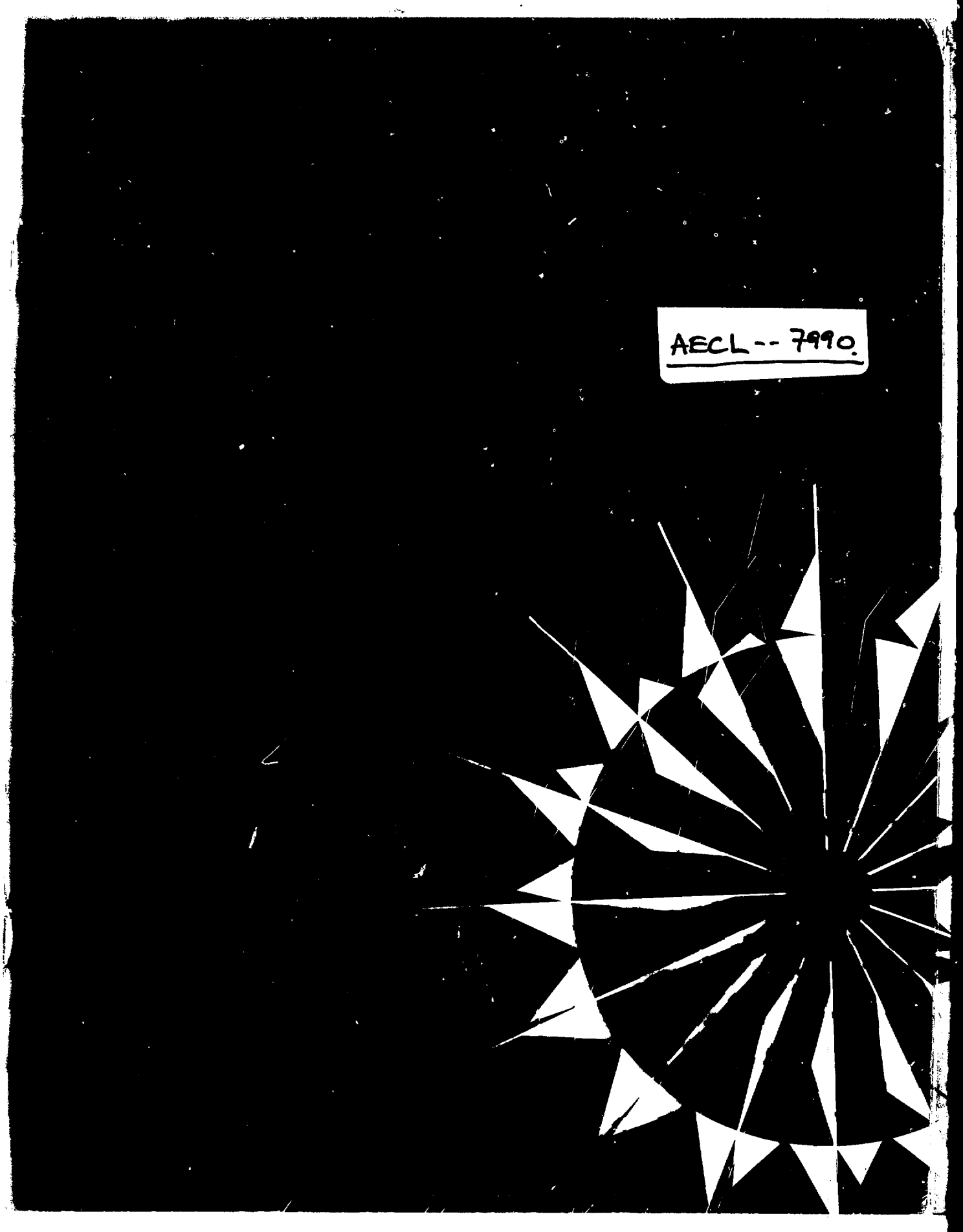
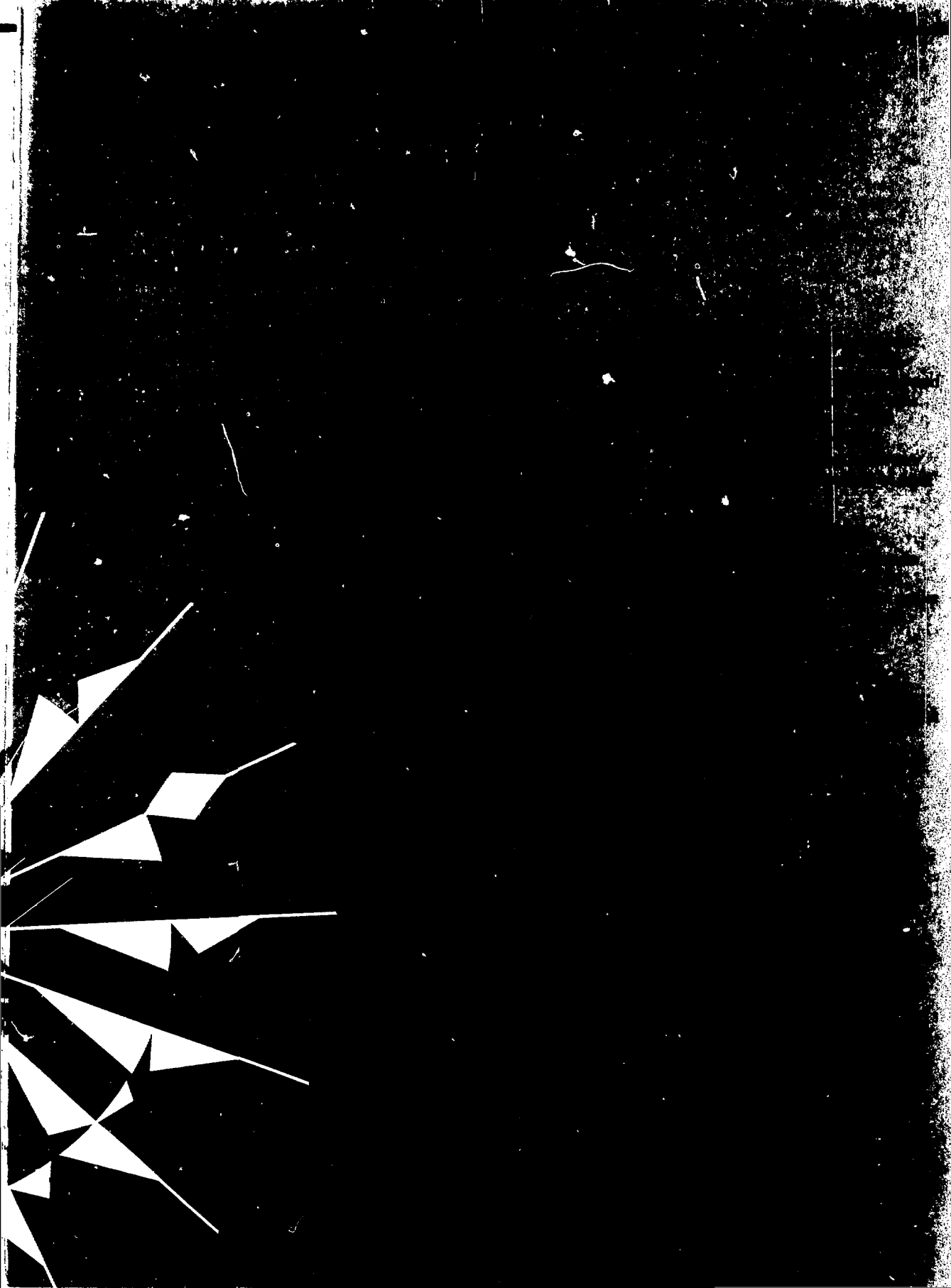
AECL--7990





