U.S. EXPERIENCE IN THE DECOMMISSIONING OF THE BN-350 FAST BREEDER REACTOR IN KAZAKHSTAN

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BN-350 FACILITY HISTORY

The BN-350 plant was constructed in 1972 to serve several purposes. It was to be a benchmark as the first commercial size sodium cooled fast reactor, providing 350 MWe electric power for the city of Aktau for commercial and residential use and serving as a desalinization plant for the city's water supply (producing 120,000 m^3 of fresh water a day). Although its most nefarious purpose was to produce weapons grade plutonium for the Soviet Union's weapon complex, none of the plutonium produced by BN-350 was ever used.

The BN-350 achieved first criticality in 1973 and being designed for a twenty-year life span, was operated on a routine basis until 1992. In 1992, the government of Kazakhstan began extending its operating license on a yearly basis. In 1995, the United States and Kazakhstan began working cooperatively to package spent fuel assemblies located in the spent fuel pool that presented a proliferation risk. The reactor was still in operation at that time, but there was an understanding between the United States and Kazakhstan that Kazakhstan would cease operating the reactor no later than 2003.

In 1998, the IAEA conducted a safety review of the facility. It was determined that the BN-350 needed major upgrade in order to continue to operate safely. In February 1999, the Minister of Science and Education, Dr. Vladmir Shkolnik, sent a letter to the US Embassy asking for technical assistance in the areas of fire protection and lowering the radioactive cesium concentration in the reactor's sodium coolant. Before a meeting on the subject took place with United States, Kazakhstan unilaterally declared on April 22, 1999 that it would shutdown the reactor. In May 1999, at an IAEA sponsored Decontamination and Decommissioning (D&D) workshop, the Kazakhstan government formerly requested financial and technical support from the US and other IAEA member states. The United States responded immediately with initial fire safety upgrades and then made an official arrangement between the U.S. Department of Energy (DOE) and the Kazakhstan government in December 1999 on further assistance.

The Kazakhstan decree stated their intention to put the reactor into a radiological and industrially safe configuration within a five-year time frame, a process called SAFESTOR, and maintain that configuration for a period of fifty years at which time dismantling would take place. Placing the reactor into a SAFESTOR condition allows for radioactive material to become less radioactive and defers large capital expenditures. For a new state with no experience in reactor decommissioning and little money for such an expensive endeavor, this seemed to be the best course of action.

TECHNICAL ISSUES OF REACTOR SHUTDOWN

The steps associated with the shutdown of the BN-350 include decontamination of sodium coolant, draining and deactivation of the bulk sodium coolant to an environmentally safe material, deactivation of the residual sodium coolant, and closure of the systems after draining. There are also key safety upgrades necessary to support this activity.

Technical Description of the BN-350

The BN-350 reactor is housed in a single building located at the Mangyshlak Atomic Energy Company (MAEC). This building contains the reactor, control room, spent fuel pond, hot cell facilities, office space and other ancillary facilities required to operate the reactor. Fresh fuel may be stored within the reactor building itself or in a separate secure fuel storage building. The core or 'driver' fuel elements contain U-235 enriched up to 26% and the blanket elements contain depleted uranium. Unlike US and European reactors, the BN-350 and Soviet era reactors have no containment separating the reactor from the rest of the plant. This represents a significant safety risk.

The BN-350 reactor is a loop type reactor with three coolant circuits. The primary and secondary circuits contain sodium while the tertiary circuit contains water. Heat is transferred between the circuits utilizing heat exchangers. In normal operation, 5 loops are in use and one loop remains in standby. The advantage of a loop-type reactor over a pool reactor is that if there is a problem with one of the loops, it can be sealed off and the reactor can continue to function.

The core of the reactor is approximately one meter in height and 1.6 meters in diameter. The reactor used enriched uranium oxide fuel in 226 stainless steel fuel assemblies. The plant was designed to be refueled approximately every 90-120 days. The reactor vessel is 12 meters high and 6 meters in diameter, containing both the core and the breeding blanket.

According to reports, there have been several accidents at the site of the BN-350 reactor. The largest of these accidents occurred in 1974 when the steam generator pipes depressurized and water entered the secondary circuit, mixing with the sodium and causing a water-sodium explosion.

Safety Upgrades

The U.S. fire protection engineers and BN-350 fire protection engineers jointly conducted an assessment in April-May 1999: their goal was to focus on the fire protection needs for a plant in a shutdown status. The assessment identified a clear and present danger to personnel and equipment particularly during shutdown operations involving sodium. A major fire would jeopardize personnel safety and material security and could lead to a major regional environmental problem.

