one year earlier and cover a much broader field including stone, sulfur, and gypsum, which are not relevant to Committee 14)

The D.B.S. statistics for R & D for 1965 may be classified by activity as follows:

Chemical Engineering	-	$ 261,000
Chemistry	-	416,000
Sub-total	-	$ 677,000

This is about 38% of the total R & D activity on non-metallic mineral products.

The industrial R & D effort overall supported 166 employees, of which 57 were professionals, 73 technicians and 36 were classed as "other". The professional employees may be divided as follows:

			Degrees		
Chemists	-	15			
Chemical Engineers	-	14	Bachelors	-	46
Other	-	12	Masters	-	7
Physicists	-	10	PhDs	-	4
Earth Scientists	-	2			
Administrative	-	4			
Total	-	57			57

Chemists and Chemical Engineers supply approximately half the total professional effort. PhDs are notably scarce in this group. Salaries and expenses per employee are both below average in this field, as compared with all manufacturing industry in Canada.

Salary per employee	-	$ 6,700
Total expenses per employee	-	10,200
Cost per Prof. man	-	31,300*

* $36,700 for all Canadian manufacturing industry.

Deficiencies and Neglected Opportunities

The gap between University and Industry was deplored by numerous people surveyed some of whom phrased it as a gap between fundamental and applied research efforts.

It is believed by a number of correspondents that there are lacks in engineering and applied research and a failure to take a systems approach. Not much commercial equipment is being designed in Canada for these fields, but there was no clear explanation as to whether this was to be blamed on a lack of designers or of demand. Failure to apply results already obtained or available was also noted.

A general response was that more should be done toward developing the North, meeting special Canadian needs and developing resources presently untapped.

The Canadian patent system does not seem to favor development in Canada. Most inventors rush to secure a U.S. Patent and may acquire an equivalent Canadian patent, at their leisure. Further, Canadian laboratory workers are at a disadvantage in establishing "reduction to practice" in the U. S., which may be important in establishing priority. If a Canadian patent were enforceable in the U.S., as would seem reasonable, this anomalous situation should not arise.

Copyright laws are also unfavorable to Canadian writers and publishers, so that a provincially authorized text-book is almost the only profitable book in the scientific field published under Canadian copyright.

Certain specific deficiencies in the separate areas may be listed as follows:

2700 Flames and Explosives

More basic research is required in all the fields to support Canadian industry.

There does not seem to be any direct utilization in industry of students trained in the field of flames, plasmas or explosives.

2701 Fused Salts

One of the major problems in fused-salt chemistry is communication. Research is scattered all across the country in small groups without effective contact.

Financial support is needed in this area and should be broadly based. It is believed that the application of fused salts to extractive metallurgy would be rewarding and may indeed be essential to remain competitive. Lack of money was noted by both basic and applied departments of Universities and is also evident in industry, probably due to failure to appreciate the opportunities.

2703 *High Pressure Chemistry*

There is a lack of contact and cooperation as between those skilled in the techniques of high pressure and experts in other fields such as kinetics.

A general lack of contact among high pressure experts is observed, especially as between institution and industry. A large time gap between study and application is suspected.

2704 *High Temperature Chemistry*

There was no Canadian participation on the committee nor in the plenary lectures of the most recent International High-Temperature symposium at Asilomar.

Most of the ceramic, glass and electrothermic plants in Canadaare dependent on imported technology. Most engineers and scientists involved with these industries were trained outside Canada; indeed there is no undergraduate course in ceramic engineering in Canada.

There is no course as yet in High-Temperature Chemistry in Canada, and no text in English is available in this field at any level. (There are good texts in High-Temperature Technology in both French and English).

There is no North American journal in the High-Temperature field and in fact no journal in English except for the delayed translation of the Russian Journal, "Teplofizika Vysokikh Temperature", (about 10 months behind published date).

High-Temperature chemistry in Canada is handicapped by lack of funds and of trained personnel. This is particularly true of the industrial field and in the applied research and development areas.