SECTION 1

SECTION 2

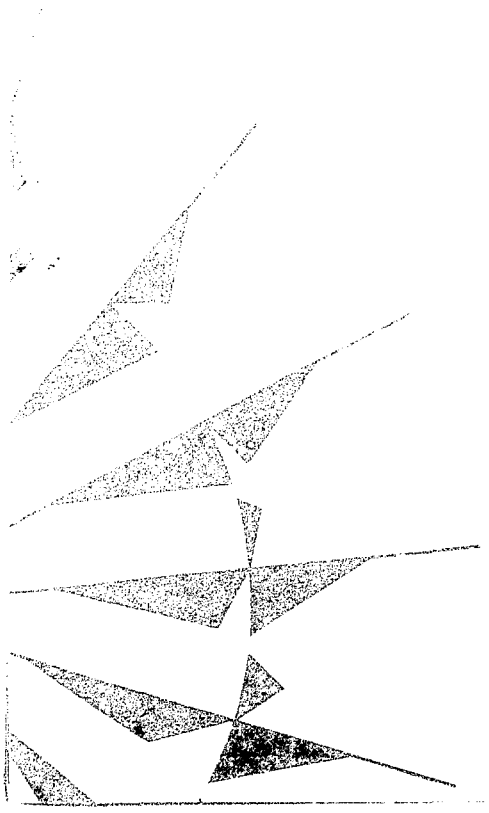
# Energy From the Atom

## *A Challenge Met . . . A Future Secured*

Across the land scientists working with over 30,000 talented Canadians are playing a prominent role in harnessing the energy of the atom for the well-being of mankind. This is the story of their work and their achievements.



While it is not a history of nuclear energy development in Canada, the story does have historical undertones. Four decades of dedicated and innovative research and development have given Canadians today a world-leading energy technology.



And for tomorrow, research now under way in Canada's nuclear laboratories is targetted at ensuring that nuclear energy will continue its vital role in Canada's growth and prosperity well into the future.

Since Canada's tiny first nuclear research reactor — the first in the world outside the United States — began operation in 1945, this country's nuclear program has grown to produce rich dividends. Our nuclear success story has given us an independent technology which assures electrical energy security on our own terms and for the benefit of this country and others.

It also enables Canada to compete effectively in world markets as a supplier of nuclear technology, not only for electricity generation but also in the rapidly advancing science of nuclear medicine and in application of radiation processes in industry and agriculture.

The cornerstone of Canada's nuclear industry is Atomic Energy of Canada Limited, incorporated as a Federal Crown Corporation in 1952 to assume responsibility for the country's nuclear research. Its mandate: "To develop, for the national benefit, the peaceful uses of atomic energy".

Experience gained with several early research reactors led, in 1962, to Canada's first power reactor, a 20-megawatt demonstration model which was the forerunner of the well-known and uniquely Canadian CANDU. Canadian-developed CANDU stations are today providing dependable and economic electric power. By international standards for safety and reliability of operation CANDU reactors are world leaders.

Today's CANDU system is testimony to the success of our mission in the early years — to develop a nuclear power system using Canadian resources to meet Canada's needs. The industry which AECL spearheads today reflects that success. Based on strong and coherent research, development and engineering capability, it incorporates the expertise and ingenuity of Canada's manufacturing industries, electric utilities, universities and consulting firms.

This achievement offers encouragement to other developing countries where nuclear energy may be the best, or perhaps only, solution to their electric power needs.

Canada's nuclear story, well respected at home and abroad, is one in which all Canadians can justifiably take pride. As we move ahead, Canadians can look confidently to a future in which energy from the atom will take on ever-growing importance.

# Research Meets the Challenge

*"I would like to express my admiration for the technological achievement of the CANDU reactor. Canada can be proud of this reactor".*
*Curt Heindenreich, European Economic Community.*

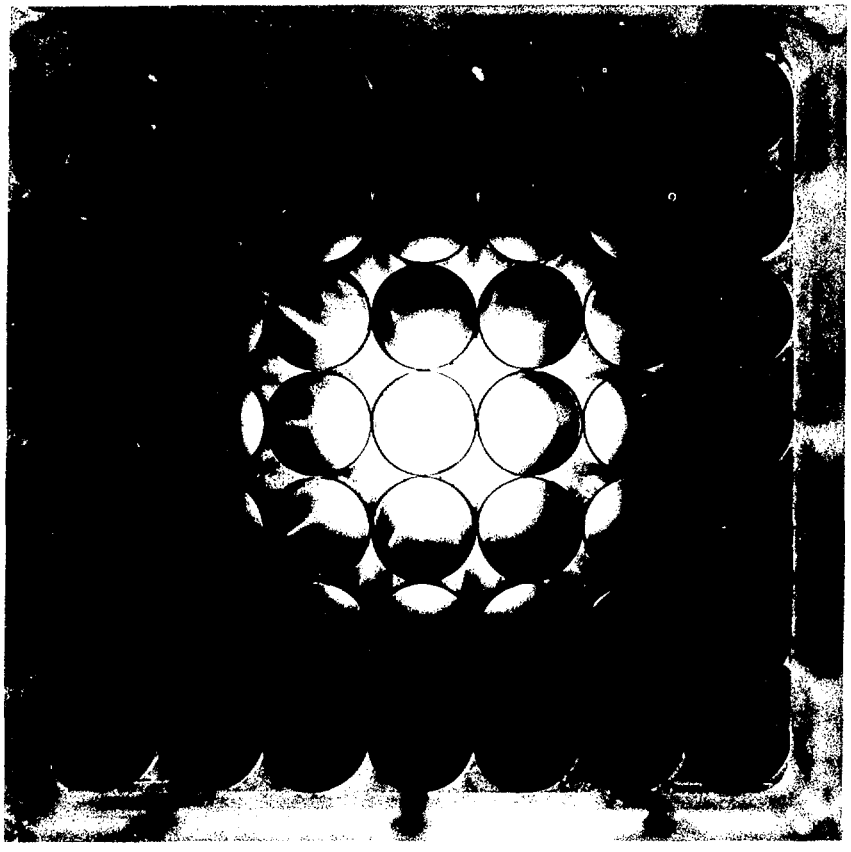


Traditionally the energy which people have relied on to maintain their livelihood has been obtained by burning natural deposits of coal, oil and gas. These fossil fuels, formed over millions of years by decaying animal and plant matter, cannot be replaced. Neither are they always readily and universally available. New energy sources had to be developed to meet the world's rapidly growing needs.

That was the important and exciting challenge facing the world's nuclear scientists in the early 1950s, even though at that time fossil fuel reserves seemed plentiful.

Atomic Energy of Canada Limited was born as a nuclear research organization at Chalk River, on the Ottawa River upstream from the nation's capital. The Chalk River research centre, along with a second centre established later at Whiteshell, in Manitoba, form Canada's national laboratory for research in atomic energy and the nuclear sciences.

