A History
The Department of Metals and Materials Engineering
The University of British Columbia
1915 to 1987

R. Butters
Sept. 1987
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Acknowledgement
The author would like to thank Mr. L.G.R. Crouch, Professor Emeritus of Mining and Dr. C.S. Samis, Professor of Metallurgy (retired) for their help in supplying details of Department activities and policies for the W.W.II and early post war period and Mrs. L. Daniells, University Archivist for her help in supplying photographs and records from the Archives.

The author would also like to thank Dr. J.A. Lund, Head of the Department of Metals and Materials Engineering, for his encouragement and help in this project.
Prologue
A "Departmental History" was commissioned in early 1986 by the incumbent Department Head John Nadeau for presentation at the first Department of Metallurgical Engineering Retreat held at Whistler, B.C. on April 19-20, 1986. Subsequent to the retreat, it was suggested that a more complete and permanent printed document be generated to preserve at least some of the history relating to the Department before it became lost to all.

The author was no doubt selected by John Nadeau because he has enjoyed the longest continuous association with the Department of any of the current faculty. Certain retired faculty members have been very cooperative in supplying information back to 1946. Fortunately, a very complete and informative history (1) was written by the first Department Head, John Turnbull, in 1951 while he was Professor Emeritus of Mining. Since there is no other organized source of information about the very early activities in the Department and since clerical records prior to 1948 are not to be found, virtually all of the early history has been extracted from John Turnbull's article.

It is to be noted that the Department name has been changed at least three times since 1915 and the current name was very recently (Dec. 1986) approved.

This history deals primarily with the Metallurgy discipline at U.B.C. Mining Engineering and Metallurgy, although starting from a common seed and sharing for so many years a common facility, always remained separate in that the students had different curricula and graduated with distinct degrees. This separation was extended in the fifties when the two student bodies no longer shared a common society (the G.M. Dawson Club). By 1968 the separation was absolute when each discipline became a separate Department in the Faculty of Applied Science and each had its own building.

In the interest of brevity, it was decided to name only those individuals holding faculty teaching positions and some Research Associates who were significantly involved in teaching. Of necessity, the names and activities of the very large number of service technicians, research technicians, secretaries, and librarians who have contributed so much to the Department over the years, will not be included.

Detailed Research activities of the various faculty members as well as their publication lists and scholarly awards are, at least in recent years, published regularly and will also not be included.

In the Beginning
(1915-1920)
The University of British Columbia was created by an act of the Provincial Legislature in 1908. In August of 1912 the convocation of the University of B.C. elected its first Chancellor and fifteen members of its first Senate.

In August of 1915 the Dean of Applied Science, R.W.Brock, contacted J.M.Turnbull (B.A.Sc. McGill, one of the first Senators and a representative of the mining community of the Kootenay) in regards to the formation of a mining department. The rationale was that "the University was supposed to provide trained men first and research second for our great industries, agriculture, forestry, and mining". John Turnbull was given the position of Head of the Department of Mining effective Sept. 15, 1915. He was allocated a budget of $700. (1) with which to purchase furniture and equipment to outfit the three empty rooms of the "Fairview Shacks" appointed to him.

Until September of 1915, the existing university facility was known as McGill University College and had a total enrollment in the 1914-1915 session of 292 students. The first two years of Applied Science were offered according to the McGill University curriculum. In September, 1915, a few students qualified for entrance into the third year of the Applied Science program but none for the fourth year program. Military training was compulsory at the time and many students enlisted outright while others took advantage of a deferred enlistment plan.

In the 1915-1916 session, third year courses were offered in Chemistry, Chemical Engineering, (1) This is from John Turnbull's report. The actual Dept. budget for the period Sept. 1915 to July 1916 was $4565.33.
and Mining Engineering (which included Metallurgy). A fourth year course in Chemical Engineering followed and the first graduate in Applied Science in Chem. Eng. was C.A.H. Wright of Trail, B.C. Until the session of 1919-1920, the shortage of students resulted in a decision not to offer fourth year courses in the other engineering departments.

In the period 1915-1920, even though students were not graduating with degrees in Mining, the Department was not idle. As a result of Government rehabilitation programs for veterans the Department put on a series of eight short courses, free for veterans, but open to prospectors, miners, and businessmen. These courses involved mining, geology, mineralogy, smelting, surveying, chemistry, shop work, and assaying.
The Post War Period
In 1919-1920 the student enrollment increased to about 1400, mainly due to returning veterans. Since the available facilities had a capacity for 800 students and since there was no increase in budgeted for new buildings, everything was very cramped and economy was the watchword. These conditions prevailed until the University moved to Point Grey in 1925.

In 1919, the Mining and Metallurgy Department (1) was augmented by the appointment of H.N.Thomson (B.A.Sc. McGill, 1897) as full Professor of Metallurgy and G.A.Gillies (M.A.Sc. McGill, 1908) as Assistant Professor of Mining. At the same time G.A.Comrie was appointed laboratory assistant. The Department was now up to full strength and for the first time offered a full four year course in Mining. In 1920-1921 a fourth year in Metallurgy was offered and the first student graduated from Metallurgy in May 1921 (2).

Teaching equipment was scarce during this period due to the very limited funds available. Nevertheless some very successful graduates were produced. To indi-

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**Information for Students in Applied Science.**

V. Metallurgical Engineering.

**First and Second Year.**

As in other engineering courses. (For details see page 138.)

**Third Year.**

As in Mining Engineering. (See Above.)

