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RESTORATION OF NRX REACTOR

Behind the start-up of the NRX reactor today at Chalk River liés an exciting story of a unique scientific and engineering accomplishment. For the first time, so far as is known, a nuclear reactor of high power rating has been taken apart after several years of operation and has been restored as an even more powerful atomic furnace.

One afternoon in December 1952 a siren wailed at the Chalk River project. It was the order to stay indoors. As staff members of Atomic Energy of Canada Limited looked out over the 150 structures within the 100 acres of fenced in area, not a soul was seen. The project, which employs about 1,700 people, looked strangely deserted.

Most of the staff did not know whether this was just a drill or whether the emergency signal meant business. Then they saw personnel in gas masks and it became obvious that the signal meant something serious.

Shortly the evacuation siren was sounded by Dr. A.J. Cipriani, director of the Biology and Radiation Hazards Control Division. Staff members locked filing cabinets, placed handkerchiefs over their faces and headed for the main gate in accordance

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with an established procedure. Buses took them to their homes in Deep River, Chalk River and Pembroke.

In the meantime, key personnel around the project stayed on duty. Personnel in the reactor control room had been more than busy, putting into operation the safety devices which shut down one of the most concentrated energy sources ever devised by man.

The breakdown of the reactor occurred while experiments were being conducted at low power. When uranium atoms split they give off tremendous quantities of heat. The amount of heat potentially available within uranium is three million times the heat that can be liberated from an equivalent quantity of coal. Therefore the uranium fuel rods must be cooled with water from the Ottawa River to prevent them from melting (uranium melts at about 2066 degrees Fahrenheit). For the experiments being conducted, a small number of the 176 uranium rods within the reactor had a reduced flow of cooling water going through them. These experiments were similar to those which had been carried out successfully many times before. Owing to a complex chain of events, a mechanical failure in part of the system occurred and a power surge in the reactor resulted. ("Power" in a reactor is a direct measure of the number of uranium atoms splitting per second and appears as heat.)

This power surge overheated the uranium rods which had a reduced flow of cooling water over them. Some of the uranium fuel and aluminum in the rod assemblies melted and sheathing on the uranium rods ruptured. Highly radioactive fission products entered the cooling water. When a uranium atom splits it gives off neutrons, heat, and gamma rays and the two fragments into which the atom splits, known as fission products.

The uranium rods are sheathed in aluminum to prevent these highly radioactive products from entering the cooling water or escaping into the cooling air that is sucked through the reactor.

During normal reactor operation the cooling water is pumped to huge storage tanks where it is kept until the radioactivity dies away. When the reactor broke down, however, the cooling water plunged into the reactor basement. And the cooling water could not be turned off for uranium oxidizes rapidly in air and a uranium fire might have resulted. About 10,000 curies of fission products (for comparison, some 1,500 curies of radium have been produced in the world to date) were washed into the basement in a million gallons of water.

The reactor is cooled by both water and air. Great fans suck air through the reactor structure and it is then discharged from a 200-foot stack. When the power surge occurred, radioactivity also entered the cooling air and because of a unique atmospheric condition it was not dispersed, as it usually is, by air flowing past the top of the stack. It fell on the plant area. While this radioactivity was harmless as far as the plant staff was concerned, it could upset experiments and monitoring control in several laboratories if it had been tracked about the project. The plant evacuation signal was therefore sounded.

The first problem in the decontamination and reconstruction of the reactor, which commenced immediately, was to get the contaminated water out of the basement. It was first pumped to a huge storage tank. Special burial pits were prepared within the 10,000 acres of land controlled by the project. Then a four-inch pipeline more than a mile long was constructed from the storage tank to the burial pits. This job was an accomplishment in itself for the line was built and insulated against freezing in mid-winter temperatures within nine days. The contaminated water was then pumped from the tank to the pits.

Scientists and engineers designed special viewing devices to survey the extent of the damage within the reactor. The structure was so highly contaminated that it was not possible to look directly into it to study the melted and fused uranium and aluminum.

The first attempt to pull the damaged fuel rods out of the reactor failed. It was then decided to remove the huge circular shields above the calandria -- the two and a half ton aluminum tank which contains heavy water and into which the 176 uranium fuel rods are inserted. This tank is about eight feet in diameter and 10 feet high.