Experimental assembly to study flows of air and water mixtures for reactor research



From this national laboratory comes the technology which is keeping Canada in the front ranks of world nuclear energy development. Research at Chalk River and Whiteshell brings together the expertise of many of the scientific as well as engineering disciplines, including chemistry, physics, materials science, biology, medical biophysics and environmental studies.

**Wide Spectrum of Research**
Fundamental to the scientific progress which is the lifeblood of human survival is a better understanding of the natural environment. AECL's research and development programs extend over a wide spectrum to achieve this goal, covering such areas as radiation damage in solids, environmental studies, new uses for nuclear energy and development of CANDU fuels for the long-term future.

**Understanding Matter**
AECL research scientists are playing an internationally respected role in probing the mysteries of nature to extend still further the contribution which energy from the atom can make to human progress.

Nuclear physicists are pursuing far-reaching studies using sophisticated scientific equipment such as the tandem accelerator and superconducting cyclotron, designed and developed at Chalk River.

Operating together, these two devices form a powerful atom-smashing machine which provides intense beams of energetic particles. Through study of what happens when these high-speed particles collide with target nuclei, scientists are able to determine the internal structure and energy states of nuclei, and hence obtain a better understanding of the fundamental properties of matter.

Artist's conception of the Underground Research Laboratory, part of the waste management program

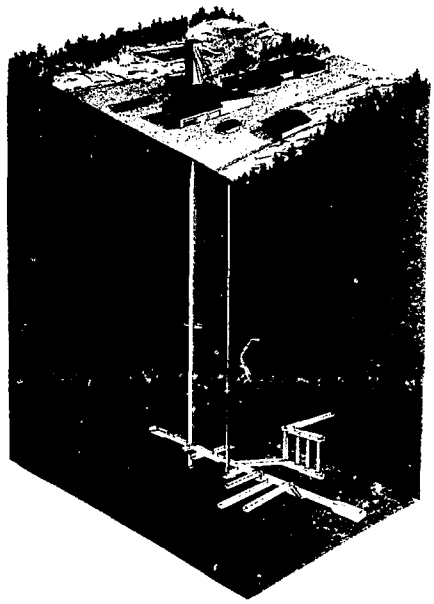
The knowledge obtained is vital not only to nuclear energy's future role in service to mankind, but to the broadest reaches of science.

**Effects and Benefits of Radiation**
One of the principal thrusts of AECL research is a better understanding of the effects of radiation on all living organisms. This, in turn, leads to improved assessment of radiation standards used for health protection.

The most sensitive target for radiation in a living cell is the genetic material known as DNA. AECL researchers are investigating the effect of radiation on DNA. The research, funded jointly by the U.S. National Cancer Institute and AECL, enjoys international recognition.

Although there is public concern about the effects of radiation, it in fact has many beneficial uses for cancer treatment and medical diagnosis, as well as in industry and agriculture. These applications are part of this scientific pursuit.

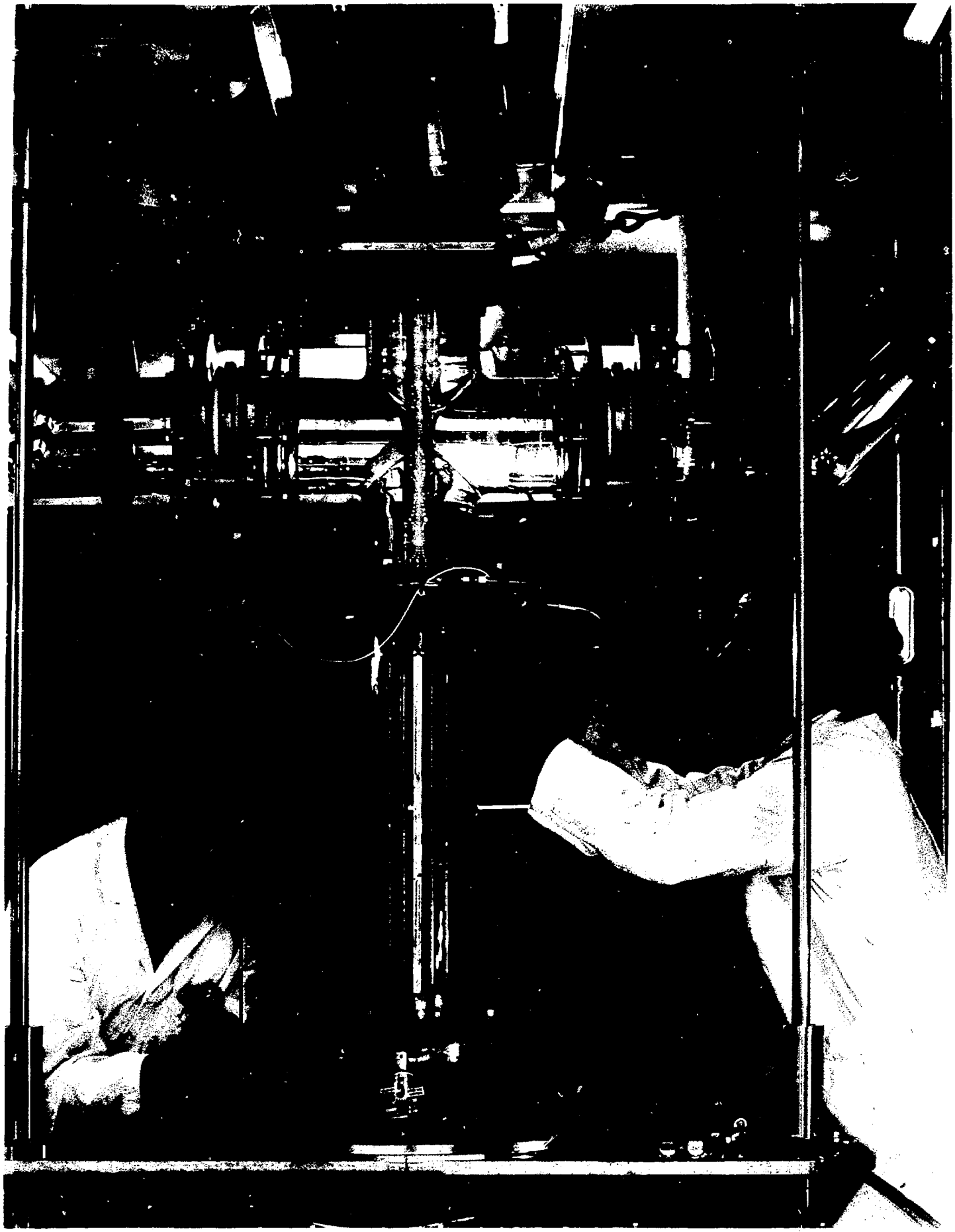
**Reactor Safety**
Operation of a nuclear reactor results in production of highly radioactive materials, which are contained in a controlled environment subject to the highest safety standards. Defence-in-depth features of the CANDU system include multiple containment barriers, shut-down and other safety systems and high quality reactor components consistent with world standards.



This precision technology coupled with Canadian operating expertise have enabled CANDU to achieve an unsurpassed safety record.

Despite the minimal risk, AECL research teams continue to give high priority to ensuring that, even should a reactor malfunction occur, radiation doses to the public would still be within established limits. The broad range of reactor safety research includes programs to define the behavior of the reactor fuel, the fuel channels and the cooling and containment systems following various hypothetical malfunctions.