**Fourth Year.**

<table>
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<tr>
<th>Subject</th>
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**Short Course in Mining.**

The regular Short Courses in Mining for the Session of 1920-21 will commence on January 10th, 1921, and will continue for eight weeks. These courses include Mining, Smelting, Ore Concentration, Geology and Ore-deposits, Mineralogy and Rock Study, Fire Assaying, Chemistry, Surveying, and Blacksmithing.

The courses are thoroughly practical in nature. They are not intended for those who have had a technical training, but rather for those who have had practical experience in Mining and Prospecting, or are connected with the business of mining in any way. The courses are designed to give practical technical knowledge, helpful in practical mining work and business.

Extracts from U.B.C. Calendar, 6th Session, 1920-1921
cater the relative buying power of the dollar, a copy of a quotation relating to the first purchase order of the Mining Department is included. It is noteworthy that at least one and possibly more than one item listed in the quotation is still in use.

1920-1921 was a year of extensive preparation in the faculty of Applied Science such that in 1921-1922 ten courses leading to a degree of B.A.Sc. were offered and twenty two students graduated in 1922 with that degree.

In 1925 the University of British Columbia moved from the crowded "Fairview Shacks" to its present location at Point Grey. The move resulted in a significant increase in the space and equipment, convenience, and privacy for the Mining and Metallurgy Department.

(1) Whether the Dept. Name was officially changed or whether the new name reflects the fact that for the first time, separate degrees in Mining and Metallurgy were available is not known by the author.

(2) This is from John Turnbull's report. U.B.C. alumnus records show that the first two students graduated in 1922, N.W. McLellan and O.A. Jackson.
Department of Mining and Metallurgy

Professor of Mining: J. M. Treadwell
Professor of Metallurgy: H. N. Thomas
Assistant Professor of Mining: Gen. A. Gillespie
Assistant Professor of Metallurgy: —

Mine Surveying—This course covers the application to mining problems, of the general principles of surveying, under the following heads:


Lectures one hour per week in the Second Term of the Third Year.

No text-book is required.

Prerequisites: Surveying, I.

Ore-dressing—Owing to rapid and radical changes in the practice of ore-dressing in recent years, and the immense number and variety of machines in use, an attempt is made to describe all the machines. Most of the time is spent in considering fundamental principles, typical machines, and their general operations and relations in modern modern milling practice.

Students are taught the commercial and technical characteristics of ore-concentrating ores, the general principles on which the size, character, size, and other features of a mill are designed. The general lay-out of crushing, handling, and separating machinery. The laws of crushing and of various classifying and separating actions, and the design, operation, and comparative efficiency of typical machines, such as crushers, rolls, stamp, ball and tube mills, jig, tables, screens, classifiers, and similar handling devices.

Attention is paid to concentrate, magnetic, electrolytic, flotation, and other special processes, including coal-washing.

Two lectures per week throughout the Third Year.

Reference books: Theory and Practice of Ore-dressing, E. S. Waddell; Concentrating Ores by Flotation, T. J. Hoover; etc.; Current Mining Journals;Trade Catalogues.


Metallurgy I—This course covers the fundamental principles underlying metallurgical operations in general, and is introductory to subsequent more specialized study.

The lectures follow in general the subject as taken up in Principles of Metallurgy, by Chas. H. Falloon, including the following main subjects:


Lectures one hour per week during the First Term and three hours per week in the Second Term. Third Year.


Reference books: General Metallurgy, H. O. Hodson; Current Mining and Metallurgical Journal; Trade Catalogues.

Prerequisites: Chemistry I, and Physics I and II.

Fire Assaying—Quantitative determination of Gold, Silver, Lead, and Platinum by fire-assay methods, with underlying principles.

Lectures and laboratory work, eight hours per week during the First Term of the Third Year.


Excerpts from the U.B.C. Calendar, Sixth Session (1920-1921)
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<th>Item Description</th>
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**Totals**

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**Totals**

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A quotation relating to the first purchase order made by the Mining Dept., August 1915.
The Development of Metallurgy
(1925-1944)
In 1925 W.B. Bishop, former superintendent of the Granby Smelter at Grand Forks, was appointed as assistant in Metallurgy. He served in this position until his death in 1941. In 1935, Professor Thompson passed away leaving, in the words of John Turnbull, “an unfilled gap” and “marking the end of an era in which Chemical Metallurgy was supreme”. It was possible that John Turnbull’s words were somewhat premature. In 1935, Prof. Turnbull served as acting Dean of Applied Science after the death of Dean Brock.

Frank Forward (B.A.Sc., U. of T.) was appointed Assistant Professor of Metallurgy in 1936 to continue the teaching done by Professor Thompson and to develop a research capability in the field of Metallurgy. Frank Forward did not actually start at U.B.C. until 1937 and his duties were performed by B.J. Walsh (Queens U.) during the 1936-1937 session. In 1937 G.A. Gillies was appointed Professor of Metallurgy responsible for Ore Dressing. At this point in time the Department was made up of one Professor of Mining and three Professors of Metallurgy.

Frank Forward undertook the restructuring of all Metallurgy courses but was seriously restricted by the constraint policy adopted as a result of the Great Depression of 1932. Financial conditions gradually improved and the teaching of Physical Metallurgy was started during the 1942-1943 session (1).

During the fall of 1941, a very dark time for the Allies in the Second World War, H.V. Warren of the Department of Geology, Frank Forward, and various representatives of both the Provincial and Federal Governments carried out discussions on how the University might help the war effort. The results of these discussions were the creation of the War Metals Research Board on April 27, 1943. This organization received Government funding and sponsored much effective work which was carried out at U.B.C. The Board also provided funds to allow the Mining and Metallurgy Department to purchase items of modern equipment such as a high frequency induction furnace and a Rockwell hardness tester.