To protect the scientists and engineers working around the reactor from radiation, steel and concrete shielding -- the latter eight feet thick -- surround the calandria. Over the top of the calandria were seven huge shields. Three of these were water-cooled, hollow steel shields weighing about 15 tons each. Above these were four concrete shields, about a foot thick, weighing from 17 to 19 tons eadh.

The steel shields were particularly active. The one immediately above the calandria was so contaminated that it could not be cleaned. It was therefore buried in the project's disposal area.

With the shields removed, work once again commenced on the removal of the damaged fuel rods. To protect the workers from the radiation being given off by the calandria, a special lead shield with a sliding door was constructed.

Skilled tradesmen operated drills and cutting tools from above this lead shield and in some operations they worked from inside a lead box called a "coffin." In all the operations the strict safety rules of the Chalk River project were enforced. The project has never had an injury due to radiation exposure.

Once the fuel rods were removed the next big operation was the removal of the extremely "hot" calandria which had an estimated activity equal to half of all the radium that had been produced in the world.

As it was not possible, due to the high radiation, to go within 50 feet of the calandria without special shielding, the removal had to be done by remote control. Some 70 men carried out the operation. A dummy calandria was built and lowered into the reactor structure on top of the contaminated calandria. To this was attached the maze of ropes that would be used in the actual removal. Then the dummy was lifted out, lowered into a canvas bag on a skid raised against the side of the reactor, the skid lowered to the reactor floor and towed to the project disposal area to practice every removal procedure.

Then the removal crew practiced on a scale model of the calandria and reactor structure. At 6:30 p.m. one evening, when there were few people at the project, the actual removal got under way. A dozen men trained to handle any of the many jobs connected with the removal stood by to handle emergencies.

An announcer located in the reactor control room called out the 28 steps one by one. Slowly the stained aluminum tank rose above the reactor structure. Health survey men moved to prearranged points to take readings with their radiation detectors. Photographers moved up to take photographs that would be used for later scientific studies.

Then the removal procedure continued. The crane operator, working in a lead-shielded cab high in the reactor building, followed signals from a man stationed well away from the calandria. Though the crane man could not see the calandria, he lifted it out of the reactor and lowered it smoothly into a canvas bag attached to a skid beside the reactor structure.

A blast from the project whistle warned guards and others on duty that the calandria was now to be towed out of the fenced-in portion of the project area. A funeral-like cortege moved slowly through the project -- supervisors in cars ahead of the grader towing the skid, and health surveyors following to check the road for possible contamination. Guard stations were unattended as the calandria passed them and pen recorders on radiation monitors in buildings along the route went off scale.

At the disposal area a bulldozer heaped sand over the calandria to shield it. Studies of the calandria, which was subjected to five years of neutron bombardment, will yield valuable information.

Many of the operations in the reactor restoration consisted of arduous scrubbing to remove contamination. Thousands of costly instruments were saved for further use.

As a result of the NRX breakdown revisions were made to the control system and to the reactor structure itself. The restoration provided valuable information which has been applied to the reconstructed NRX reactor and also has been incorporated in the design of the NRU reactor now under construction. This data will also affect the power production reactor whose design is now under study at Chalk River.

In the reconstruction of the NRX reactor the Chalk River staff received valuable assistance from No. 1 Radiation Detection Unit of the Canadian Army, which did much of the decontamination work. The Royal Canadian Navy and the Royal Canadian Air Force sent personnel to Chalk River to work with the Army Unit.

When the reactor broke down the United States Atomic Energy Commission immediately offered its assistance. The United States Navy, particularly the U.S. Naval Radiological Defence Laboratory, was extremely helpful in the early months of dismantling and decontamination. These United States groups generously contributed a steady flow of tradesmen, many with a specialized knowledge of radioactivity. They also contributed special equipment which speeded the operations.

The exchange of information between the United States and Canada on the problems associated with the contaminated NRX reactor was practically unrestricted and both countries profited from this free exchange.

The Chalk River project will now be able to re-establish the production of radioactive cobalt for Cobalt-60 Beam Therapy Units which are used for the treatment of cancer. Some cobalt had been partially irradiated in the NRX reactor when it broke down. This cobalt has been put back into the reactor for further irradiation and it should be available within a few months. The time required to irradiate cobalt to the necessary intensity depends upon its location in the reactor and the operating power of the reactor. This varies from time to time, depending upon the reactor program. A period of 10 to 18 months is, however, normal to get the high specific activity desirable in therapy units.