Test apparatus simulating the Slowpoke mini-reactor is fabricated in Pyrex to enable visual monitoring of experiments.



Assembly of micro-circuits is a delicate task which must be done in a dust-free environment at AECL laboratories.



**Disposal of Wastes**
Ninety-nine per cent of the radioactive material produced in the operation of a nuclear generating station is contained in the used fuel discharged from the reactor.

At present wastes are stored safely at reactor sites, under water which is a barrier to radiation. However, to meet the needs of future generations which will rely on a greater presence of nuclear energy, AECL, along with nuclear agencies in other countries, is developing techniques for permanent disposal.

A full-scale scientific program at the Whiteshell research centre is aimed at burying the waste in an underground storage vault deep in the granite of the Canadian shield. Research so far indicates that nuclear waste in such a facility would not pose any significant hazard to mankind or the environment.

The program brings together scientific expertise from government, private industry, universities and the utility sector.

**The Environment**
Closely linked to the waste disposal program are investigations to learn more about the environmental behaviour of radioactivity and how it can be controlled.

Studies of surface and sub-surface water movements are giving scientists a greater understanding of the basic mechanisms which control dispersion of radioactive material in the environment. As well, research on the transfer of the radioactive elements cobalt-60 and strontium-90 through aquatic food chains is providing insight into processes controlling accumulation of radioactivity by living organisms. The effects of radiation on plants and animals in a natural environment are being studied at Whiteshell.

**Technology for Quality**
The unsurpassed performance record which CANDU reactors have achieved has not come about by chance. It is the result largely of the high degree of attention given to quality and performance of the components of the reactor system which operate under a unique combination of conditions.

Continuing research is aimed at developing component materials even better able to withstand these conditions and at perfecting water chemistry control to further reduce corrosion of reactor components.

Other programs in support of the CANDU system are targetted at increasing the power that can be obtained from the fuel and at further improving performance and safety through state-of-the-art reactor instrumentation and control equipment.

In its various research programs, AECL maintains close cooperation with Canadian industries through research and development contracts and licensing agreements. And to help assure Canada's nuclear expertise for tomorrow AECL researchers work closely with universities on joint research programs, contracts, staff exchanges and student employment.

On-power fuelling – a key to CANDU's success

# CANDU — The Technical Marvel

*"It is a technical wonder. Not only is it very conservative in fuel, but it works with a regularity and reliability that are absolutely fantastic."*
*American scientist and Nobel Prize winner Dr. Hans Bethe on CANDU.*



The Canadian designed and developed CANDU nuclear reactor is the only realistic competitive nuclear system to the Light Water Reactor (LWR), originally designed and developed in the United States. It is the centrepiece of a multi-billion dollar Canadian industry.

The close cooperation between Atomic Energy of Canada Limited, the designer, Canadian utilities, and the component manufacturing industry continues to be a key factor in the successful development of the CANDU system. With more than 100 companies producing CANDU components, Canadian content of CANDU reactors built in Canada is close to 90% of capital cost and includes all main components. These companies are grouped under the

- CANDU has the best uranium utilization of any commercially available system yet devised, by a margin of 20%. This results partly from the use of heavy water, which moderates or slows the speed of the neutrons, giving more efficient use of the uranium, and partly because all components are designed to obtain maximum neutron usage; the basis of good economy in a reactor.

- CANDU reactors are re-fuelled while they are in operation, a major reason for the world leading performance figures that put CANDU well ahead of its rivals in terms of capacity factor, the amount of electricity produced relative to what a reactor could produce at 100% power for 100% of the time.

- CANDU makes use of Canada's major resources of uranium without need for costly enrichment of the fuel. This, and the simple fuel design, help explain the fact that CANDU has the lowest fuelling costs.

umbrella Organization of CANDU Industries, which represents the private sector of the nuclear industry and participates with and assists AECL in the development, promotion and export of CANDU reactors.

A number of specialized characteristics of the CANDU system have contributed to the outstanding success of current CANDU units and will guarantee continued high performance well into the future:

CANDU fuel bundles being assembled at plant of Canadian General Electric

Uranium mining at Denison Mines uranium operations at Elliot Lake, Ontario



- CANDU has inherent safety features absent from other systems, including the existence of a separate moderator providing a large supply of cool water readily available in the event of an accident.

- CANDU design can accommodate future fuel cycles to make more efficient use of uranium without any basic change in reactor design.

**Evolutionary Design**

The development and design of the CANDU reactor has passed through a long period of evolution. The engineering section of AECL, located near Toronto and in Montreal, has been involved for almost three decades in design development. This section also supplies nuclear equipment and provides management services to Canadian and overseas utilities. In addition, it is responsible for tendering and sales support for the CANDU system.

The AECL Sheridan Park Engineering Laboratory (SPEL), near Toronto, provides engineering and design support services for current CANDU projects, and for the maintenance and operation of nuclear components in the stations once they are operating. SPEL develops specialized equipment to solve specific problems and offers on-the-job experience in diverse areas for outside engineers.

Construction activity at Ontario Hydro's Bruce B nuclear station (above). Inspecting a turbine rotor (below) prior to a turbine start-up.



Standardization of a detailed reactor design has many advantages in economy and adaptability and AECL has adopted the 600 megawatt CANDU design as a standard. This size is ideal for electrical systems of relatively restricted capacity, or power stations using more than one reactor.

For utilities with systems capable of handling large blocks of power, AECL has designed a standardized 950 megawatt CANDU, using the same basic components as the CANDU 600. This puts the Canadian nuclear industry in a strong position to offer proven plants incorporating equipment designs already excelling in service, to cover all commonly required power needs for both domestic and overseas markets.