Cesium Issues

Due to previous fuel failures and experimental assemblies, BN-350's primary sodium coolant is contaminated with an estimated 3.7×10^{14}Bq (10,000 curies) of Cesium^{137}. The current Cesium^{137} level in the BN-350 primary sodium has been estimated to be 740,000 Bq/g (20,000 μCi/kg). The EBR-II, a similar U.S. reactor located at Argonne National Laboratory in Idaho, measured a final concentration of approximately 370 Bq/g (10μCi/kg) before it was decommissioned. At this level, the contact dose rates from containers containing BN-350 primary sodium could be expected to be in the low milli-Rem per hour range just from the Cesium^{137}. The US Department of Energy sets a whole-body administrative dose limit at 2 Rem per year per individual.

In order to mitigate the safety issues resulting from such high cesium contamination, US and Kazakhstani engineers began to develop a cesium trap design based on the experience and technology of Argonne National Laboratory. The design objective was to reduce the cesium activity concentration in the sodium to the same level reached in EBR-II prior to sodium draining; that is about 370 Bq/g (10μCi/kg).

Using detailed information from the EBR-II reactor at ANL-W, the design team developed a cesium trap system suitable for use within the BN-350. This team consisted of engineers and scientists from Kazakhstan as well as the United States Department of Energy (ANL-W). As part of the design effort, a detailed safety analysis was performed to ensure the safety of the proposed design.

Following the approval of the design and safety analysis by the Kazakhstani regulatory body, a certified company within Kazakhstan fabricated seven cesium traps. The Byeklamit facility, located in Almaty, Kazakhstan, fabricates pressure vessels for the oil and gas industry as well as other equipment in accordance with international codes and standards, including ASME and PNAE-G.

The traps will be installed in the primary coolant system one at a time. Each trap contains a core of reticulated vitreous carbon (RVC). The RVC acts as a filter as the sodium passes through it, trapping the cesium. Once a trap becomes saturated, another trap will be installed until all seven traps have been used and acceptable levels of cesium are achieved. The cesium traps, each with its own integral shielding, will be removed and stored as high-level waste.

Sodium Draining

The next shutdown activity is the draining of the sodium from the primary loops, secondary loops and the reactor vessel. The primary coolant loop for the BN-350 contains about 500 cubic meters (130,000 gallons) and the secondary coolant circuits contain about 450 cubic meters (about 120,000 gallons) of liquid sodium. The primary loops of the BN-350 were designed so that they could be drained as necessary for maintenance and then easily refilled. The primary vessel itself, however, was not designed to be drained. In order to support the complete draining of the primary vessel, a specialized system will be designed and installed.

Even after draining, it is anticipated that the primary vessel will still contain approximately 3 cubic meters of residual sodium below the bottom deflector plate of the reactor vessel. There will be another 3 to 4 cubic meters of residual sodium left in primary system locations. This "residual" sodium must be deactivated to prevent hydrogen gas build-up. A system will be designed to carry a cover-gas to the primary and secondary circuits to deactivate the residual sodium.

Sodium Processing

Currently the BN-350 has no capability to either process or deactivate sodium. To that end, the U.S. has proposed to assist Kazakhstan in this area. It is planned to convert the bulk sodium to anhydrous sodium hydroxide, which is a solid form that will be put in drums. It is estimated that there will be a total quantity of solid waste from processing of 1300 cubic meters. However, in order to complete the processing of the sodium, a facility must be constructed. The BN-350 sodium processing facility will be either located inside the BN-350 reactor building or separately just outside the building with a sodium transfer line connecting the facility with the building. The waste will ultimately be disposed in a radioactive waster landfill, whose location has not been determined.

Decommissioning Planning

The Kazakhstanis have opted to place the reactor into SAFSTOR for a period of fifty years before finally decommissioning and dismantling. The above-mentioned technical procedures are all part of placing the reactor into SAFSTOR. In parallel, the United States, in cooperation with the European Union, the United Kingdom, the International Atomic Energy Agency (IAEA) and Japan, is working with the Kazakhstan to produce a detailed decommissioning plan to present to the IAEA for peer review, eventually leading to a donor's conference. This work has been on-going for several years and the plan is in its final stages. The plan will be submitted to the IAEA for peer review before the end of 2002.