In July of 1943 J.F. Walker, Deputy Minister of Mines for B.C., suggested to the Chancellor of U.B.C. that a B.C. Industrial and Scientific Research Council be created. At meetings in January and March of 1944 involving both Governments, representatives of Industry and Labour, officials of U.B.C., and members of the War Metals Research Boards, the Research Council was established with its Head Office on the U.B.C. Campus and sharing the facilities of the Mining and Metallurgy Department.

The chairman of the newly formed Research Council soon appointed F.E. Maddigan as its permanent director (after a brief period during which Dr. Gordon Shrum served as interim director). This appointment created a serious situation in the Department because Frank Forward, who had worked so hard and long to have the Research Council created and who had, no doubt, been instrumental in provid-
ing the physical facilities for the actual laboratories, obviously was looking forward to being actively involved in the operation. Shortly after, the Research Council moved away from the Metallurgy building into its newly constructed facilities on the Campus, taking its staff and much of the modern equipment with it. By August of 1944 Frank Forward was left alone with a depleted research facility and a decaying War Metals Research Board.

(1) The first polishing equipment; cut-off saws, heat treat salts, etc. were requested in 1940. Saltpots and a metallurgical microscope were ordered in 1941. Orders prior to 1940 were mostly for mineral dressing equipment and analytical supplies.
Discovery and Expansion
(1945-1956)
In 1945 John Turnbull retired as Department Head and was designated Professor Emeritus of Mining. He remained active for many years and was a well-known figure at meetings of the Faculty. He passed away in 1982 at the remarkable age of 104 years.

Frank Forward was made Department Head to replace John Turnbull. The Department then consisted of Frank Forward, G.A. Gillies, and Prof. Emeritus Turnbull.

In 1944 the total University enrollment was less than 4000 students. Due to returning veterans, this number jumped to about 9600 by the 1946-1947 session. Obviously, some expansion of facilities and staff was indicated. In order to quickly provide lecture rooms and housing, the buildings from west coast military bases were trucked to the campus and set up in orderly rows.

Because of timetable complications resulting from limited staff and laboratory facilities, classes started at 8:10 A.M. and ran until 10:00 P.M., Monday to Friday, and from 8:10 A.M. until noon on Saturdays.

The impending retirement of Prof. Gillies in 1946 and the flood of returning veterans forced Frank Forward to acquire more faculty to cope with the work load. In September of 1945 he brought in Clarence S. Samis (Ph.D. London) as an Associate Professor to teach Process Metallurgy and Leslie G. R. Crouch (M.A.Sc., U. of Utah) to teach Mining. One year later, in July of 1946, he brought in Henry M. Howard (B.A.Sc., U. of T.) to teach Mineral Dressing and in September of 1946, W. M. Armstrong (B.A.Sc.,
U. of T.) to teach Physical Metallurgy. In 1947, Gordon Bell (B.A.Sc. U.B.C.) was appointed Assistant Professor. He served in the Department for only two years.

By 1948, sixty-six students had already graduated with a B.A.Sc. degree in Metallurgy and eleven more graduated in 1948. In this year also the Department’s first graduate students (M. Robinson and D. Scott) obtained M.A.Sc. degrees in Metallurgy.

The author had the good fortune of working temporarily with Frank Forward during the summer months of 1948. At this time Frank Forward and his graduate student Mr. Kudryk were developing an extractive process to recover nickel, copper, and cobalt from concentrates and mattes. The steps involved at that time in their process were to roast all the sulphides to oxides, selectively reduce the nickel, copper, and cobalt to metals using hydrogen, and to dissolve them away from the gangue minerals with aqueous ammonia using air as an oxidizing agent. The process worked but yielded only dilute solutions and involves many expensive process steps. This research was being done for the Sherritt-Gordon Mining Co. for possible application on their Lynn Lake nickel concentrate, but in 1948 the available Lynn Lake concentrate was old and oxidized and, for convenience, much of the work was carried out using a matte obtained from the Falconbridge Nickel Company.

During June or July of 1948, a routine experiment intended to reveal the amount of free metal in the matte revealed that the sulphides dissolved readily in aqueous ammonia under oxidizing conditions. Frank Forward immediately recognized the significance of this and within one week outlined a revised program with very ambitious objectives. By September of 1948, most of these objectives had been achieved. A process to recover the nickel from the leach solution as a pure nickel salt and to recover valuable leaching chemicals had also been developed. Fresh Sherritt concentrates were obtained and in a short time (about one year) the Sherritt Nickel process had advanced to the pilot plant stage. This significant achievement had a lasting influence on the development of the Mining and Metallurgy Department at U.B.C.

In 1948, while all this was going on, Fred Hames (M.A.Sc., Queens) was appointed Assistant Professor to help in the teaching of Physical Metallurgy. He stayed until 1950 and in this time he was instrumental in obtaining modern X-Ray diffraction equipment and in starting a program of magnetic alloy research that would continue for many years.

Also, during the period 1948-1950, Ralph Barer (M.A.Sc., M.I.T.) served as sessional instructor of Metallurgy.

The author rejoined the Department in June of 1950 as a temporary Research Assistant, which position evolved through Research Associate to Assistant Professor.