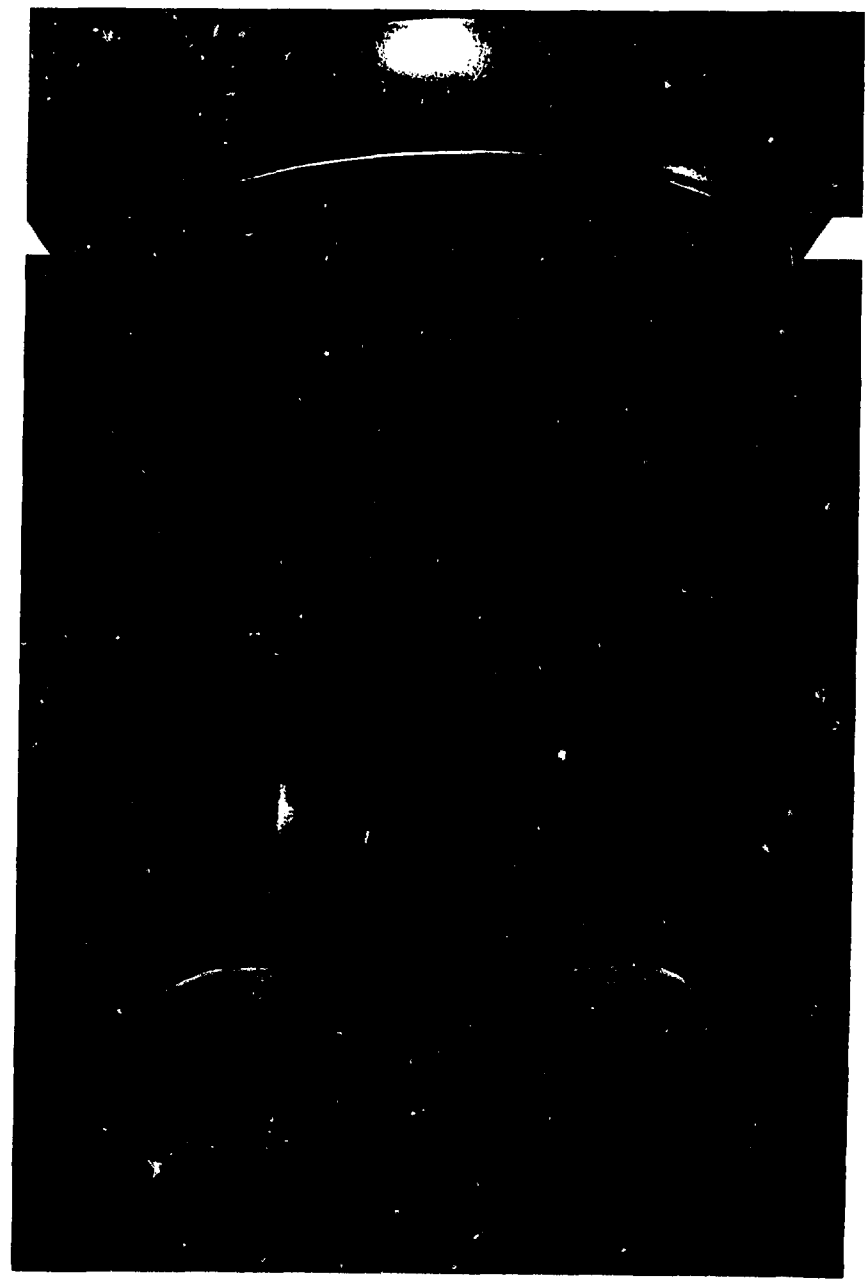
Features of these standardized designs are modified to incorporate improvements at controlled stages, and here AECL keeps abreast of technological developments and safety standards, often leading the way.

**Heavy Water Expertise**

Coincident with the evolution of the CANDU reactor from its early stages has been the development and refinement by AECL of expertise in production of the heavy water which plays a vital role in the CANDU system.

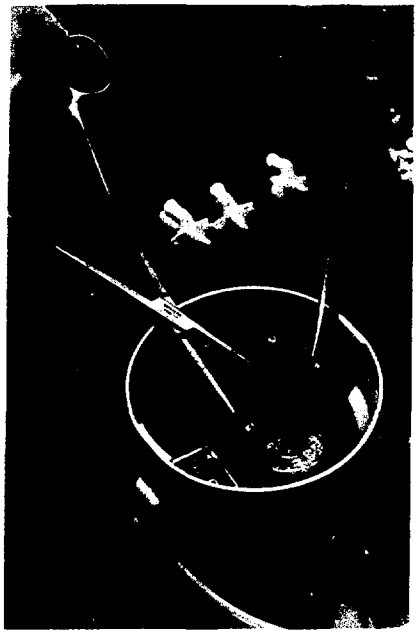
# Nuclear Technology and the Life Sciences

*Nuclear energy can "make a positive contribution to the quality of life and decrease the rate of degradation of the environment".*
*World Health Organization*



Radioisotopes are packaged for dispatch worldwide





Nuclear energy has extensive beneficial uses in addition to its known role in the economic generation of electricity. Nuclear products, such as radioactive isotopes, have already contributed greatly to the lives of people all over Canada and in many overseas countries in medicine, industry and agriculture.

Radioisotopes are produced by placing materials in a nuclear reactor, where they are made radioactive. For over 30 years AECL has been among the world leaders in these applications, making a quiet but valuable contribution to human well-being; both in terms of extending lives and improving the quality of life.

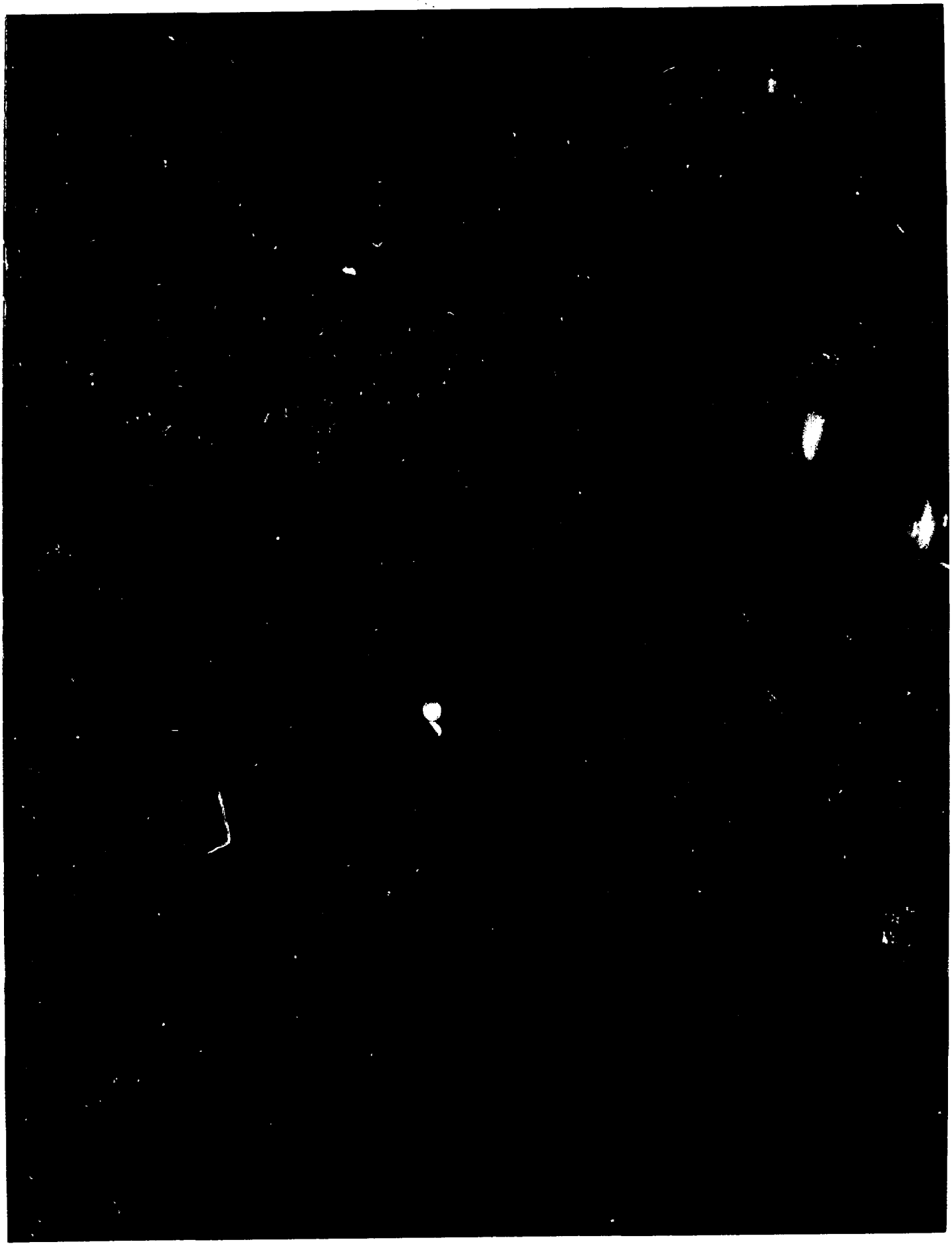
The role of cobalt-60, a radioactive isotope produced in the CANDU reactors, is an important resource in this effort. About one-third of the world's disposable supplies used in surgery is sterilized through radiation technology using cobalt-60, including sutures, hypodermic needles, bandages and other medical products. The irradiation process leaves no harmful residues while ensuring that disease-causing bacteria and viruses are destroyed.