2707 *Low Temperature Studies.*

Better solutions are needed for a number of cold-weather problems such as batteries, icing of windshields, building construction materials, (mortar, cement) etc., perma-frost, muskeg, food storage, highway construction, power and communication lines, etc. There is no existing good way of patching pot-holes in highways during cold weather.

A lack of chemically-trained investigators in the field of super-conductivity is predicted, if even part of the developments forecast for high intensity magnetic fields, power transmission and magneto-hydro-dynamics come to fruition.

Recommendations

2700 *Flames and Explosives*

With the recent developments in instrumental technology, rapid strides could be made in the study of hot flames, detonation and shock waves, and of plasmas. The chemical aspects of these studies will require capital funds for equipment and operating funds for a research staff. A capital equipment grant of $200,000 per laboratory and a sustaining grant of $25,000 per professor for research students would be a minimum. It is recommended that several laboratories in different universities be set up, with Government funds, in order to maintain a national industry. Some support from aeronautically oriented groups and industry should be available.

Shock tubes may be used for the study of chemical reactions related to hypersonic flow, of high-temperature kinetics including the decomposition of materials, and of detonation in the gas phase. A centre of excellence is recommended for work in this general area. The nucleus may already exist at Toronto.

Research on flames and plasma may well be a field in which Canada could excel. Flame synthesis of organic chemicals has been often proposed, but the mixture of products obtained has discouraged industrial interest. Recent advances in flame technology and theory open new potential for controlling such syntheses. Electrically assisted flames are also of interest both from the chemical synthesis point of view and as an economic source of high-temperature.

2701 Fused Salts

One of the major problems in fused-salt chemistry is communication. An informal group meeting semi-annually, and including industrial, academic and governmental research workers from all across the country could effectively co-ordinate work and exchange information. Such a meeting on a three-day basis in the general format of a Gordon conference is recommended. Government support and probably leadership would be required. Quite possibly the fused-salt group could be joined by other high-temperature workers for such an occasion.

Financial support for fused-salt chemistry should come from a wider base than is presently available. Support from A.E.C.L. (for atomic energy applications) from the Department of Energy, Mines and Resources and from the extractive metallurgy industry might reasonably be expected. Much more work should be done in Universities and industrial laboratories in this area.

The Technical University of Norway at Trondheim has become a centre of excellence in fused-salt research associated with extractive metallurgy. As a resource-based economy of similar interests*, Canada should be able to at least match this achievement. An exchange of staff or students with this institution would be instructive.

2703 High Pressure Chemistry

A system of research grants which would encourage joint projects e.g., combination of high-pressure and kinetics studies would be desirable.

N.R.C. in Ottawa has a large well equipped high-pressure laboratory. It is recommended that machinery be devised to allow graduate students to obtain their degrees through research conducted in this facility. Such a scheme is already in operation at A.E.C.L. facilities.

Any increase in grants in this field should be devoted to improving communication among workers on existing projects.

2704 *High Temperature Studies*

It is recommended that the Department of Industry in funding joint research projects with industrial laboratories attempt to tie in University people either as consultants or collaborators.

One or more centres of excellence in the high-temperature field are desirable. These should include a specialized research team with broad training outside the high-temperature concentration. A high-temperature laboratory will require exceptional electrical facilities, (possibly including shielding) and an annual support rate of at least $50,000 per professional investigator.

Good analytical and shop facilities are required for a centre of excellence. It would also be desirable to have access to rocket equipment and ballistic ranges.

Undergraduate training leading to this field should be reappraised, otherwise graduate students and plant operating personnel will have to continue to be imported or converted from other fields. We need to know whether material and process engineers can replace electrochemists and ceramic engineers or does chemical engineering now embrace all these functions.

Specific graduate and undergraduate courses in high-temperature chemistry are recommended to the Universities.

Funds should be made available to encourage travel to U.S. and international meetings on high-temperature and to encourage visits to leading laboratories in other countries.

2707 *Low Temperature Studies*

The following low-temperature chemistry areas are recommended for further investigation and support:

(1) Road patching methods suitable for cold weather application.