Prior to the author’s return, Anna Margaret Johnson (later Mrs. W.M. Armstrong) came to the Department to work with Frank Forward on the Sherritt process. She contributed greatly towards a more complete understanding of the chemical fundamentals of the process. She stayed on in the Department for many years in various capacities including teaching and entering a
Doctoral research program. Her early death in 1968 was a great loss to everyone in the Department.

At about the same time (1948-1950) Frank Forward became involved in a massive investigation of the hydrometallurgy of uranium. The development of atomic energy demanded an ever increasing supply of pure uranium and the few very rich deposits were rapidly becoming exhausted. Numerous low grade deposits were soon discovered in Canada and Frank Forward undertook to develop economic extractive processes for the low grade ores. To this end the services of Jack Halpern (Ph.D., McGill) were obtained. A small wooden building was taken over and hastily modified into a research lab containing autoclaves and analytical facilities. For a short and very active period virtually all of the commercial assaying of uranium ores from all Canadian properties was carried out in this one building, intermixed with graduate student research and mineral dressing. At one time (during the summer of 1951) as many as 26 researchers were doing something or other in this one small hut. The entire operation was covered by the Official Secrets Act because of the strategic nature of uranium. R.C.M.P. officers visited regularly to see that security procedures were followed. Things were happening so fast that it is doubtful that any one man, with the possible exception of Jack Halpern, really knew what was going on.

Working at such a pace inevitably leads to disaster. A spectacular flash fire, involving large amounts of ether, totally destroyed the building in 1951. Miraculously, no one was seriously injured and virtually no research papers were lost. Most of the equipment was salvaged and many of the major projects were soon back in operation wherever space in the main Mining building could be found. The insurance payments from the fire were sufficient to justify the construction of a permanent two story Physical Metallurgy building which was officially opened in October of 1956.

Jack Halpern continued working in the field of hydrometallurgy until 1959, during which period he enjoyed appointments in both the Metallurgy and Chemistry Departments at U.B.C.

In 1951 Eric Morgan (Ph.D., Birmingham) was appointed as Research Associate to continue the work on magnetic alloys started by Fred Hames. He stayed with the Department until 1953.

In 1952 Harry Evans (B.A.Sc., Alberta) was appointed Research Associate and later Lecturer in Metallurgy. His interest were in the field of Materials Science and he acquired some excellent electrical measuring instruments, some of which are still in use. He was probably the best glass blower ever to work in the Department. He left in 1955.

1952 was also the year of the creation of the Sherritt-Gordon Chair of Metallurgy. Frank Forward was spending so much time away from Vancouver helping to set up the Sherritt nickel process that the company established the Chair, primarily to sponsor a replacement lecturer to continue Frank Forward’s teaching responsibilities. John Warner (B.A.Sc., Royal School of Mines) was brought in as instructor to teach Professor Forward’s courses. John Warner stayed only until 1955 but the Sherritt Chair...
continued until 1969, during which period it sponsored much fundamental and practical hydrometallurgical research.

In 1953, two more Research Associates were hired; Peter Myers (Ph.D., Sheffield) to continue the work on magnetic alloys and Jim Parr (Ph.D., Liverpool) to carry out alloy research. Both were involved in the teaching of Metal Physics. Dr. Myers resigned in 1956 and Dr. Parr in 1955.

By now it should be evident that a large number of people were coming to the Department at the level of Research Associate only to leave after a few years. The reason for the rapid turnover was probably that Frank Forward could not (or possibly would not) offer tenure track positions to these people. In some cases, notably that of Dr. Parr, very heated discussions about promotions to faculty status were common and some Research Associates left the Department with a feeling of disappointment.

In 1955, Don Wiles (Ph.D., M.I.T.) joined the Department to develop a radioactive tracer facility for fundamental inorganic chemical research. He stayed until 1959. By this time, after forty years of existence, the original Mining Department had developed into a Department of Engineering in which Mining was represented by two faculty members, Leslie Crouch teaching Mining Engineering subjects and Henry Howard teaching Mineral Dressing, and in which Metallurgy related subjects such as Hydrometallurgy, Pyrometallurgy, Physical Metallurgy, and Inorganic Chemistry were taught by numerous Faculty Members and Research Associates. The Department had, under Frank Forward's leadership, achieved recognition as a major school of Extractive Metallurgy.

The Physical Metallurgy Building, U.B.C. Campus
The New Generations
(1956-1964)
It is only logical that when a school has reached a high level of esteem, it will turn to its own graduates for new faculty positions. The first occurrence of this here was the return of John Lund (Ph.D., Birmingham) in 1956 as Assistant Professor to teach Physical Metallurgy. Prior to receiving his Doctoral degree, John had obtained a B.A.Sc. in Metallurgy at U.B.C.

John Lund quickly became involved in investigations to find ways to convert the nickel powder produced by the Sherritt-Gordon company into more valuable dense products. He soon set up a strong research group in the field of Powder Metallurgy. As a result of his work, Sherritt-Gordon set up a powder rolling facility and became a major producer of nickel coinage. Dr Lund has maintained his interests in powder metallurgy to the present and is, at the time of this writing, the Head of the Department.

1956 was the year also in which Ed Teghtsoonian (Ph.D., Toronto) came to the Department as a Research Associate to work in the field of metal physics. He was appointed to Faculty in 1959 and has remained until the present, during which period he served as Department Head for some fourteen years between 1966 and 1979. Recently, he has become active in the field of composite materials.

Also in 1956, W.C. Lin (Ph.D., McGill) was appointed to supervise the Sherritt research. He was also Honorary Lecturer until he left in 1959. Hans Brandstetter was appointed as Instructor II during approximately the same period.

