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Definition Project – Nuclear Accident Reconstruction.

THEME AREA: Nuclear Emergency Preparedness and Response

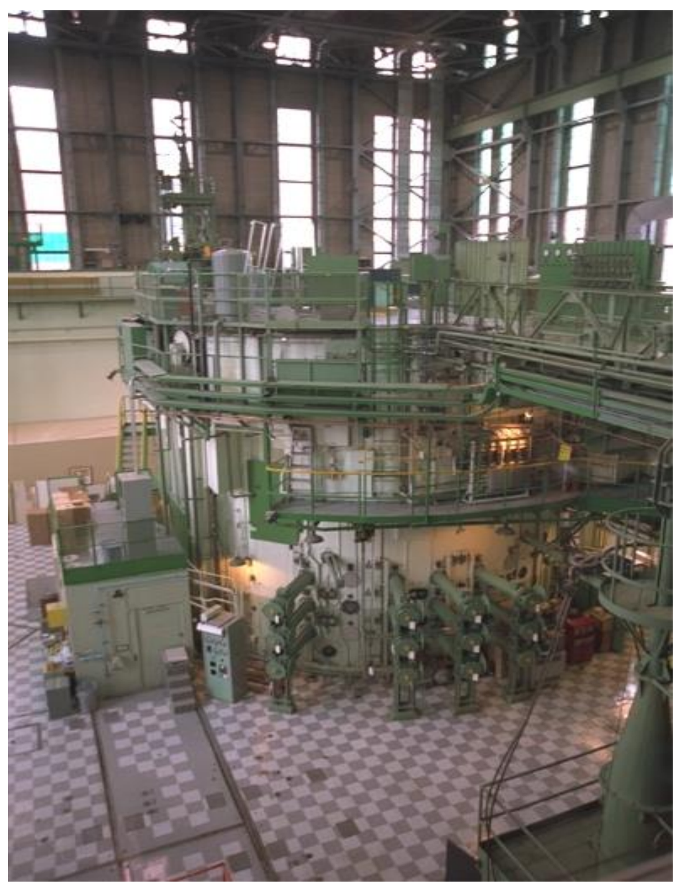
SUB THEME AREA: Develop modeling capabilities for severe accidents and emergency response

CNL PROGRAM AREA: Safety and Security **PROJECT LEAD:** Alexandre Trottier

PRINCIPAL INVESTIGATOR: Geoffrey Edwards **START DATE:** 2019/04/01 **END DATE:** 2019/09/30.

INTERESTED PARTIES: CNL/ERM, IAEA, CNSC, AECL **PRIMARY STAKEHOLDER:** CNSC

Background: A severe accident occurs due to a breach in fuel cladding which exposes the metal or oxide nuclear fuel to coolant or air after an external chemical explosion or build up of heat in the fuel that is too rapid to be removed by coolant, thus creating the potential for radioactive contamination to be spread. **One such severe accident occurred in the NRX reactor in 1952;** the only severe accident resulting in significant external releases from a heavy water moderated reactor. CNL is uniquely positioned to develop a detailed model of the progression of the accident as it has inherited the records of operation of the reactor and the detritus of the accident in its waste management areas. Such a model would provide an excellent test of severe accident modeling capabilities and would also provide validation data against which the codes could be assessed.



Project Objective:

Determine whether sufficient information exists to construct and validate a model of the accident.

Work Completed:

- Task 1: Evaluation of reactor operating data before and during the accident, Task 3: Research into the location of damaged fuel rods and contaminated coolant water

Future Work:

