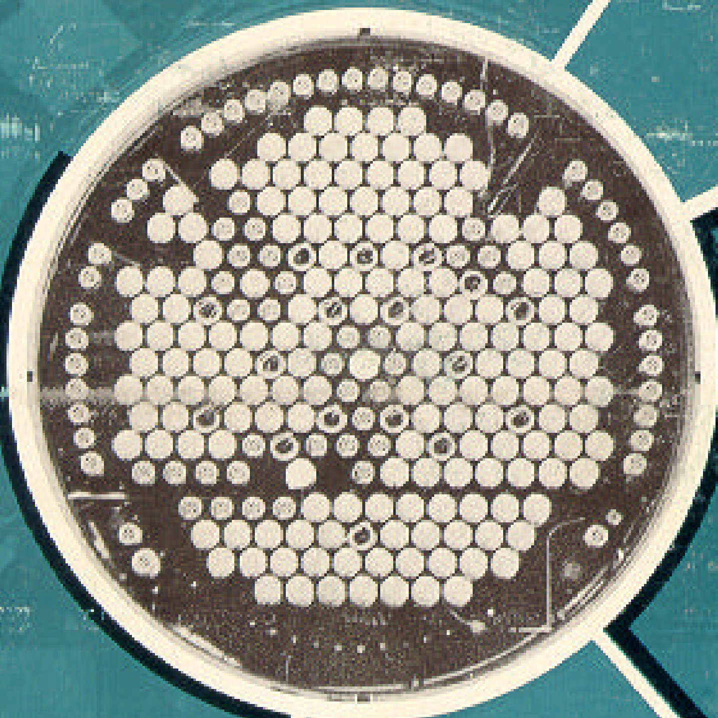
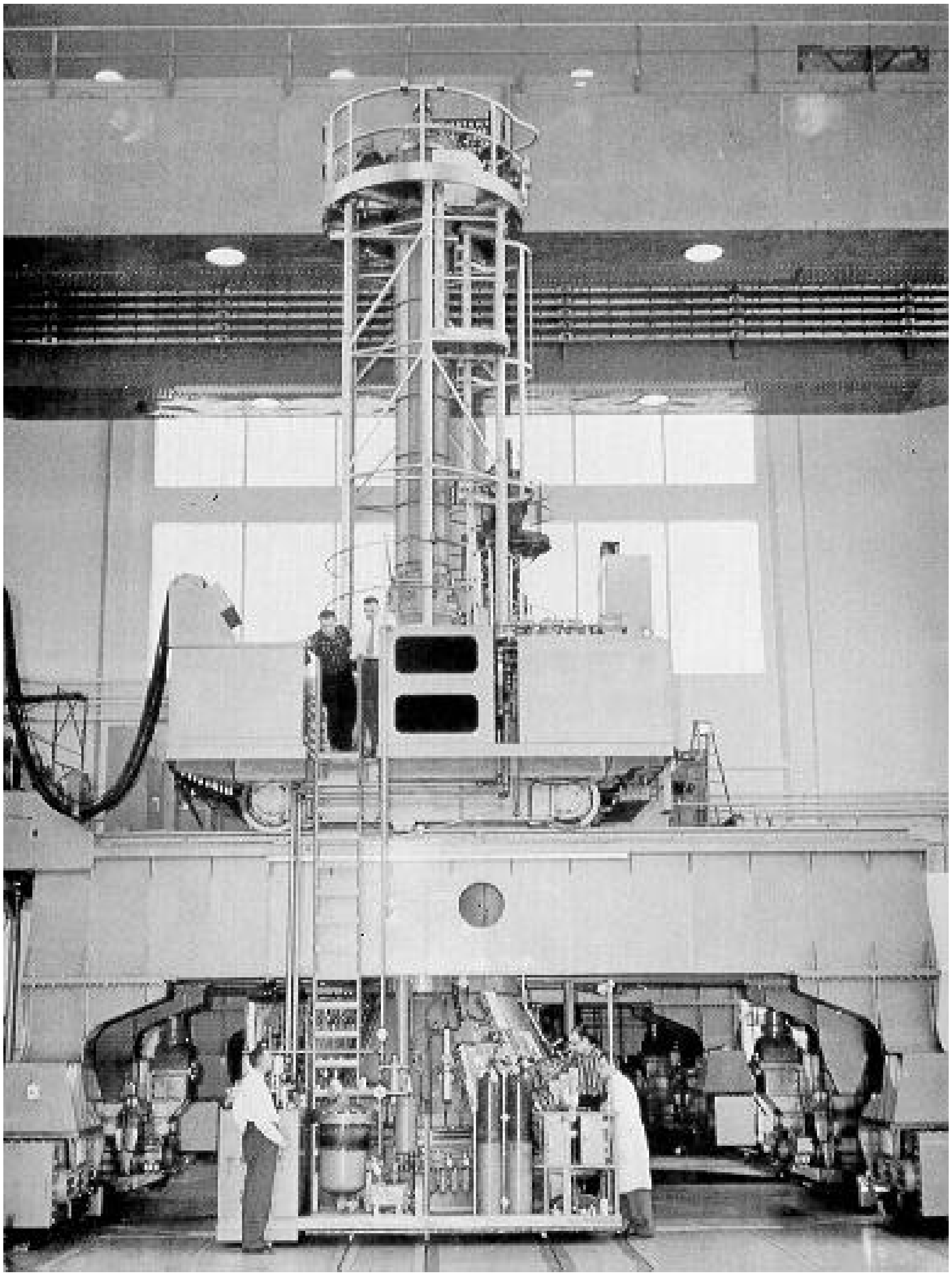
CHALK RIVER
REACTOR SCHOOL



ATOMIC
ENERGY OF
CANADA
LIMITED



CHALK RIVER REACTOR SCHOOL

ATOMIC ENERGY OF CANADA LIMITED
Chalk River, Ontario, Canada

Contents

The 240-ton fuelling machine that inserts and removes rods while the NRU reactor continues to operate.

Foreword . . . . . .