Between 1957 and 1959, Vernon Griffiths (Sc.D., M.I.T.) served as Research Associate and Lecturer in the field of Physical Metallurgy.

In 1958 Ian Warren (Ph.D., London) came to the Department in the capacity of Post Doctoral Fellow. He was appointed as Associate Professor in 1964 and taught in the field of Extractive Metallurgy. He resigned his position in 1980 but stayed on as Honorary Professor until 1984.

In the same year that Dr. Warren started, Ernest Peters (Ph.D., U.B.C.) was appointed Assistant Professor to teach Extractive Metallurgy. Dr. Peters, who studied and obtained his degree under the direction of Jack Halpern, was the second of the “second generation” professors to be taken on by Frank Forward. Dr. Peters is still with the Department and has become a widely recognized authority in his field.

In 1959, Frank Forward appointed Asoke Chaklader (Ph.D., Leeds) as Research Associate to study ceramics and cermets. This appointment was a bit unique in that Dr. Chaklader had specialized in the field of Ceramics, an entirely new area of study at U.B.C. Frank Forward’s decision was possibly motivated by the fact that other Universities (e.g. U. of Washington) taught Ceramics and Metallurgy in the same Department. Dr. Chaklader gained faculty status in 1964 and he is still very active in the Department.

In 1960 Henry Howard suffered a serious illness and was forced to be away on sick leave for at least a year. Bill Adams (B.A.Sc., U.B.C.) was taken on to take over Henry Howard’s duties. As well as teaching Mineral Dressing, Bill was instrumental in setting up a service course in Material Science to be
taught to most of the undergraduates in Engineering at U.B.C. He stayed on in the Department until 1963 in various capacities and the course he set up is still being taught each year to more than 200 students.

Also in 1960 Bruce Ekelund (Ph.D., Gotenburg) was brought to U.B.C. to help with the teaching of Material Science and to do research in that field. For a variety of reasons this arrangement proved less then ideal and Dr. Ekelund left the Department in 1962.

At this time it was very evident that the interests and activities of Mining Engineering and Metallurgy were diverging more and more and the point was expressed by the Dean of Applied Science, Dr. Myers, at a meeting of Faculty on September 20, 1961. Dr. Myers suggested that Mining Engineering would better be associated with Geological Engineering within the Faculty of Applied Science. Frank Forward strongly supported this idea. Within two months, the Department of Mining and Geological Engineering was formally established and the newly named Department of Metallurgy retained all the faculty members with the exception of Leslie Crouch and Henry Howard.

At the same time that these changes were going on, Frank Forward proposed that the Department be renamed “Metallurgy and Material Science” but he withdrew the proposal when he learned that it would be challenged by other Department Heads.

Three years later (Nov. 1964), Mineral Engineering separated from the Geologists to form the Department of Mineral Engineering.

By this time the novelty of Hydrometallurgy had worn off and research in this area had become more fundamental in nature. Uranium research had dwindled and further work was centered around finding new uses for the mineral since everyone had so much of it (as “spent” uranium) and it was impractical to recycle it as atomic fuel. At this time the Department hosted the Canadian Uranium Research Foundation, whose primary purpose was to search the literature and prepare the “Uranium Abstracts”, - a compilation of all the current knowledge on the uses of Uranium.

In 1963 Des Tromans (Ph.D., Leeds) was brought in to initiate research in electron microscopy, a field in which he specialized previously. It is interesting to note that Dr. Tromans, having established a very strong electron optics capability in the Department, went on to become a specialist in corrosion chemistry, a field in which he is still very active.

In the same year Laurence Brown (Ph.D., Glasgow) was acquired to replace Bruce Ekelund as a teacher of Materials Science. He still teaches this subject and also does research in Metal Diffusion and in Superelasticity.
The End of an Era
On June 30, 1964, Frank Forward resigned as Head of the Department of Metallurgy. He continued as Professor of Metallurgy on an extended leave of absence while he served as the Secretary of the newly formed Science Secretariat in Ottawa which post he kept until mandatory retirement at age 65. For a short time after his retirement, he returned to U.B.C. to set up a new Office of Research Administration. Sadly, he succumbed to leukemia a few years later.

Bill Armstrong became Head of the Department to replace Frank Forward in 1964, a position he held until 1966 at which he became Dean of Applied Science. Later he served as Deputy President of U.B.C. until his resignation in 1974. He remained active in the field of education, serving in the area of University-Government Liaison and as Science Advisor to the Provincial Government until his retirement in 1979.

During Bill Armstrong's two years as Department Head he was responsible for getting the necessary funding to build a new and very elaborate building to house the Department. He worked long and hard on every aspect of the design of the new Faculty, much to the frustration of the Architects and Design Engineers assigned to the task. His efforts were not in vain and in September of 1968 the Department moved into its new and most impressive home named after Frank Forward.

In 1966 Ed Teghtsoonian became the Head of the Department replacing Bill Armstrong and at about the same time Neil Risebrough (Ph.D., U.B.C.), a recent Ph.D.
graduate in Metallurgy, was appointed to the faculty to teach Physical Metallurgy. Dr. Risebrough left the Department for some years to serve the Dean of Applied Science as Director of the Core Programme, and the U.B.C. President’s office as Vice Provost (1982-87). He returned to the Department as a teaching faculty member in 1987.
Rapid Expansion
(1967-1970)
By 1967, after the departure of Frank Forward and Bill Armstrong and separation of the Mining Department, the faculty strength of the Department stood at nine. Only three lasting additions had been made in the previous seven years. The graduating class enrolment had been at about 25 students for three years, about ten graduate students were completing programs each year, and a large new Metallurgy building was almost ready for occupancy.