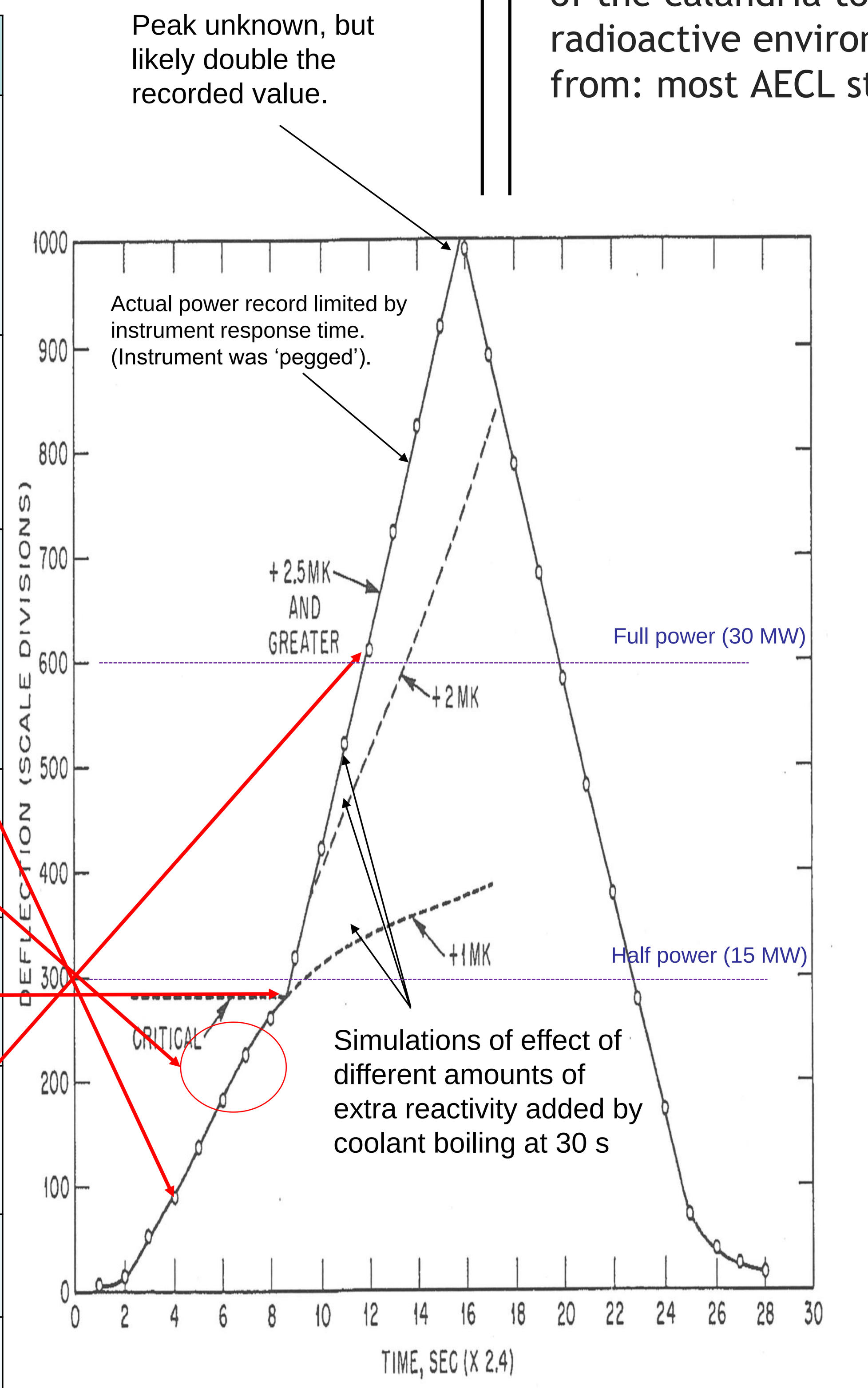
- Task 2: Evaluation of the capability of the severe accident modeling code 'Melcor' to determine the amount of expected damage to fuel rods.

Task #1: Review of documentation

This task determined that sufficient details of the exact state of the reactor before, during and after the accident were recorded contemporaneously to model the accident. A brief description of the accident follows below.

- The reactor had been shutdown, and was being restarted to low power for an experiment which required several fuel rods to be cooled by external hoses. These hoses supplied insufficient cooling for high power operation.
- Normal procedure was to raise all shut-off rods, then slowly fill the tank with heavy water to the critical point. However, because the experiment required the reactor to go critical at the normal heavy water level, and the reactor had extra reactivity because of the shutdown, only five shut-off rods were to be raised. This required a manual set-up of the rods.
- During the manual set-up, the reactor tripped, dropping the shut-off rods in the core. An operator was sent to the basement to prepare the equipment to resume the manual procedure, but, misunderstanding his instructions, started raising all the shut-off rods manually.
- The control room supervisor left his post to go into the basement to turn off the pneumatics for the raised rods, expecting gravity to drop them back into the core. However, never properly tested for gravity-only insertion, three of the shut-off rods fall only a little way, before getting stuck. Nobody suspected that these three shut-off rods of remained out of the core. It was now ~3:07 on Friday afternoon.