The staff of Atomic Energy of Canada Limited is now applying its extensive experience with natural-uranium, heavy-water reactors to the design of nuclear power plants. These give promise, under certain specific Canadian conditions, of producing electricity at costs comparable to those of plants using coal-fired boilers. In view of the interest both in Canada and abroad in this reactor system, it has been decided to establish a Reactor School at Chalk River. The basic principles of such reactors will be made available to those qualified scientists and engineers who desire to gain practical knowledge in their design and operation.

It is hoped that this service will extend the peaceful application of atomic energy in a field which is of special interest to all countries envisaging the development of this new source of energy.

J L Gray

President
Atomic Energy of Canada Limited

The Chalk River establishment of Atomic Energy of Canada Limited on the Ottawa River, about 130 miles west northwest of Ottawa, Ontario. The plant, which employs 2,400 people, includes five reactors and various physics, chemistry, engineering, metallurgy, biology and medical laboratories.

Canada's Atomic Power Program

The major practical application of nuclear energy for peaceful purposes, apart from the use of isotopes, is the production of power. As the many problems become solved and experience is gained in design, development, fabrication and operation of reactor plants to produce heat or electric energy, costs will come down and many of the early predictions of the benefits of nuclear energy will be nearer to realization.

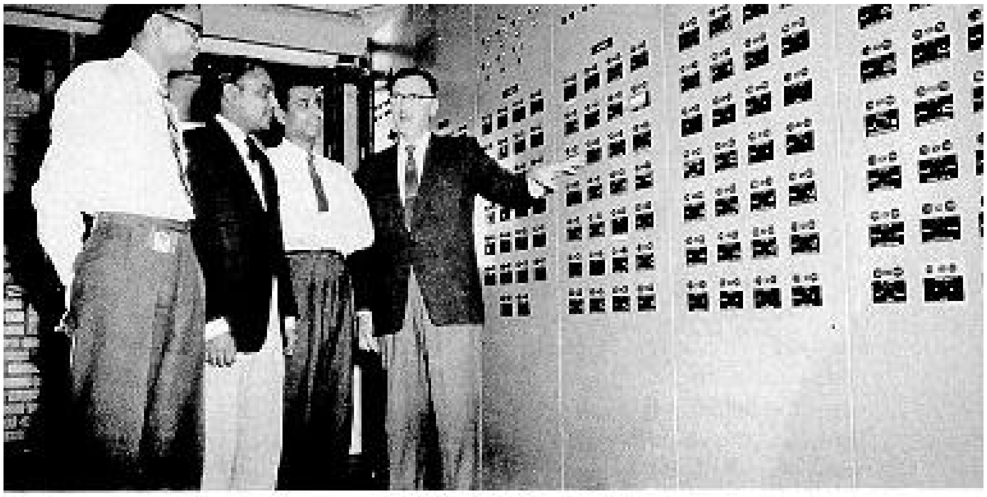
Nuclear power to be economic must meet the conditions that apply to each country and to each individual area and circumstance. In Canada the competition from hydraulic resources and fossil fuels varies tremendously across the country. There are areas where undeveloped water power is still available. It is very doubtful if nuclear power will ever compete with reasonably good hydraulic sites adjacent to load centres. There is a large area in Western Canada where low cost fossil fuels—coal, oil and gas—are available in abundance. There are other areas, however, where the growing demand for power can only be met by thermal plants and where the most economic conventional fuel is United States coal. The cost of this coal sets a target for a nuclear plant. In a public utility enjoying low capital charges, this target is 6 mills per kilowatt-hour.

Canadian scientists and engineers are confident that this objective can be met and, in fact, bettered with a natural-uranium-fuelled, heavy-water-moderated reactor. Canada has devoted much of its attention to this reactor system, has pioneered its development, and has had over ten years experience with the operation of heavy-water research reactors.

The Nuclear Power Demonstration plant (known as NPD-2) is Canada's first nuclear power plant. This plant is under construction at Rolphton, Ontario, about 20 miles from the atomic energy research and development centre of Chalk River. It will have an output of 20,000 kilowatts of electricity and is scheduled to go into operation in early 1961. It will be fuelled with natural uranium in the form of oxide. It will not produce economic power but it is expected to demonstrate the reliability of this system in operation and the economics of the fuel cycle. It will also provide training and will serve as a prototype for a larger station.

A large station known as CANDU (Canadian Deuterium Uranium) has been under design and development for the past three years. This station will have many of the features of NPD-2 and will have an output of 200,000 kilowatts of electricity. It was described in general in Paper 208 at the Second United Nations Conference on the Peaceful Uses of Atomic Energy held in Geneva in 1958. CANDU is scheduled for completion in 1964. It is expected to produce power at costs competitive with coal-fired plants of similar size now operating in Ontario, if the research and development costs are excluded.

Canada is also studying the use of organic materials as coolants for a heavy-water moderated reactor. A specific design of a 40,000 kilowatt thermal reactor experiment using organic coolant is under investigation. A study is also being made of enriched reactor systems of small size for possible application at remote Canadian sites. This latter is relying largely on information and experience from the U.S. program and relating them to specific Canadian conditions.



Staff members of India's Department of Atomic Energy study the NRX reactor at Chalk River.

Chalk River Reactor School

Director

D. A. Keys, Ph.D., D.Sc., LL.D., F.R.S.C.

Secretary

W. R. Livingston, M.Sc., Ph.D.

Staff

D. A. Bromley, M.Sc., Ph.D.
F. Brown, M.A., Ph.D.
R. L. Clarke, B.Sc., Ph.D.
R. E. Manson, B.Sc.
C. H. Millar, M.A., Ph.D.
J. D. Stewart, M.Sc.

Special Lecturers

G. C. Butler, B.A., Ph.D.
Director, Biology and Health Physics Division

R. F. Errington, M.A.
Manager, Commercial Products Division, Ottawa

J. L. Gray, M.Sc.
President,

J. C. Horsman, B.A.Sc.
Reactor Research and Development Division

W. B. Lewis, C.B.E., Ph.D., F.R.S., F.R.S.C.
Vice-President, Research and Development,

J. M. Robson, M.A., F.R.S.C.
Physics Division

C. G. Stewart, M.A., M.D., D.T.M.
Director, Medical Division

Syllabus

The course is intended to provide the basic instruction in those concepts which a student requires in order to understand the design, construction and operation of a nuclear reactor. Special emphasis is given to reactors moderated with heavy water and fuelled with natural uranium, the type with which Chalk River staff have had considerable experience.

