ATOMIC ENERGY OF CANADA LIMITED

Chalk River, Ontario

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START-UP OF THE NRX REACTOR

At 10:30 a.m., Wednesday, February 17, Dr. David A. Keys turned a switch on a panel in the control room of the NRX reactor at Chalk River and the start-up of one of the world's most advanced reactors was under way after a 14-months shut-down.

Dr. Keys, Scientific Adviser to the president of Atomic Energy of Canada Limited, activated the mechanism that lifted a boron shut-off rod out of the aluminum tank known as the calandria in the heart of the reactor. When NRX is running at normal power as many as 60 million million neutrons, highly penetrating uncharged particles, pass through each square half inch within the two and a half ton tank that contains heavy water and uranium fuel rods. Boron absorbs these neutrons and therefore, to stop the reaction within the calandria several shut-off rods made of this material are lowered into the heavy water.

The 176 uranium fuel rods had been inserted in the reactor several days before Dr. Keys turned the switch that started the hours-long start-up procedure. Uranium spontaneously and continually gives off a few neutrons but these are travelling too fast to initiate the nuclear fire (which the scientists term

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a "chain-reaction") within the atomic furnace.

Before neutrons will strike uranium atoms and readily split or fission them, the uncharged particles must be slowed down from a speed of about 10,000 miles per second to about one mile per second. This is done by surrounding the uranium with heavy water which slows down or moderates the neutrons.

After the uranium fuel rods had been inserted in the reactor, heavy water was pumped into it until the calandria was about one third full. Lights flashing on a neutron counter in the NRX control room gradually speeded up, indicating that neutrons had actually started to split uranium atoms which were releasing more and more neutrons. But the boron shut-off rods inserted in the heavy water absorbed the neutrons, dampening the nuclear fire.

Now with the first shut-off rod lifted out of the calandria, excitement grew in the NRX control room. The other shut-off rods were lifted. Then an engineer pressed a red button that caused the single cadmium control rod to be lifted. Like boron, cadmium absorbs neutrons. Therefore, the extent of the nuclear fire within the reactor is controlled by moving a cadmium rod -- the more it is inserted into the calandria the more neutrons it will absorb, reducing the number of neutrons available to split uranium atoms.

A scientist watched the lights flashing on the neutron counter which showed vividly the approaching moment of criticallity -- that is, the moment when the nuclear fire (the chain reaction) would maintain itself.

To a huge panel covered with hundreds of small red and green lights come the wires from more than 900 "trips" -- safety devices that will "trip" or shut down the reactor. As the NRX reactor is an experimental reactor, its controls are extremely complex.

For many days engineers and technicians checked and re-checked these trip systems. Now that the shut-off rods and the control rod were lifted out of the calandria and the height of the heavy water was being increased, engineers kept a close watch on the multitude of trip systems.

Operators scanned the many instrument dials which told them how the reactor cooling water and cooling air were behaving, indicated the temperatures in the various parts of the reactor, gave a measure of the radioactivity being induced in the cooling water which flowed to huge storage tanks, and showed the reactivity or the extent of the uranium fissioning within the calandria. The heat that could be released from uranium is three million times greater than the heat that can be liberated from an equivalent quantity of coal. Therefore, the uranium fuel rods, the aluminum calandria and the shielding around the calandria must be cooled.

As the uranium atoms split, in addition to giving off two or three neutrons and a tremendous quantity of heat, they give off beta and gamma rays. The neutrons and the gamma rays are highly penetrating. To protect the engineers, operators and scientists, therefore, the tank within which the nuclear fire burns must be surrounded by shielding. Around it are cast iron and concrete shielding, the latter eight feet thick. Above and below the aluminum tank, which is about eight feet in diameter and 10 feet high, are great circular concrete and metal shields. Above the calandria, for example, are the following circular shields: (1) hollow aluminum, water-cooled shield about a foot in thickness and 12 feet in diameter, (2) two hollow, water-cooled steel shields that weigh about 15 tons each, and (3) three solid, concrete shields that weigh from 17 to 19 tons each.

There was an air of expectancy in the NRX control room as the long-awaited reactivation of the atomic furnace approached, but the young engineers charged with the responsibility of starting up one of the most concentrated energy sources ever devised went about their various jobs with confidence. They knew well the meaning of every alarm bell and the meaning of every flashing red, green or orange light; they knew that although the reactor was extremely complex they had many safety devices to fall back on. At any moment anything went wrong they could send the several boron shut-off rods plunging into the calandria to dampen the nuclear fire as effectively as if they were throwing water on a camp fire. Or they could dump the heavy water into storage tanks below the reactor thus making the neutrons ineffective as uranium splitters.

The reactivity of the NRX reactor -- that is, the rate at which the splitting or fissioning of uranium atoms takes place -- can be altered by a very slight change of conditions. It is controlled by changing the height of the heavy water within the calandria or by moving the cadmium control rod. If the reactivity is changed by one half of one per cent, the reactor power ("power" in a reactor is a direct measure of the number of uranium atoms splitting per second and appears as heat) will double within three and one half seconds.

But now in the NRX control room a scientist marked a graph which recorded the "counts per minute" -- the number of uranium atoms being split within the calandria. After several hours the scientists, engineers and operators saw the graph reach a point which indicated the reactor had become "critical" -- a self-sustaining chain reaction had been realized. The NRX reactor was back in operation after a 14-months reconstruction job.

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