In the light of this, Ed Teghtsoonian brought in four new faculty members in 1967; Alec Mitchell (Ph.D., Oxford) to teach thermodynamics, Tom Alden (Ph.D., M.I.T.) to teach deformation theory, Bruce Hawbolt (Ph.D., U.B.C.) to teach Materials Science, and Fred Weinberg (Ph.D., Toronto) to teach solidification.

At about the same time, Ed Teghtsoonian finalized the formal establishment of the Center for Materials Research, originally conceived by Frank Forward during his last years as Department Head.

This Center was one of three similar centers funded by N.R.C. at the time. The Department received about half a million dollars to set up the research center and it was to be perpetuated by support from both Industry and the University. Four Research Associates were employed for at least three years. They studied various subjects relating to materials science and engineering but most of the work was directed toward developing procedures to produce high strength carbon and graphite fibers from pitch. This early interest in fibers no doubt was instrumental in
the development of the current program on fiber reinforced composites.

Unfortunately the financial and political situation in Canada at the time was such that the Center never did get the necessary support from industry and as a result it withered and vanished.

In the following year (1969) Denton Coates (Ph.D., McMaster) was hired as Assistant Professor to teach Theoretical Thermodynamics. He stayed only a short time, leaving the University in 1971.

This period of rapid academic expansion ended with the appointment in 1970 of Keith Brimacombe (Ph.D., London) to teach Thermodynamics and the Analysis and Design of Metallurgical Processes, and John Nadeau (Ph.D., U. of California) to teach Ceramics and related subjects.
Retrenchment
At this time the faculty stood at seventeen. The number of students graduating had dropped steadily from twenty eight in 1967 to seven in 1970. Government funding for higher education was becoming less available and, as a result, the allocation of monies within the universities was much more competitive.

The undergraduate enrolment reached a crisis state in 1975 when only two students were graduated and there was a teacher-to-student ratio of seventeen to nine. A great deal of effort was expended by many faculty members to try to increase the undergraduate numbers by talking to first and second year Applied Science students and to grade XII students in the schools to try to interest them in Metallurgy. In addition much time was spent, largely by Keith Brimacombe, “beating the bushes” all over the world to increase the number of graduate students and to acquire funding for graduate research.

The result of these efforts was that the undergraduate enrollment started to increase gradually and the amount and quality of graduate research increased very greatly as did the necessary funding.

In 1976 Clarence Samis became seriously ill and was away for a significant period. Fortunately he recovered completely and returned to work for about a year before mandatory retirement in 1977. The University policy at the time (and still at the present) was to “retrench” faculty positions created by resignation or retirement. The Samis position was lost from the Department budget. The teaching duties of Clarence Samis were
redistributed and carried on largely by Keith Brimacombe and Alec Mitchell.


A serious problem in teaching responsibilities occurred following the resignation of Ian Warren in 1980. Again, despite all efforts at the time, there was no possibility of refilling Ian Warren’s position with a permanent junior faculty member and in this case, unlike that of the retirement of Clarence Samis, there was no one in the Department willing or able to take over Ian Warren’s duties.

The problems created by the absence of both Clarence Samis and Ian Warren were solved temporarily by bringing in during the period of 1978 to 1982, three visiting professors, Neville Rice (Ph.D., Imperial College), Surya Mehrotra (Ph.D., I.T.T. Kampur), and Neil Gray (Ph.D., Adelaide). All this time negotiations continued with the Dean of Applied Science to refill at least one of the vacancies and finally, when some engineering expansion funds were provided by the Provincial Government, Greg Richards (Ph.D., U.B.C.) was appointed Assistant Professor in 1983 to take on the undergraduate teaching load handled previously by the visiting professors and to direct advanced research in process metallurgy.

While this shuffling was going on, Keith Brimacombe was working to develop an advanced research program in mathematical modeling of metallurgical processes. His efforts in this project lead to the establishment of the Stelco Chair of Metallurgy in 1980. Since so much of Keith Brimacombe’s time is spent in fulfilling the obligations of the Chair, someone had to be found to take over his teaching responsibilities. Indira Samaresekara (Ph.D., U.B.C.) was engaged as assistant Professor, with her salary funded by the Stelco Chair. This “Grant Tenure” faculty position was welcomed by the University because it did not require a continuing financial commitment on the part of the University but in all other respects was a normal faculty position.

During the same period (about 1975), a decision was reached to make available to the Mining Engineering Department certain unfinished portions of the Forward Building. The Mining Engineering Department had been given a sum of money to build a new facility for itself but, due to very rapidly escalating costs, the allocation fell short of the amount needed to build the planned facility. Since the Forward Building had some unfinished areas, it was considered expedient to offer these areas to the Mining Engineering Department, thus allowing them to obtain a new facility at a somewhat reduced cost.

The ultimate result was that the Mining Engineering Department (currently called Mining and Mineral Process Engineering) in 1981 took possession of one floor of the Forward Building.

In 1985 John Nadeau became Head of the Department, but serious health problems interfered with the carrying out of his responsi-
bilities of Department Head. Unfortunately, he was forced to resign his position as Head during the summer of 1986 and he passed away shortly after.

The last three names to be introduced into this saga are three more “grant tenure” Professors, Anoush Poursartip (Ph.D., Cambridge), Scott Dunbar (Ph.D., Stanford), and Peter Barr (Ph.D., U.B.C.), all of whom were appointed in 1986.