The syllabus covers relevant parts of physics, mathematics, chemistry and metallurgy. This is followed by the theory of reactor design, including the necessary knowledge of shielding, radiation effects on fuels, metals, moderators and coolants. Reference will also be made to radiation protection, health physics and waste disposal.

In addition to lectures there will be some laboratory work in the fundamental sciences, electronics and measurements, but the main emphasis will be on practical experience in the operation of heavy-water-moderated reactors and on the use of loops for testing fuels designed for power reactors.

The length of the course will be twelve weeks.

I. Physics, including shielding and electronics.

Fundamental concepts of nuclear physics, atomic and nuclear structure; nuclear radiations and their detection; radiation shielding; design and use of nuclear electronic instrumentation; neutron scattering; nuclear reactions; resonance; partial and total widths; cross sections; relaxation lengths; fission process; chain reaction; neutron balance in reactors; multiplication factors; critical sizes that have direct relevance to reactor design; problems illustrating various aspects of the subject matter discussed.

25 lectures — D. A. Bromley

II. Mathematics and Reactor Physics.

An introduction to the mathematics used in reactor theory; exponential and trigonometric functions; differential, integral and difference equations; Bessel functions. Multiplication of neutrons by fission; critical size of multiplication medium; cross-sections; mean free path for scattering; capture; random walk and diffusion theory; fast fission; slowing down of neutrons; resonance escape; thermal utilization; slowing-down area and migration area; reactor equation for steady state. Effect of reflector; two-group theory of neutron migration; theory of heterogeneous reactors; kinetic behaviour of a reactor; control rods; fission product poisoning; delayed neutrons.

20 Lectures — J. D. Stewart

III. Chemistry and Metallurgy.

The role of chemistry and metallurgy in reactor technology. Production of heavy water and uranium; separation of isotopes; measurement of cross-sections and fission yields; mass spectrometry; effects of radiation on materials, such as fuels, moderators and coolants; corrosion; determination of burn-up; poisons; production of plutonium, its separation and properties; production of isotopes.

20 Lectures — F. Brown

IV. Reactor Control.

The relation of reactor control to fundamental equations of reactor theory; basic reactor kinetics; stability problems and operational aspects. A survey of reactor control components, safety and operational systems.

10 Lectures — C. H. Millar

V. Reactor Engineering.

This course will be based on the technology of heavy-water reactors. Canadian reactors will be described in detail and examples will be taken from actual experience to illustrate problems of heat transfer, fluid dynamics, design problems, engineering experiments and operation of loops and reactors.

50 lectures and demonstration periods — R. E. Manson and others.

VI. Health Physics and Waste Disposal.

Radiation instrumentation and dosimetry; protection against airborne contamination; decontamination equipment; clothing and remote control equipment; radiation surveying and bioassaying; methods of waste disposal.

10 lectures — G. C. Butler, C. G. Stewart and divisional staff.

VII. Isotopes in Industry, Agriculture and Medicine.

The Commercial Products Division of Atomic Energy of Canada Limited manufactures many unique instruments in which radioactive isotopes, notably cobalt-60, produced at Chalk River are used for industrial and medical therapeutic purposes. These isotopes and instruments are not only sold to Canadian users but are shipped to countries throughout the world. The uses of these various isotopes and instruments will be described.

5 Lectures — R. F. Errington and others.

VIII. Research, Testing and Power Reactors.

An account will be given of typical types of reactors in use in different countries for research, testing materials and for generation of electric power. This will be a survey indicating the special characteristics of such reactors with emphasis on those that have been constructed for generation of electricity. The relative efficiencies of such reactors for meeting the economic demand for generating electricity, producing steam for space heating and process purposes will be discussed.

5 Lectures

J. L. Gray
W. B. Lewis
and others.

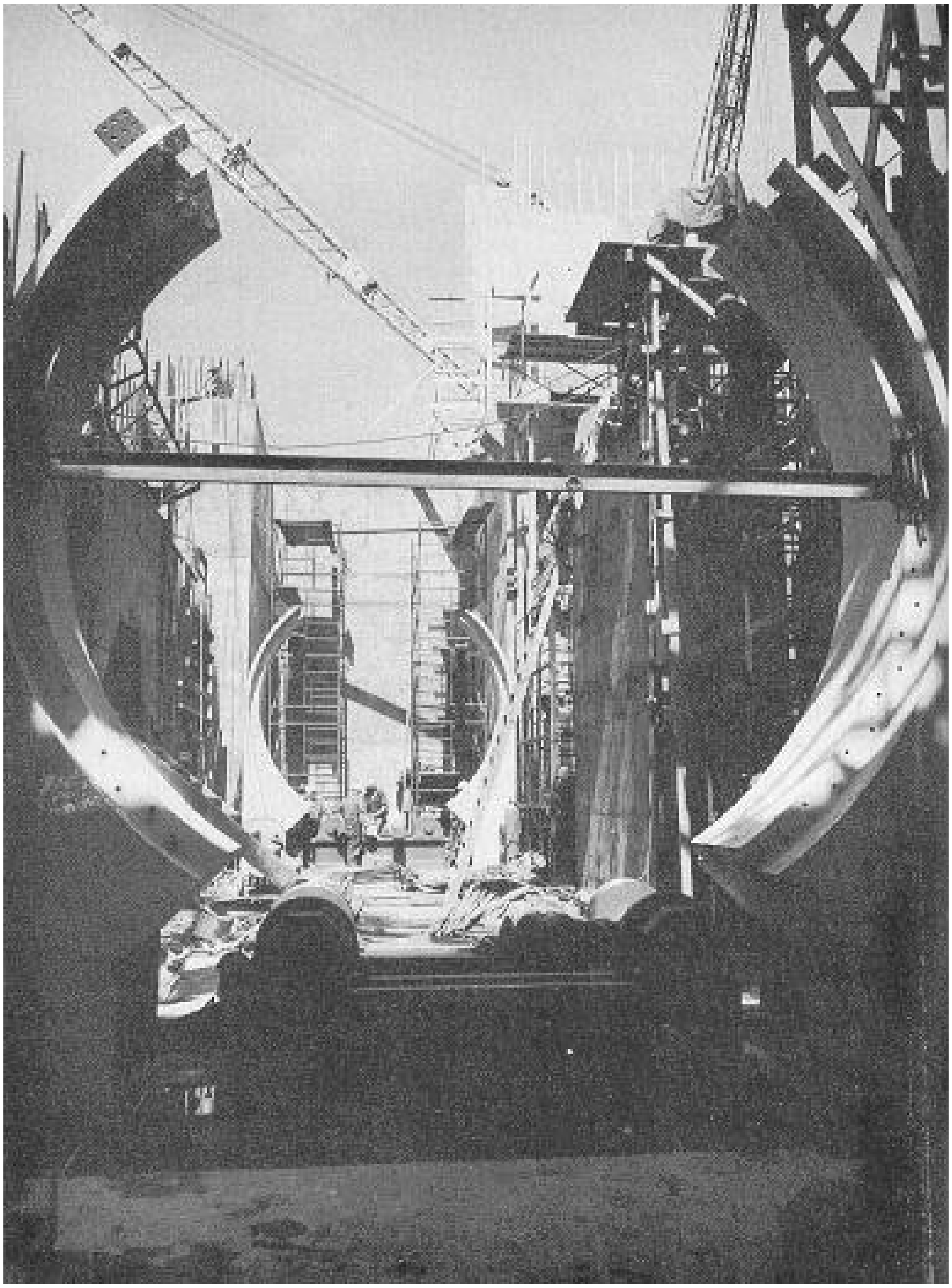
IX. Laboratory work.

