ZEEP: Canada's first nuclear reactor

Canada's first nuclear reactor, ZEEP (Zero Energy Experimental Pile), went into operation on September 5, 1945 at Chalk River Laboratories, initiating the first nuclear chain reaction in Canada.

In the late 1930's, a group of researchers at the National Research Council in Ottawa were conducting experiments in nuclear research. By the early spring of 1940, the team, led by the eminent Canadian physicist Dr. George C. Laurence, had completed calculations which suggested that a nuclear chain reaction might be possible using uranium as the fuel and heavy water (deuterium oxide, D_20) as the moderator. The objective was to bombard a uranium compound with a weak source of neutrons to see if more neutrons could be produced as the result of nuclear fission.

Given the rich uranium ore deposits in Canada, it wasn't too difficult to find a source of uranium, but because most of the world's supply of heavy water was in Norway, Laurence was forced to find an alternative moderator. It soon became evident to him that a chain reaction could not be produced unless extremely pure graphite and uranium—unavailable to Laurence—were used.

Following the outbreak of hostilities in Europe in 1938 and Canada's entry into World War II in 1939, nuclear research took on a new focus.

While Dr. Laurence was conducting his nuclear research, three scientists working in France, Frédéric Joliot-Curie, Hans Halban and Lew Kowarski, were attempting to prove that a large nuclear reaction, producing many neutrons, could occur by placing uranium oxide in heavy water since heavy water would trap fewer neutrons. But before they could carry out their experiments, Nazi Germany's Panzer Divisions had advanced across France, and the three scientists were forced to flee. Halban and Kowarski escaped to Cambridge, England, bringing with them 185 kilograms of heavy water—most of the world's supply—obtained from Norway.

The fall of France to the Nazis left Britain in a vulnerable position, and Canada, the senior member of the British Commonwealth, overnight assumed a new importance. Scientific and engineering resources in Canada were marshalled to aid in Britain's defence.

The transfer to Canada of the heavy water and the Cambridge scientific team, led by Hans Halban, was finalized in 1942, and preparations were begun for the establishment of Canada's first large-scale nuclear laboratory.

The Anglo-Canadian nuclear research laboratory was set up at the University of Montreal in 1942-43. The objective was to design a pile, or reactor, in which the fission of uranium could be stepped up to a controlled chain reaction and plutonium could be produced for possible use in an atomic weapon. In 1944, an agreement to collaborate on nuclear research was reached with the Americans, who had initiated a nuclear chain reaction at the University of Chicago in 1942, under the direction of Enrico Fermi.

A site had to be found for the Canadian facility for nuclear research. A top-ranking British nuclear scientist, John Cockcroft, was selected to direct the project. A site near the Town of Chalk River, an important rail centre, was selected. In addition to being relatively close to Ottawa and Montreal, the site was near the Ottawa River, whose waters are very deep at this point. The site's proximity to Canadian Forces Base Petawawa was also a key factor, since the research centre had to be built under a cloak of wartime secrecy.

The site had to be cleared, fenced and fully serviced with utilities. A residential village to house the staff had to be built nearby. An area of 550 acres for construction of housing had been secured in a village that would be named Deep River. By August 1, 1944, twenty-four engineers and draftspeople and six other personnel were busy on the Chalk River construction project. Five days after the Chalk River site was selected, Paris was liberated, and the Free French government requested that French nationals working on the Canadian project be released to return to Europe. Post-war planning in England was vitalized with VE Day in May 1945, and in August, the dropping of atomic bombs on Hiroshima and Nagasaki signalled the end of World War II.

▶ When work on the Chalk River site started in August 1944, the scientists, engineers and administrators were pioneers, forced to conduct highly sophisticated experiments in an area located in several thousand acres of unoccupied bush. Supplies were often scarce, roads were almost non-existent, and facilities were primitive. Temperatures frequently plummeted below -40 degrees C. in the winter.

The ZEEP (Zero Energy Experimental Pile) reactor was designed in 1944-45 and went into operation on September 5, 1945 at Chalk River. Too late to be of use for war efforts, it was used as a test reactor to assist in the design and start-up of the much larger NRX (National Research Experimental) reactor, which would go into operation in 1947. ZEEP produced just one watt thermal on its first day of operation, but could produce up to 250 watts. It would operate for 25 years.

ZEEP is about eight square metres in size and stands five metres high. It is made up of a calandria or tank, a graphite shield, uranium fuel rods, cadmium-coated stainless-steel shut-off rods, and uses heavy water as a moderator.

The natural uranium fuel pellets measured 15 cm in length and 3 cm in diameter and were stacked inside three-metre tall aluminum rods which were spaced in a regular lattice and suspended from moveable beams in heavy water. The lattice arrangement of the rods and the depth of heavy water were adjustable, enabling the reactor to produce the number of neutrons required for a given experiment. The maximum capacity of heavy water it could hold was slightly more than nine tonnes. The heavy water was stored in a tank beneath the calandria. A metre of graphite shielding, used to reflect neutrons back into the core, surrounded the calandria. Tanks of ordinary water added extra protection outside the graphite shielding. A removable wax lid was placed over the top of the rods when the reactor was operating. Later, moveable shielding and a concrete wall and lid were added.

Two sets of stainless-steel shut-off rods measuring 25 cm in length and 3 cm in diameter were suspended vertically, ready to fall, when needed, into the heavy water to absorb neutrons and bring the fissioning to a standstill. One control rod was used to regulate the power of this "pile" or early reactor. The reactor was so low-powered that it did not require a coolant. The rate of fission was controlled by the depth of the water.

In 1966, ZEEP was designated a historic site by the Archeological and Historic Site Board of Ontario. A plaque attesting to the historical significance of this reactor is located in the museum at Chalk River Laboratories. Tours of the labs frequently begin here as a reminder of the origins of Canada's nuclear story.

Like more information? Contact Public Affairs, AECL Research, Chalk River Laboratories, Chalk River, Ontario K0J 1J0.