Dr. Poursartip is a specialist in the field of composite materials and came to the Department to work with Ed Teghtsoonian and John Nadeau in that area. Scott Dunbar and Peter Barr came to teach numerical methods in modeling and combustion and heat transfer processes respectively, both of which subjects are related to the interests of Keith Brimacombe.

On July 1, 1987, John Lund became head of the Department, and the faculty strength stands at eighteen, including four grant-tenure Professors. Undergraduate student enrolment is burgeoning. The feelings of insecurity which were so noticeable five or ten years ago have dissipated.
The Future
In the first seventy two years of its existence, only three faculty members have served until normal retirement, Professor Turnbull, Professor Gillies, and Dr. Samis. In the coming six years no less than five more faculty will have reached retirement age and others may consider early retirement. It is not unreasonable to assume that the policies and priorities of the Department might change significantly in the near future.

For a while it appeared that the Hydrometallurgy discipline started by Professor Forward soon would fade to just another aspect of Extractive Metallurgy taught at the undergraduate level. Fortunately Dr. Peters very recently managed to establish an Industry Chair in Hydrometallurgy thus almost securing the continuance of this discipline at U.B.C.

Dr. Mitchell also recently established an NSERC/Industry Chair in Nickel Alloy Development thus securing the future of related areas of expertise in the Department for many years.

At this time it seems that the Department will continue to show strength in the following areas; Materials Science, Composite Materials, Ceramics (including "High Tech" Ceramics), Process Metallurgy (including mathematical modelling of processes), Solidification, Hydrometallurgy, and Corrosion.
Degrees Granted
(1922-1987)
B.A.Sc. Degrees Awarded
(1922-1987)
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O.J.DeLong
K.C.Freeze
J.A.Ganshorn
E.C.Harmre
H.K.Kidston
J.V.Koziak
B.R.Leslie
F.Loeven
G.W.Lorimer
P.M.Mackinnon
A.R.McCombs
L.G.McKenzie
E.M.Schulson
R.H.Watson
M.L.Wayman

1965
E.S.Andrichuk
J.A.Barber
M.Fairweather
T.S.Dicks
R.A.Green
S.H.Groom

N.J.Hopland
H.P.Jacobi
P.A.Jacobson
D.M.Joe
E.S.Katai
R.K.H.Lo
K.G.McQuahe
A.D.Murray
W.E.Norquist
I.C.G.Ogle
R.W.Pugh
K.W.Putt
C.J.Rogers
K.J.Rooney
C.C.Sanderson
R.W.Shindel
E.K.Stanley
P.W.Sunderland
R.J.Waldron

P.J.Player
H.R.Reid
R.S.Roberts
J.F.Schuss
R.E.Seymour
E.Tenta
D.M.Thomson
A.W.Wild

A.S.Ballantyne
H.R.Bartel
G.T.Beynon
C.A.Bishop
J.B.Brodie
M.L.Connolly
F.W.Crocker
D.W.Deane
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L.E.Hambly
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J.E.Stevenson
A.K.Surges
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R.I.D.Barton
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J.G.Clarke
F.L.Kaempffer
D.E.Lefevre
D.MacDuff
W.D.Madeley
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P.G.Olson
C.L.D.Radford
R.F.Reynolds
A.M.Ross
R.M.St.John
N.J.J.Salkus
S.Shinde
F.S.Somerville
C.H.Weaver

1966
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J.K.Brimcombe
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K.Donaldson
G.Kehoe
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W.D.Ogilvie
R.D.Peterson

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R.B.Ferguson
J.K.MacLean
T.E.O'Brien
P.A.Sandaluk
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K.R.Wood

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C. N. L. Pollard  P. Middler
J. G. Roemer  H. Poisl
R. F. Willan  D. Ruffelle
T. L. Williams  A. Schmalz

1986
A. Burgess
K. Dyck
T. Gee
R. Hark
P. Jebbink
B. Kozak
A. Kylo
K. Legeard
C. McCulloch
M. Parmar
T. Richards
D. Ross
G. Sakaki
D. Verhelst
W. Woo
T. Wu

1987
R. Anderson
J. L. Brendzy
T. Delija
K. Dyck
E. R. Lalli
M.A.Sc. Degrees Awarded
(1922-1987)
1947
M.D.E. Robinson
D. Scott

1948
V. Kudryk

1949
R.E. Carter
R.J.T. Charles
A.W. Greenius
D.W. Morgan

1950
R.B. McIntosh
J.F. Stenhouse

1951
J.E. Andersen
E. Peters
R.C. Shney

1952
G.A. Deitz
R.N. O'Brien

1953
R.G. Dakers
J.I. Fisher
G.V. Kidson
R.M. Shier
G.P.A. Shirokoff

1954
M.L. Swanson
S.C. Sircar
G.C. Wootton

1955
L.G. Bell

1956
F.S. Death
H.N. Halvorson
L.M. Howe
E.R. MacGregor
J.R. Rawling
D.S. Turnbull

1957
S.J. Merrick
D.R. McKay
I. Saaremaa

1958
M.J. Finlayson
H.Y. Milants
(M.Sc)
B.F. Peters
B.C. Whitmore
N.V. Vanderpuye

1959
J.F. Clarke
K.G. Davis
D.P.H. Hasselman
P.K. Jena (M.Sc)

1960
W.G. Davenport
L.R. Dilworth
E.A. Hahn
S. Saito
R.F. Snowball
G.W. Toop

1961
W. Allday
R.A.J. Costanzo
M.L. De Cleene
D.G. Evans
R.W. Fraser
H.J. Harding
W.R. Irvine
A.P. Joshi
V.B. Lawson
J.W. Matousek