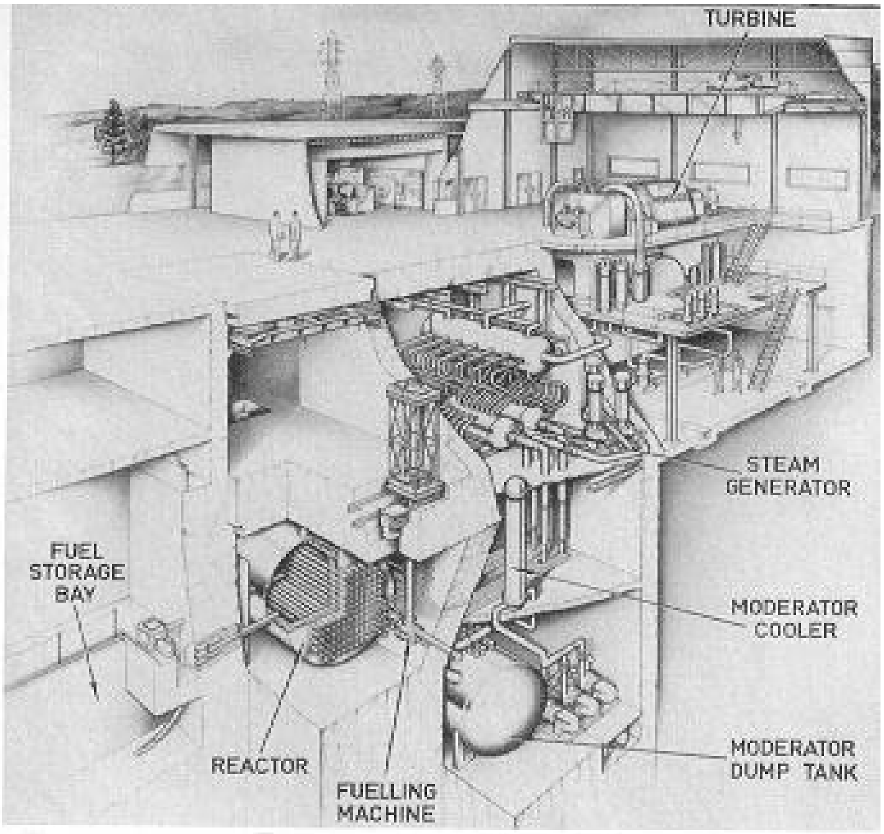
A practical course on the use of various types of detectors, counters, and pulse analysers; measurement of half-lives, fission-yield curves; scattering; effect of moderators, and experiments on shielding. Use will be made of neutron beams from a reactor for experiments illustrating reactor theory. Coincident counting; ion exchange separation; radiation chemistry. Some practical use of various electronic devices will be made.

R. L. Clarke
and others.

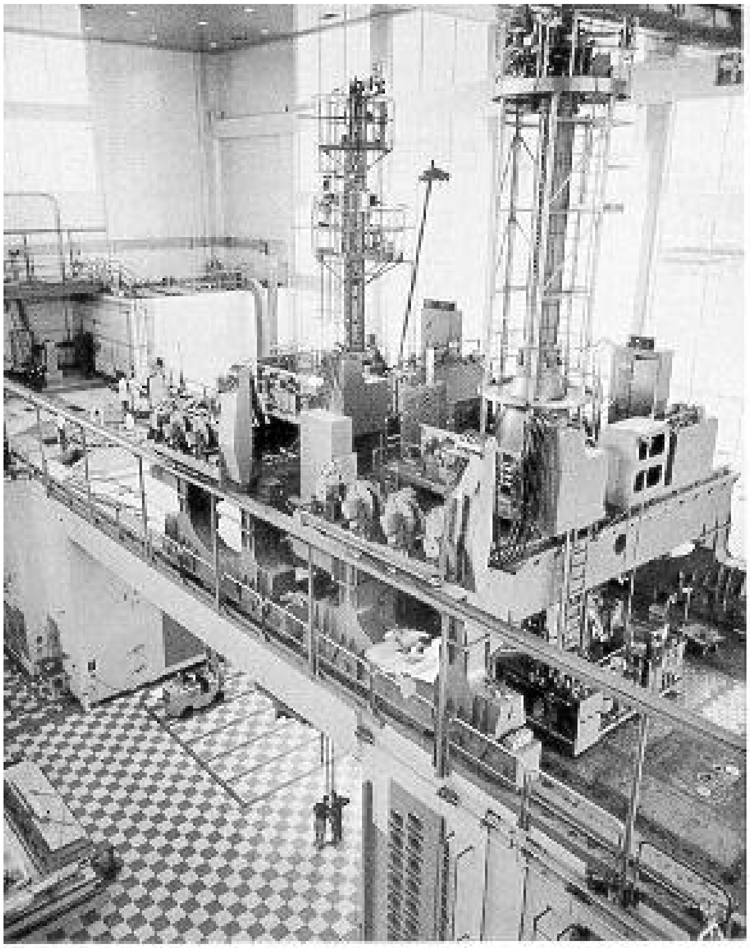
Laboratory work on reactors will include reactor tours, discussions and demonstrations of various equipments and operations as well as the use of a reactor simulator. Explanations of the construction and operation of the actual control mechanisms of the NRU, NRX, PTR, ZEEP and ZED-2 reactors will be followed by demonstrations.