Among a range of industrial and research irradiators sold world-wide is AECL's Gammacell 1000 unit, used in part to irradiate blood to destroy antibodies in donors' blood prior to transfusion to patients with immunological deficiencies. Other AECL research irradiators are used for experiments in many fields, including physics, chemistry and microbiology, as well as medicine.

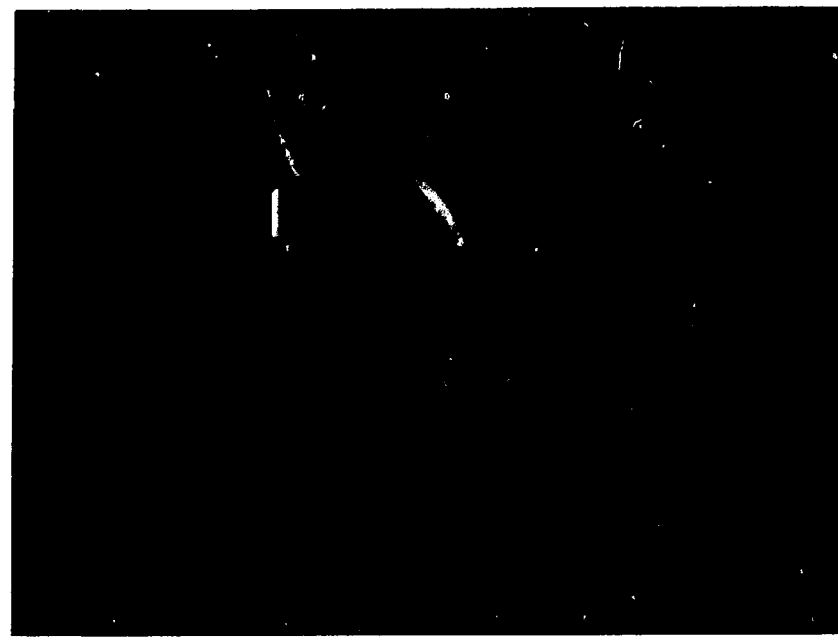
Every year nearly half a million people in 80 countries receive treatment on AECL cancer-therapy machines. The use of radiation to destroy cancerous cells is one of the major methods used in treating cancer patients, involving about half of all treatments. AECL manufactures more than 50 cancer-therapy machines each year for hospitals around the world, and there are now over 1400 AECL units installed worldwide.

Canada developed the first commercial cancer therapy unit using cobalt-60 in 1951, and this early unit has undergone continual modification and improvement since. With a cobalt machine, gamma rays flowing from the tiny cobalt-60 pellets are concentrated onto a tumor, destroying the malignant cells and minimizing the damage to nearby healthy cells. Each cobalt-60 source will typically give over 31,000 treatments to 1500 patients over a five-year period.

Planning cancer therapy treatment on a simulator.



AECL's Therascan scanner makes possible early and accurate diagnoses at the Montreal Neurological Institute



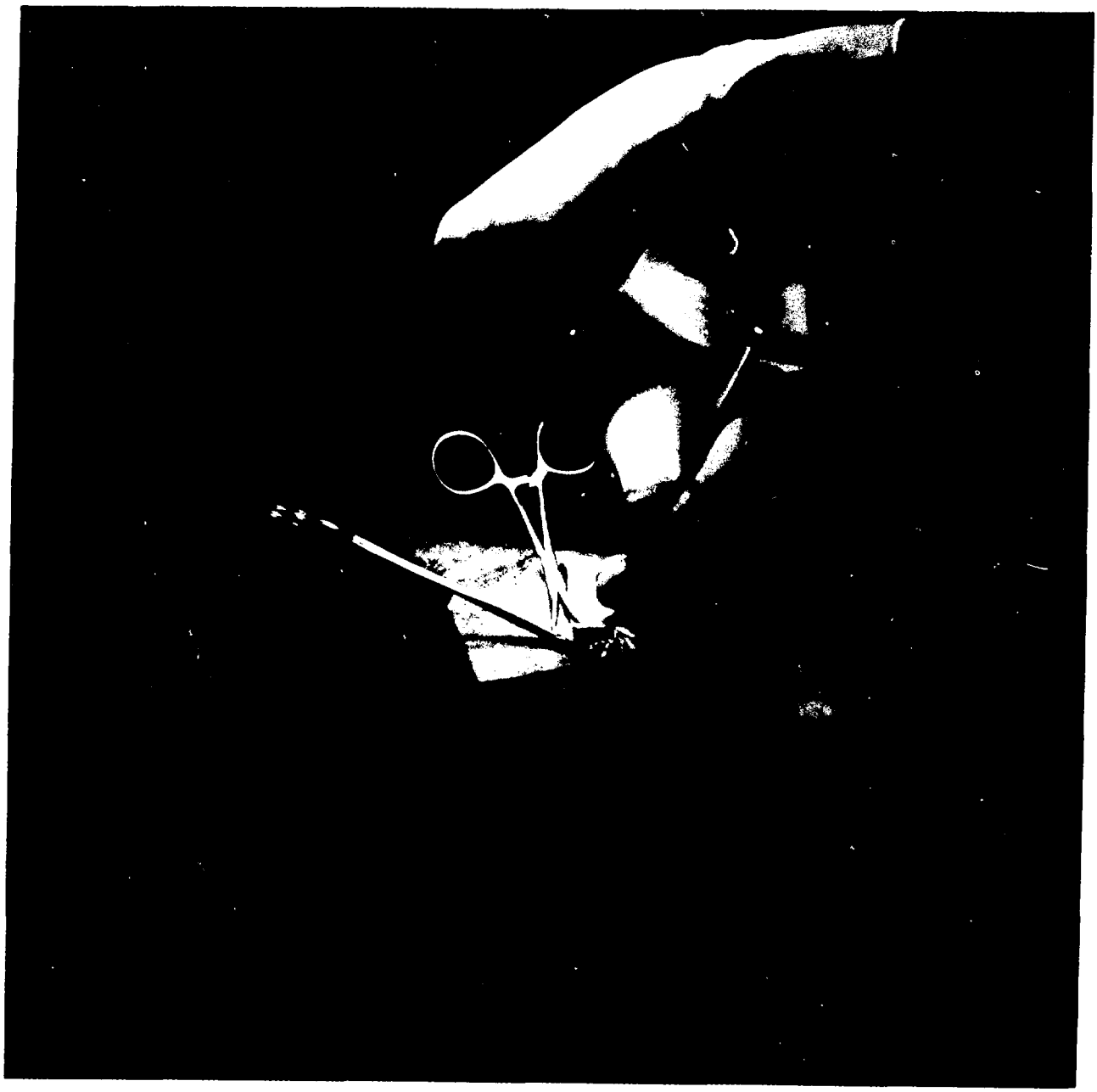
A leading breakthrough in the cancer-therapy technology is the linear accelerator, of which AECL's Therac-25 is the latest development. These accelerators produce electromagnetic beams many times more powerful than the radiation from cobalt-60. Because of their greater energy, these beams penetrate skin and tissue more easily to reach and destroy deep-seated tumors, with highly developed precision.