1962
P.E.J. Aylen
G.E. Forward
D.J. Rose
Z. Rebmann-Huber

1963
J.T. Armstrong

1964
A.R. Causey
J.F. Clayton
R.H. Martinson
R.D. McDonald
S.K. Misra
L.A. Simpson

1965
E.B. Hawbolt
G.C. Howard
T. Krantz
H.D.W. Ney
F.L. Parkinson
C.P. St. John
K.N. Street
J.P. Thiriar

1966
M.J. Fraser
J.C. Mitchell

1967
V.T. Baker
A.K. Bhan
J. Kim
A.J. Monhemius

1968
M.D. Bath
P. Bernheim
G.B. Brodie
R.C. Cook
R.G. St. Jacques

1969
B.C. Burel
V.S. Surana

1970
S. Birley
E.A.P. Devuyst
F.L. Kaempff
K. Oishi
T. Ramanan
P.W. Sunderland
A.K. Surges

1971
G.A. Barclay
M.A. Clark
G.B. Eisenwasser
K. Jibiki
S.K. Morton
<table>
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<tr>
<th>Year</th>
<th>Members</th>
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| 1972 | S.R. Bala  
      | R.S. Bradbeer  
      | L. Cambal  
      | G.W. Fox  
      | R.O. Jackson  
      | C.J. Rogers  
      | D.M. Turner |
| 1973 | K. Aihara  
      | J.M. de Larios  
      | I. Dvorak  
      | M.G. Hay  
      | J.E. Lait  
      | J.R. Michel  
      | B. Prabhakar  
      | J.W. Scott  
      | D.A. Wensley |
| 1974 | M.M. Bell  
      | P.H. Hodkinson  
      | G.W. Izard  
      | T.E. O'Brien |
| 1975 | 1975 |
| 1976 | 1976 |
| 1977 | 1977 |
| 1978 | 1978 |
| 1979 | 1979 |
| 1980 | 1980 |
| 1981 | 1981 |
| 1982 | 1982 |
| 1983 | 1983 |
| 1984 | 1984 |
| 1985 | 1985 |
| 1986 | 1986 |
| 1987 | 1987 |
| 1988 | 1988 |

- C. Nikolic
- A.S. Rao
- G.L.D. Roach
- K. Aihara
- J.M. de Larios
- I. Dvorak
- M.G. Hay
- J.E. Lait
- J.R. Michel
- B. Prabhakar
- J.W. Scott
- D.A. Wensley
- M.M. Bell
- P.H. Hodkinson
- G.W. Izard
- T.E. O'Brien
- L.K. Bailey
- B.E. Magee
- G.N. Oryall
- R.G. Barton
- K. Esashi
- A.A. Ismay
- T.P. Nikiforuk
- V. Venkateswara
- S.M. Gupta
- D. Hirschfeld
- J.S. Mitchell
- A.J. Russell
- E.O. Hoefele
- P.E. McConnell
- R. Maiti
- G.J. Parsons
- L.A.D.S. Baptista
- A.V. Da Costa e Silva
- D. Mounsey
- C. Reid
- G. Sucre
- P. Agarwal
- R. Raudsepp
- D. Singbeil
- D. Crowe
- A. Godoy
- H. Goonetilleke
- D. Gupta
- S. Hibbins
- P. Ivo
- R. Kannan
- N. Munroe (M.Sc)
- L. Orman
- P. Radford
- J. Stenhouse
- R. Hackl
- J. Iyer
- B. Kuban
- E. Samuelsson
- J. Sathaye
- N.E. Tuffrey
- M. Uehara
- K. DeGraaf
- C. Harrison
- S. Minakawa
- S. Ramakrishna
- D. Sarkar
- C. Schvezov
- R. Sriram
- G. Sure
- K. Takagi
- O. Yavuz
- C. Fong
- S. Mulford
- J. Iota (M.Sc.)
- R.B. Mahapatra
- K. Magee
- J. Rechberger
- B. Wiskel
Ph.D. Degrees Awarded
(1922-1987)
Teaching Staff
(1915-1987)
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TEACHING MEMBER

W. Adams
T. Alden
W. M. Armstrong
P. Barr
G. Bell
W. B. Bishop
K. B. Briscoeabe
L. C. Brown
R. G. Butters
R. C. D. Chaklader
G. Coates
L. G. Crouch
S. Dunbar
B. Eklund
H. Evans
F. A. Forward
G. A. Gillies
U. Griffiths
J. Halpern
F. Haes
E. B. Hewbolt
H. Howard
J. Lund
A. Mitchell
E. Morgan
P. Myers
J. H. Nadeau
J. Parr
E. Peters
R. Poursartip
A. Richards
N. R. Risebrough
I. Samarasekara
G. S. Semel
E. Teghtsoonian
H. N. Thompson
D. Troians
J. M. Turnbull
B. J. Walsh
J. Warner
I. Warren
F. Weinberg
O. Wiles

--- FFF
--- FFFFFFFFFFFFHHHFFFFFFF
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--- FFFFFFFFFFFFHHHFFFFFFF
--- FFFFFFFFFFFFHHHFFFFFFF
--- RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
Departmental Budget
DEPARTMENTAL BUDGET
Operating Expenses not including Research Funds

1916-1987

BUDGET (MILLION $)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.1 1.2

YEAR ENDING, 19--