R. E. Manson
C. H. Millar
and operational staff.

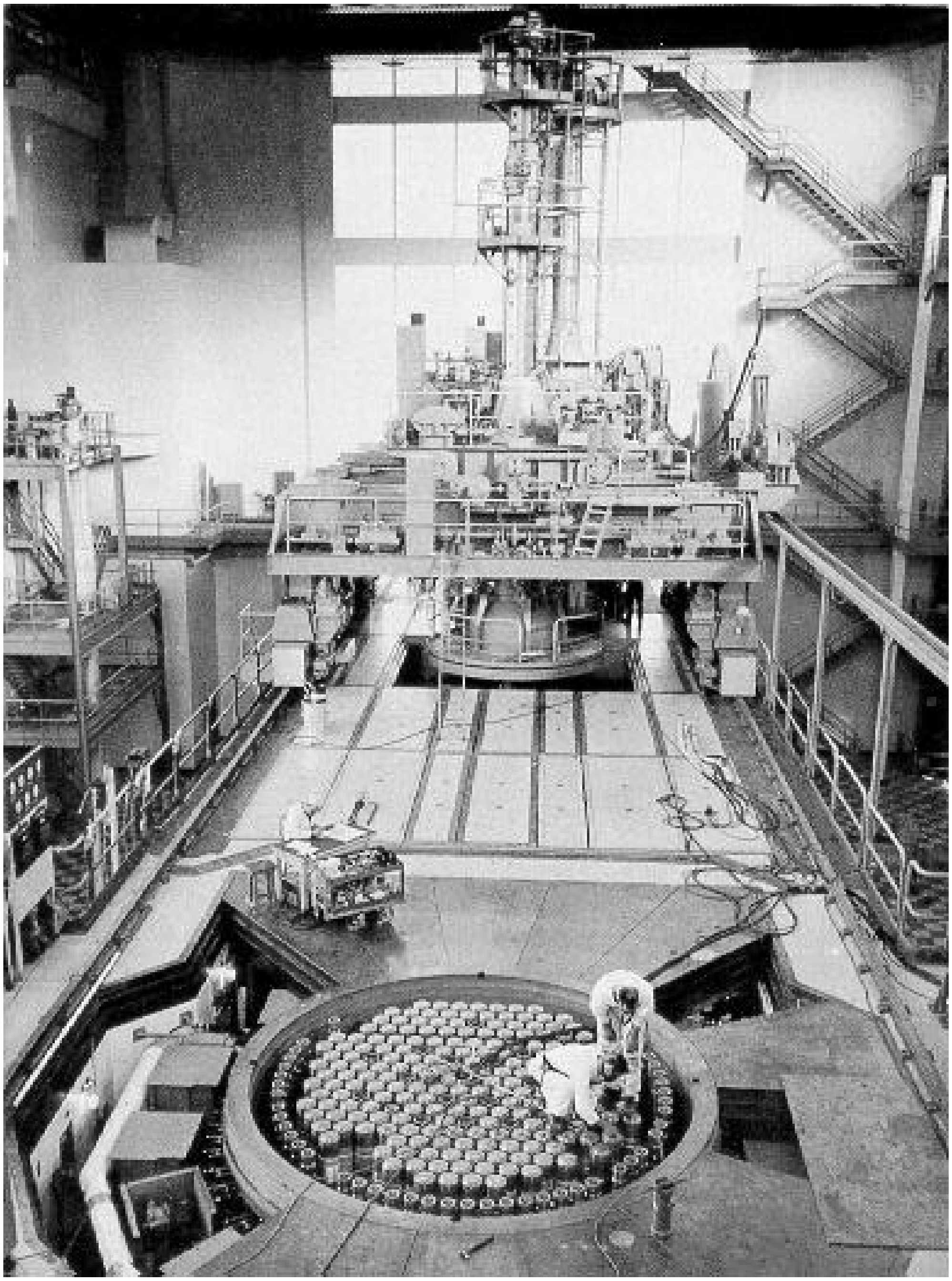


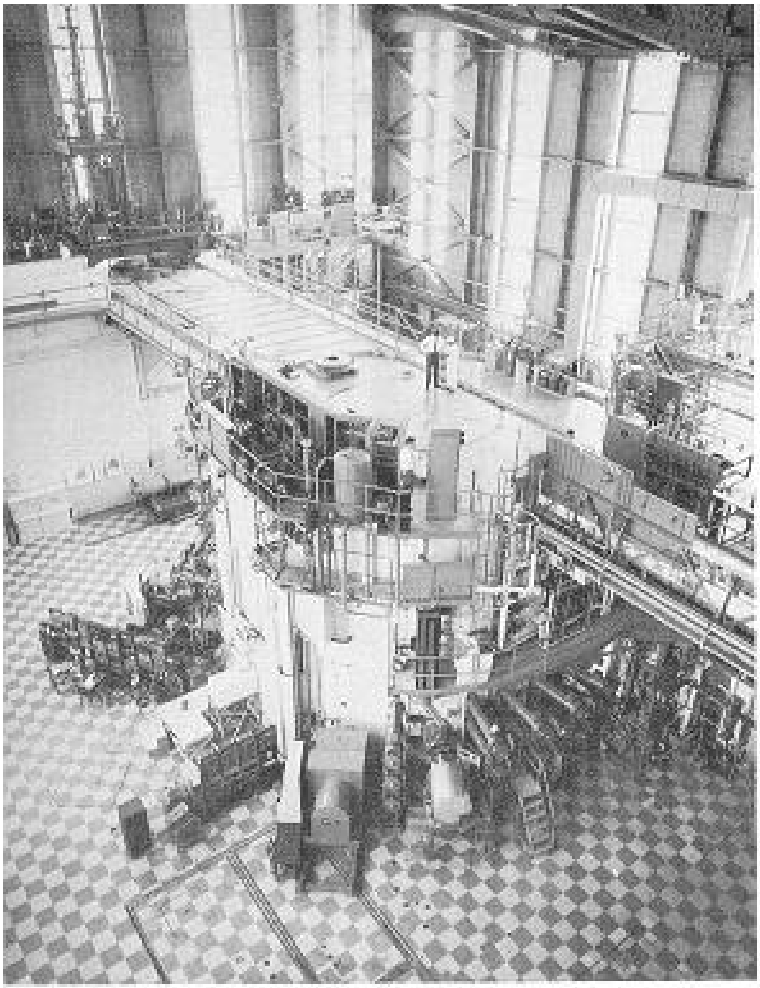


Canada's first atomic power station, shown under construction at left and illustrated above, is known as NPD (Nuclear Power Demonstration). It is a joint project of Atomic Energy of Canada Limited, the Hydro-Electric Power Commission of Ontario, and Canadian General Electric Co. Ltd. The NPD station will produce 20,000 kilowatts of electricity when it goes into operation in 1961 and will serve as a prototype for large-scale plants. It uses natural uranium, in the form of uranium oxide, for fuel and heavy water for moderator and coolant. A.E.C.L. has