**Diagnosis Technology**

Nuclear medicine techniques, which help doctors see problems that are not visible by X-ray, are becoming increasingly important in the diagnosis of disease. One such technique, which involves a radioactive isotope combined with a drug, allows an image of the organ being studied to be traced. Doctors can thereby determine without surgery whether or not a patient has a medical problem. About a third of all major hospital diagnosis today involve nuclear medical technologies, and AECL supplies the isotopes from which 25-50 million diagnoses are carried out each year.

In this field of medical diagnostics, AECL has developed, in cooperation with the Montreal Neurological Institute, what could be called a mind-reading machine. The Therascan 3128 allows doctors and researchers to observe body chemistry and organ function within a patient's head. The Therascan image of chemical activity in tissues shows the distribution of a radioactive tracer across any chosen cross-section and can show abnormalities before they are sufficiently defined to be revealed on an X-ray. This equipment offers the prospect of a major advance in the diagnosis and study of stroke and epilepsy, and can detect the changes associated with mental disorders such as schizophrenia and manic depression.



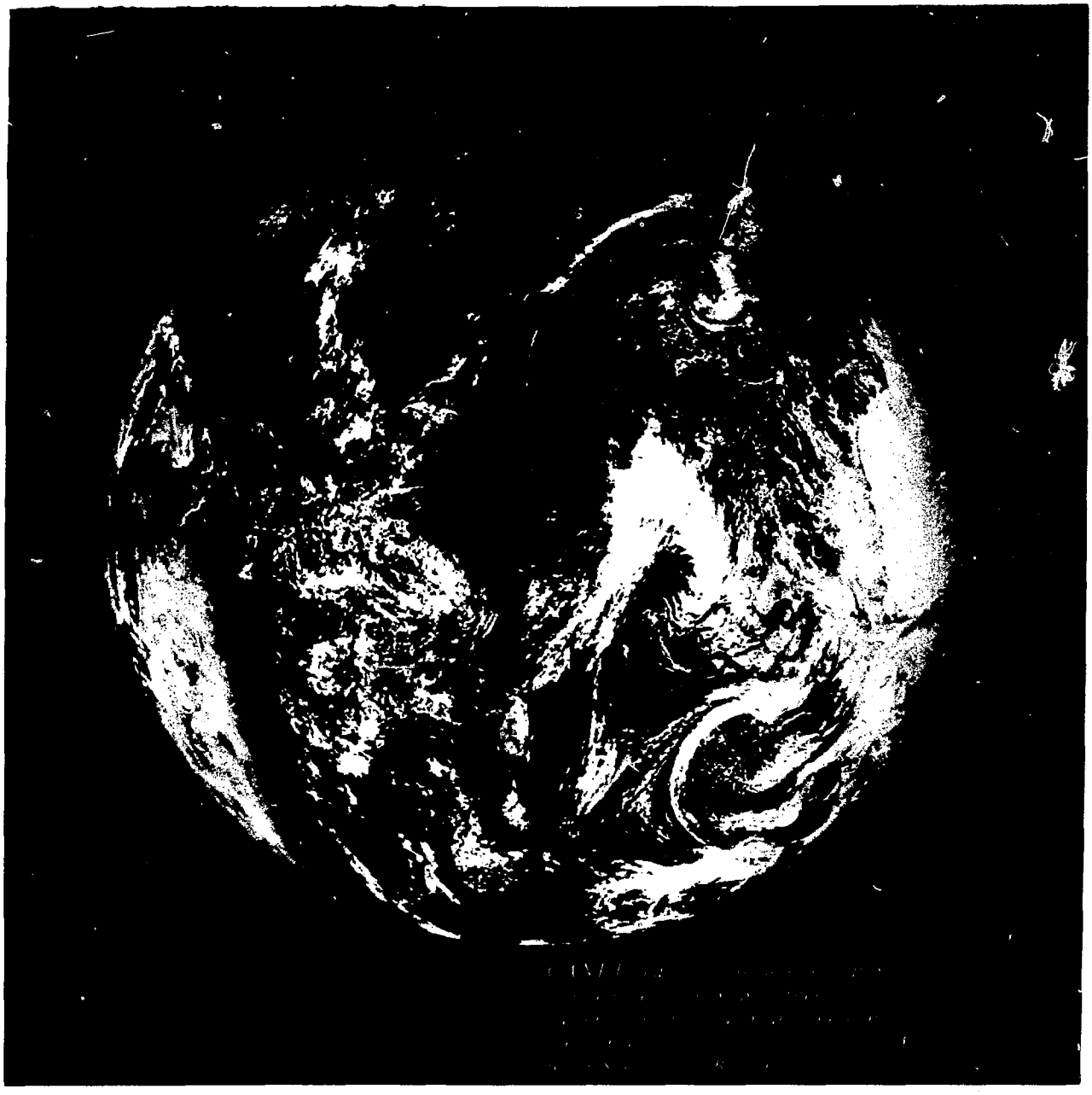
Radiation extends the storage life of potatoes



**Expanding Applications Today**
While the medical applications of nuclear technology are of major importance, nuclear technology will bring increasing economic and social benefits through other uses in industry and agriculture:

- food preservation through irradiation is already being used in areas of the world, particularly to reduce post-harvest losses and extend the shelf life of food. This technique will become increasingly important in the advancement of nutrition, the supply of food and improvement in public health;
- excess steam is being diverted from CANDU plants for industrial use. An industrial energy park is being created adjacent to the Bruce Nuclear Power Development in Ontario for this purpose;
- process heat is also being used to grow greenhouse crops, such as tomatoes and cucumbers;
- the economics of using CANDU-generated steam for extracting oil from the Alberta tar sands is under investigation;
- to help Canada reduce dependence on fuel oil, the concept of using self-regulated mini-reactors to provide central heating in commercial complexes, institutions and remote northern settlements is being investigated.

# A Technology for World Markets



The Canadian nuclear export program is built upon two major premises:

- with the CANDU reactor, Canada has the world's most reliable nuclear energy system. There is a clear opportunity to share this outstanding example of Canadian technology with less developed countries suffering from the effects of the unstable oil situation;
- CANDU sales act as a strong support for the domestic nuclear program and bring other economic benefits to Canada.

The CANDU reactor is fully compatible with the aspirations of many developing countries faced with the task of setting up an indigenous nuclear power program. These countries have a need for more energy, a need for reduced oil dependence and are eager to integrate energy development with broader economic development objectives extending far beyond the basic supply of additional electrical generating capacity.

Over the past three decades, Canada has created a proven reactor and the Canadian technology developed is available to help other countries obtain the economic benefits associated with nuclear energy.

This 600 MW CANDU station at Wolsung is providing nuclear electricity for the Republic of Korea



Through agreements established with AECL, Canadian academic institutions, manufacturers and utilities, Canada can offer all the educational, training and technology transfer arrangements arising from 30 years of experience.