(2) De-icing chemicals and procedures.

(3) Stabilization of highway foundations to eliminate "frost-boils".

(4) Hail prevention research.

(5) Materials and methods for super-conducting magnets.

(6) Dependable low-temperature batteries. (Both primary and storage).

General

A hard look at the Canadian patent system should be taken, since its present effect is not encouraging to industrial research in Canada. To protect his or his company's interest an inventor must now apply for a U.S. patent at his earliest opportunity. Even so doing, he is at a disadvantage as compared with an American resident working in the same field.

More cooperation between universities and industry should be encouraged by any available means or incentive.

No useful recommendation seems possible to correct the lack of development or application of known methods and procedures. Risk capital and development personnel are both lacking. Until these are available it is not likely that much will be accomplished.

1967-68 Graduate Students & Schools

	2700 (Flames)	2701 (Fused Salts)	2703 (High Pressure)	2704 (High Temperature)	2707 (Low Temperature)
Graduate Students	82	11	13	61	56
PhD.	46	4	11	32	33
M. Sc.	36	7	2	29	23
Profs. Supervisory	47	9	11	44	46
Chemistry	9	7	3	8	2
Chem. Eng.	12	1	-	14	-
Chem. & Chem. Eng.	21	8	3	22	2
Metallurgy	-	2	-	28	-
Physics	21	-	2	2	33
Mech. Eng.	25	-	3	-	4
Other	15	1	5	9	17
Major Universities	Toronto (20) B.C. (10)		McMaster (3)	McMaster (18)	Toronto (9) Dalhsie (6)
Profs. without students 67-68	15	16	17	20	16
Government Investigators	2	3	5	47	15
Industrial Laboratories	Nil	2	3	13	2
Industrial Investigators	Nil	3	3	34	5

Out of 223 graduate students engaged in work on theses having at least some chemical content (or indistinguishable by title from one which could be carried out by a Chemistry or Chemical Engineering Department) only 56 or 25% were actually working in a Chemistry or Chemical Engineering Department.

Of these students 126 were PhD. candidates and 97 were taking their masters degree. Altogether 157 professors were involved for less than 1.5 students per professor. Also there are 84 professors interested in these fields who have no graduate students listed as of 1967-68. Apparently at least 100 more graduate students could be accommodated without trouble.

SUMMARY OF RECOMMENDATIONS

COMMITTEE 14

General

Strengthen the Canadian patent system to protect the Canadian inventor and encourage industrial research in Canada.

Provide incentives, (possibly riders on research grants) to encourage collaboration as between industrial laboratories and Universities.

Improve communication by organizing and financially supporting a regular meeting of research workers in the field of high-temperature.

Flames and Explosives (2700)

Establish a centre of excellence for study in the field of shock tubes, detonation in the gas phase, high-temperature kinetics and hypersonic flow.

Support several university laboratories to work on plasmas, hot flames, electrically assisted flames, detonation and shock waves and flame synthesis.

Fused Salt Chemistry (2701)

The A.E.C.L. should support research in the field of fused salts for atomic energy applications.

The Department of Energy, Mines and Resources and the extractive metallurgy industry should support fused salt research in the metallurgical field.

Contact with the Technical University of Norway at Trondheim is recommended by visiting or exchange professors and grants for exchange of students.

High Pressure Chemistry (2703)

Work out a system for allowing graduate students to earn their degrees through research conducted in the high pressure laboratory at N.R.C.

High-Temperature Chemistry (2704)

10. Establish one or more centres of excellence in the high-temperature field.

11. Institute specific graduate and undergraduate courses in high-temperature chemistry at the Universities.

12. Re-examine the undergraduate training required for the ceramics, glass and electrothermics industries.

13. Support and encourage travel to meetings of high-temperature groups in U.S. and abroad.

Low-Temperature Chemistry (2707)

14. Expand research on practical applications related to Canadian conditions such as cold weather road-patching, de-icing, frost boils, hail prevention, etc.