begun the final design of a 200,000 kilowatt (electrical) station known as CANDU (Canadian Deuterium Uranium). This plant is scheduled for completion in 1964.

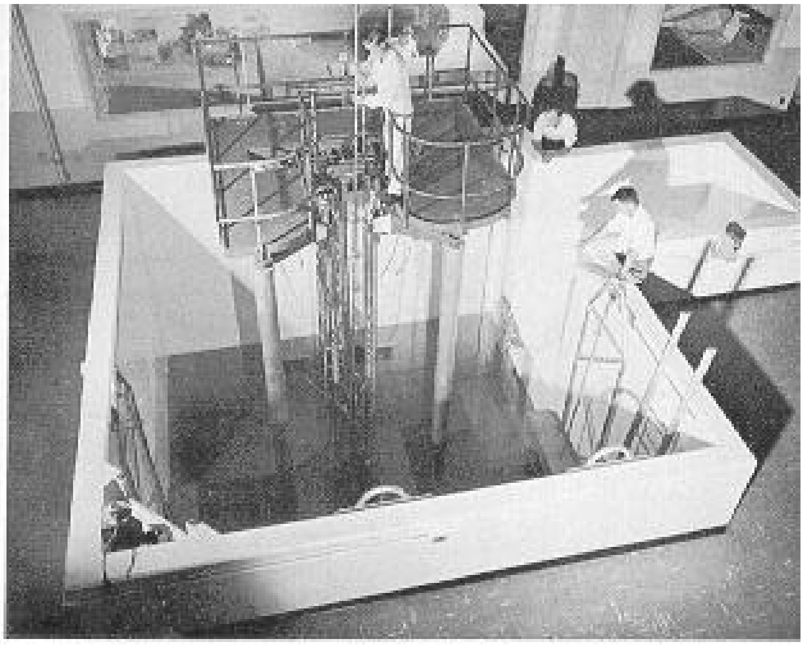


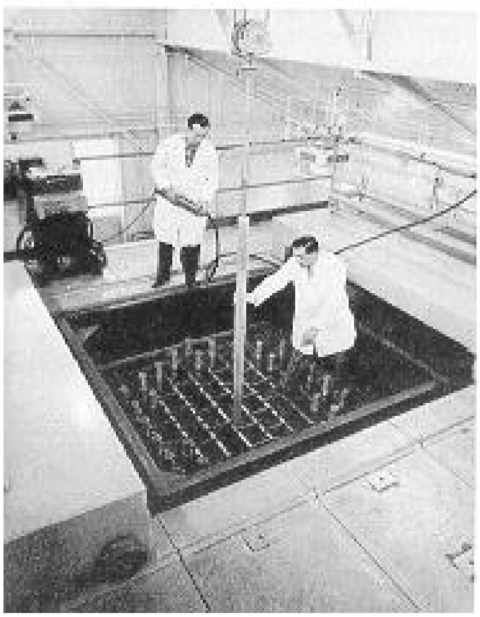
The 200,000 kilowatt (thermal) NRU reactor is fuelled with natural uranium and cooled and moderated with heavy water. A triple purpose machine, it produces plutonium, makes radioactive isotopes and has extensive facilities for research, engineering development and testing. Fuel assemblies are tested in "loops", under conditions that simulate those of a power reactor. The tower-like structures are the fuelling machine and the isotope flask.