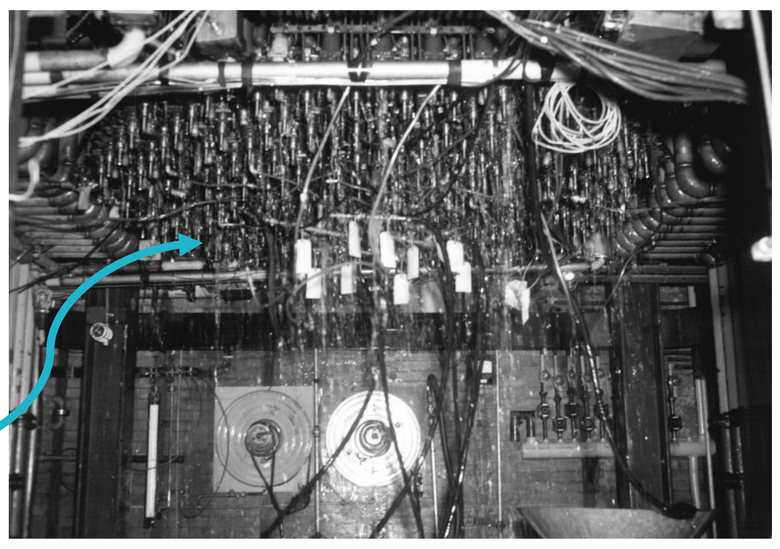
Event	Time (pm)
The supervisor telephones the control room and calls for the four shut-off rods of Safety Bank #1 to be raised. By mistake, a button is also pressed which has the effect of bleeding off shut-off rod air pressure for their pneumatic insertion.	3:07:00
The seven shut-off rods out of the core (including the three unsuspected ones) causes the reactor to become supercritical. Power doubles every ~2 s from a very low level (~100 W).	3:07:01
When the power is determined to be rising out of control, the pneumatic shut-off rod system is activated, but with no air pressure, the safety bank rods also fail to drop, except for a single rod, which drops slowly into the core by gravity.	3:07:20
The power rise starts to slow down, perhaps leveling off at 15 MW (half of full power) due to the influence of the slowly dropping shut-off rod.	~3:07:25
Coolant in the sites fueled by external hoses boils away, increasing reactivity and causing the power to resume rising exponentially.	3:07:30
Power passes 30 MW (full power). A dump of heavy water dump is initiated as an emergency shutdown measure.	3:07:44
The effect of the heavy water dump is too slow to stop a further increase in power to ~90 MW.	3:07:49
Reactor is now shut off and at low power again.	3:08:02



Task #3: Results of the accident

During and shortly after the accident, the following occurred:

- A few fuel rods melted, in some cases becoming stuck to the calandria channels.
- Shortly after the power excursion, hydrogen/oxygen explosions occurring inside many flow channels. The resultant explosions breached both the fuel cladding and the flow and calandria channels of many rods.
- The calandria developed major leaks at its base, allowing coolant to pour out of damaged flow channels into the basement of the reactor building.



A few hours after the accident, a pressure pulse caused by an explosion of gas in the calandria traveled back through lines and valves to the "gasholder", a system designed to keep a constant pressure cover gas over the heavy water in the calandria, destroying it.

Temporary cooling was put at the top of the damaged channels, numbering about a dozen in all. This highly radioactive water could not be discharged to the Ottawa River and started filling up the NRX basement. Arrangements were made to build a pipeline for the water from the bottom of the calandria to a natural basin in one of the waste management areas. Working in this highly radioactive environment was only possible for 90 seconds per person, requiring contributions from: most AECL staff, the Canadian Army, the Royal Air Force, and the U.S. Navy.

After the accident, the following occurred:

- A puff of radioactive gases went up the reactor stack.
- Radioactive water containing 10,000 curies of radio-isotopes (75% Sr-90 and Cs-137) was pumped over a mile to a sandy basin in a waste management area.
- The damaged fuel rods were removed and buried in shallow trenches in the same waste management area. (These were retrieved in 2005 and reburied in steel-lined "tile holes" at a different location at CNL).
- The calandria was removed by crane, lowered into a canvas sack, and driven to and buried in the same waste management area by a truck operator protected by a wall of lead.

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