The capability to transfer technology is an important challenge in export sales, and Canada is well placed to respond, in that technology transfer has always been an essential component in the Canadian approach to nuclear power.

The CANDU nuclear program, when undertaken by other countries, represents a long-term technological partnership that will be sustained and supported by Canada as a member country of the International Atomic Energy Agency and supporter of the Non-Proliferation Treaty.

The Canadian ability to share technology is comprehensive, extending as it does from university courses to training in manufacturing techniques on the shop floors; from mineral exploration through mining, refining and fuel fabrication to waste disposal; from electricity generation to the production of radioisotopes and their use in medicine and agriculture.

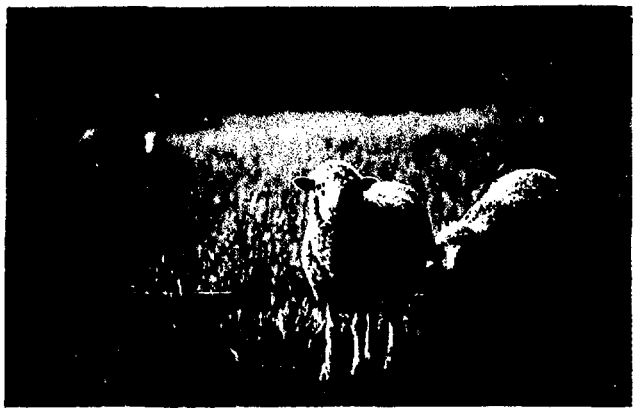
Apart from the obvious economic benefits of job creation and strengthening of the balance of payments, CANDU export sales have other important advantages. They add strength to Canada's image as a country with high technology capabilities, thus encouraging the purchase of other Canadian technologies; and they support Canada's policy to prevent the proliferation of nuclear weapons.

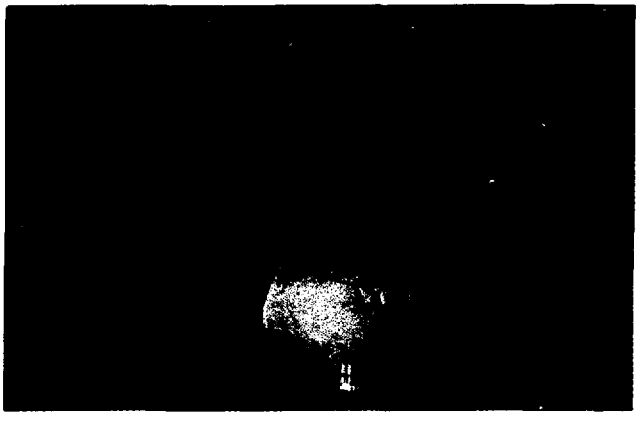
Export sales also provide an opportunity for highly qualified Canadians to find high technology employment in Canada rather than abroad. But perhaps the most important benefit is that these sales help the Canadian nuclear industry maintain the viability that is essential to serve the larger domestic program which will develop later in the century.

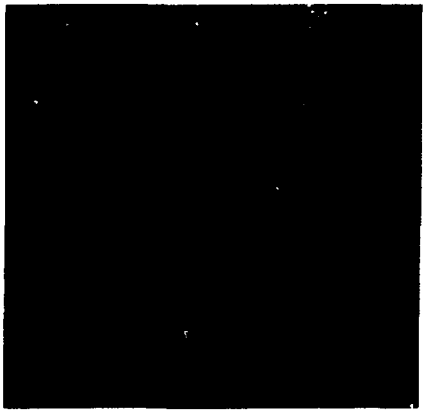
Nuclear energy is growing contributor to food production, to medicine and to electricity supply for homes and industry provides benefits worldwide

## *Technology from the Atom . . . for a Better Tomorrow*



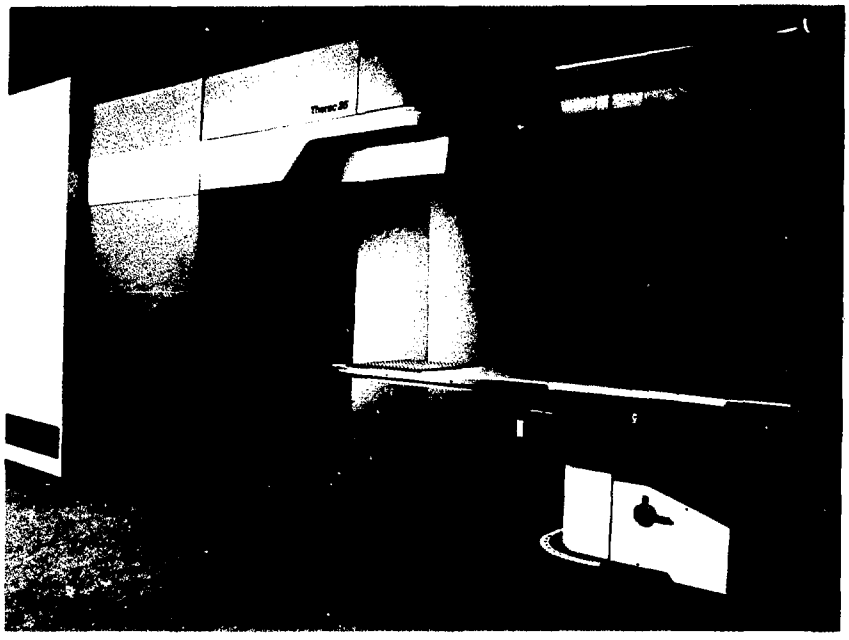






Continuing advances in cancer treatment are being made possible by new high technology equipment, such as AECL's Therac-25.





*"Nuclear breeding which is now the only sure way to an energy unlimited future . . . can be accomplished in reactors such as the Canadian CANDU type, which are technically straightforward and well proven".*
*Sir Alan Cottrell, former Chief Scientific Advisor to the UK Government.*

The unique design of the CANDU reactor gives it the potential to adapt to new technologies for decades to come. It already makes more efficient use of uranium than other reactor types. But when it becomes economically attractive to make a change, CANDU will be able to use new fuel cycles that will use uranium even more efficiently.

AECL researchers are already working to develop these new cycles, while continuing to explore and develop commercial opportunities in new avenues for nuclear energy.

In the future, nuclear processes will help man solve many current problems. With the world population growing so much faster than our ability to provide and distribute adequate food supplies, application of nuclear techniques in food and agriculture have an important continuing role to play.

Among these applications are:—

- vaccines treated by radiation to improve the quality of livestock;
- development of new strains of plants with the help of radiation;
- the application of the sterile insect technique to control insect pests, such as the fruit fly and tsetse fly;
- use of isotope techniques to reveal better ways of using costly fertilizers for several staple crops;
- nuclear techniques will also offer unique and ingenious tools to map scarce water resources of growing semi-desert regions, and to manage these resources better.

Nuclear technology is already making a substantial contribution in the medical field, and even here new applications are being developed continually. The future for the use of the atom in medicine is highly promising.

In the short space of just over three decades, Canada's contribution to nuclear technology has been immense. We are today reaping the dividends of the continuing ingenuity and talents of the dedicated people in the industry, and we can confidently look to tomorrow for equally outstanding achievements.

Main floor of the turbine hall at New Brunswick Electric Power Commission's nuclear generating station at Point Lepreau