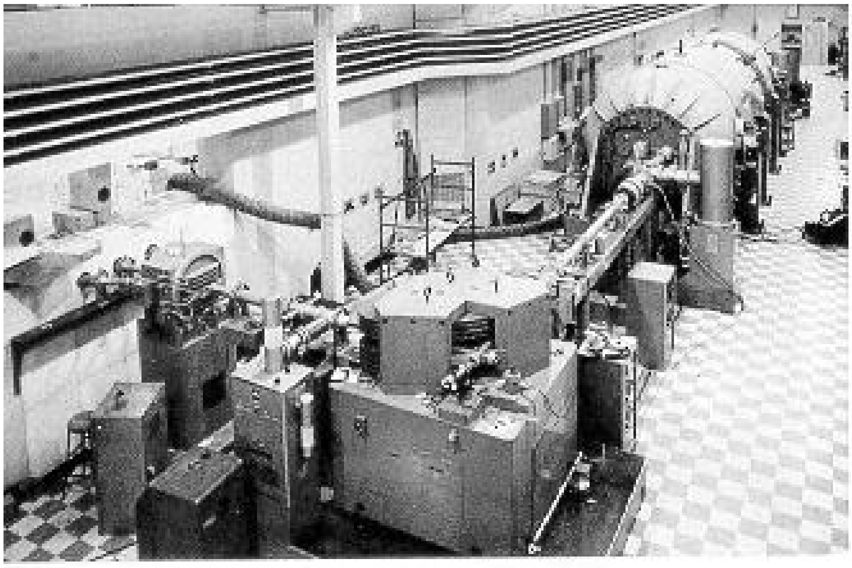


The NRX reactor uses natural uranium for fuel and heavy water for moderator. It is cooled with ordinary water. The 40,000 kilowatt (thermal) machine is used for atomic power experiments, fundamental research and the production of radioactive isotopes for medicine, industry and agriculture.

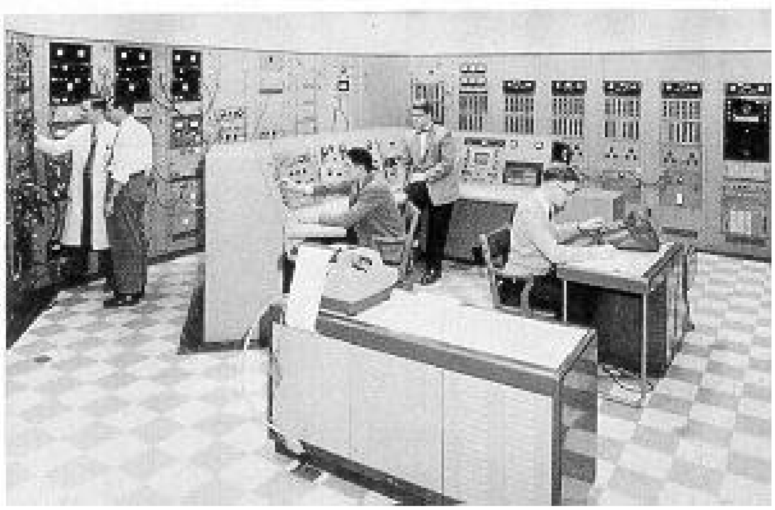


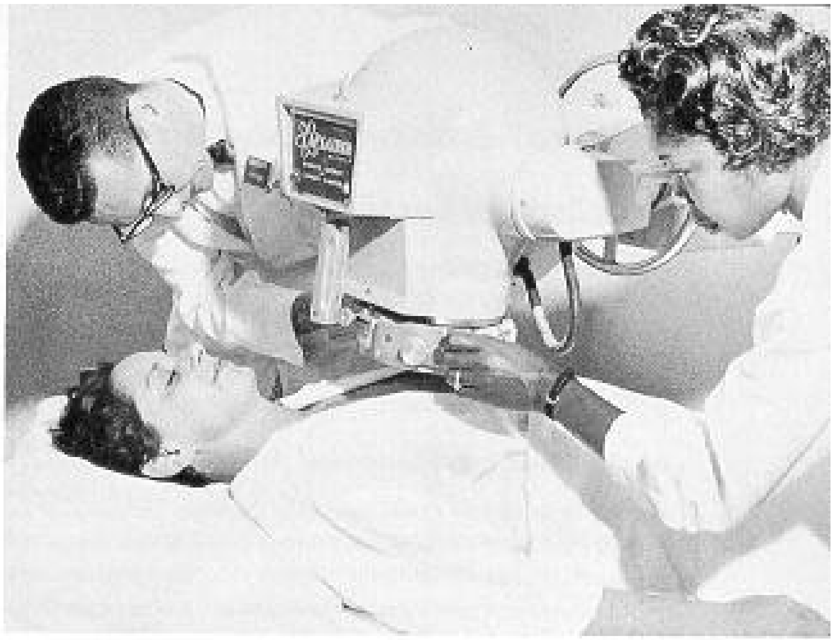


Three reactors with heat outputs of about 100 watts provide facilities for a variety of experiments at Chalk River. The Pool Test Reactor, shown above, is used for testing the reactivity of fuel samples and the neutron absorbing properties of other materials. The ZEEP reactor, left, is used to test various types of fuel rods arranged in different lattices. A large ZEEP-type reactor, known as ZED-2, is to be used primarily to investigate the physics of fuel for large atomic power stations.

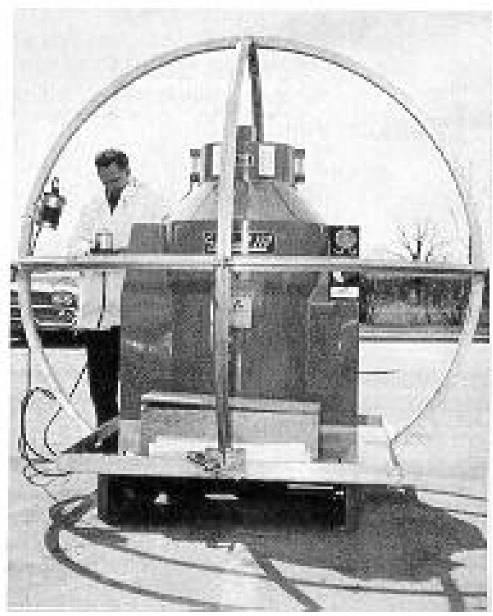


The 10 million electron volt Tandem Accelerator, the first of its type to go into operation, has extended the range of precise nuclear measurements to the heaviest elements. The control room is shown below.





A cancer patient (above) is treated with gamma rays from a Caesatron, one of several types of therapy machines manufactured by the Commercial Products Division of Atomic Energy of Canada Limited. Canada's therapy units have been installed in clinics in 27 countries. In the photo at right the shielding of a Gammacell is being tested. The machine is a portable irradiation unit that has a wide variety of applications, such as the study of effects of radiation on lubricants, plastics and drugs.



General Information

Entrance Requirements

Applicants should possess a university degree in Physics, Engineering Physics, Chemistry, Metallurgy or Engineering with a good knowledge of undergraduate mathematics. Some professional experience or post-graduate training would be desirable. A good command of oral and written English is essential.

Application for Admission

Application forms may be obtained from Canadian Embassies or Consulates, or from the Secretary, Chalk River Reactor School, Atomic Energy of Canada Limited, Chalk River, Ontario, Canada. Canadian students should send their applications to the Secretary; foreign students should send their applications to the Canadian Embassy or Consulate in their country.

Selection

The number of students admitted to each course will be limited and in selection greatest weight will be given to academic record and experience.

Regulations

While attending the school, students will have the status of employees loaned to Atomic Energy of Canada Limited and will be subject to the same supervision and regulations as regular employees. The hours of work are from 8.15 a.m. to 4.25 p.m. Monday to Friday. Students will have use of library books and may read current scientific journals in the library reading room.

Examinations

The Chalk River Reactor School does not grant academic degrees. However, examinations may be held during and at the end of the course to enable the student to evaluate the progress he has made.

Passports and Visas

Passports and visas should be arranged by the student. Atomic Energy of Canada Limited cannot be responsible for making such arrangements.

Transportation

Transportation from the student's home to Deep River and return must be arranged and paid for by the student or his sponsor.

Living Accommodation

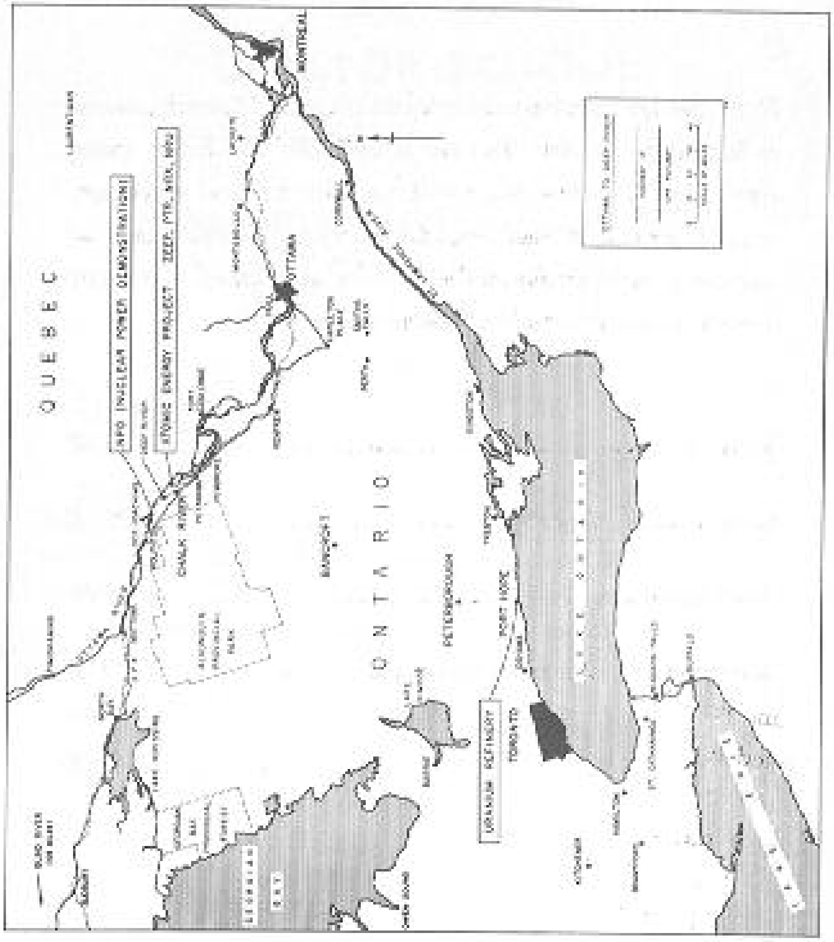
Single rooms will be provided in a staff residence in the neighbouring town of Deep River. Accommodation is not available for wives or families of students. Meals may be purchased at the staff residence dining room or at a local restaurant. A cafeteria is operated at the Chalk River Project where midday meals may be purchased.

Tuition

The tuition fee will include the cost of the text-books, laboratory books and laboratory materials that will be provided. It does not cover items considered to be personal requirements, such as slide-rules.

The tuition fee is payable to Atomic Energy of Canada Limited prior to enrolment.

The town of DeepRiver (population about 4,500) was built on the south bank of the Ottawa River as the main residential area for A.E.C.L.'s employees and their families. It is located in a region that provides excellent opportunities for fishing, hunting, skiing and boating. The town contains a bank, a theatre, a library, a post office and several stores. Various buildings and areas provide facilities for more than 60 clubs and organizations such as: Drama Club, Choral Society, Golf Club, Yacht and Tennis Club.


QUEBEC
ONTARIO
OTTAWA
MONTREAL
TORONTO
PETERBOROUGH
PORT HOPE
URANIUM REFINERY
CHALK RIVER
NPD (NUCLEAR POWER DEMONSTRATION)

Fees and Living Costs

The number of students attending each 12-week course is limited to twenty. The fee is $600.00. The living costs, exclusive of tuition fee, clothing and medical expenses, may be estimated from the following figures and should be sufficient for a single student living at a Deep River staff residence for a period of twelve weeks.

Food	$250.00
Room	$135.00
Transportation	$ 15.00
Miscellaneous Personal Expenses	$175.00
	$575.00

ATOMIC ENERGY OF CANADA LIMITED

CHALK RIVER REACTOR SCHOOL

APPLICATION FORM

Course No. Date

1. NAME
   Surname Given names in full Dr. ( ), Mr. ( ), Miss ( ), Mrs. ( )

2. PRESENT ADDRESS

3. NATIONALITY AGE MARITAL STATUS
   Married ☐ Single ☐

4. NAME AND ADDRESS OF SPONSOR

5. EDUCATIONAL QUALIFICATIONS

Diploma or degree	Pass or Honour	Course	University	Year

6. ACADEMIC RECORD (Grades obtained)

7. INDUSTRIAL, POSTGRADUATE or other EXPERIENCE

From	to	Employer	Position held

8. Person to be notified in case of emergency

9. Applicant's signature Sponsor's signature