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Safe New Reactor for Radionuclide Production (U)

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SAFE NEW REACTOR FOR RADIONUCLIDE PRODUCTION*

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Introduction

Radionuclides for the defense of the United States were made at Hanford starting in 1944 and later at Savannah River. Plutonium and tritium were the major products. Other nuclides for defense and peaceful purposes like medicine were produced in the defense reactors. All nine Hanford and five Savannah River reactors have been shut down.

Several programs to develop New Production Reactors (NPR), emphasizing enhanced safety and technological advances, were conducted by the Department of Energy (DOE) and predecessor agencies. None was completed. US production capability remains dependent on the 40-year old Savannah River K Reactor now in standby. Concepts in the recent NPR program, ended in 1992, had progressed to the engineering design phase. Some experiments were conducted.

If the nation wishes or needs new production capacity either for defense or peaceful purposes, it should avail itself of all possible technological choices including those with minimum safety risks and mature technology backgrounds. In late 1995, the Secretary of DOE is scheduled to announce a new tritium production unit. DOE reportedly favors[1] an accelerator, but it is expensive, unproven, becomes radioactive as a result of operating, and needs electricity, most likely from either a coal plant or nuclear reactor.

A safe, new reactor using mature technologies was conceived of near the end of the last NPR Program, but its merits for safe US radionuclide production were not publicized.

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Description of Work

Near the end of the last NPR Program, work was directed towards eliminating risks in the current designs and reducing the effects of accidents. Effort was focused on the primary cooling systems and accidents in these systems. In the Heavy Water Reactor (HWR) program at Savannah River, conducted by WSRC and EBASCO, the coolant was changed from heavy to light water, a decision driven by concerns over high tritium levels in the coolant that might migrate to the public through heat exchanger leaks into the secondary coolant. Low tritium levels in light water primary coolant would pose a lesser threat should leaks and secondary coolant releases occur.

Various configurations were developed for such a reactor. One design favored placing a zircaloy calandria, containing (1) heavy water moderator, (2) coolant tubes, and (3) fuel and target assemblies within the coolant tubes, inside a steel pressure vessel. The vessel contained the calandria, the light water coolant, core internal support structures, safety and control elements, and heavy water supply pipes. Difficulties with fabrication, differential thermal expansion and sealing of dissimilar metals, and in-service inspections were some limitations of the concept.

An alternative, passively safe concept uses a heavy-water-filled, zircaloy reactor calandria placed near the bottom of a swimming pool. The calandria is supported on a light-water-coolant inlet plenum and it has up-flow through assemblies in the calandria tubes. Effluent cooling water above the calandria is confined to a circular space or chimney, open at the top. Heated primary coolant does not exit the chimney top but is swept into coolant piping on the chimney side and goes to the suction of the primary coolant pumps.

The pumps and heat exchangers of the primary coolant system handle 100% of the light water flow. Flow from the heat exchangers splits with about 90% returning to the inlet plenum and 10% going to a purification-filtration system before it is discharged near the basin floor outside the reactor. This 10% flow cleans the pool water as it circulates through the basin towards the top of the chimney. The flow enters the chimney, flows downwards towards the pump suction lines, and joins the reactor effluent coolant flowing to the pumps.

Without flow in the forced-cooling system (e.g., loss-of-coolant accident conditions), heat from the reactor core is removed by natural convection flow up through the plenum, core, chimney and into the general pool area. The water is cooled by heat transfer to the pool walls and earth heat sink in which the pool is built. The cooled water sinks to the pool bottom and enters the plenum through now-open check valves.

Thus, primary cooling and backup emergency cooling are continuously available and in parallel at all times. Backup cooling starts when forced cooling decreases to the point the check valves open. Pumps, piping and heat exchangers are located in the basin so system leaks will not drain the pool.

Fuel discharge takes place under water, as is done for LWR units, but the refueling canal in an LWR must be filled, whereas the discharge water is always present in the basin.

Thus, the basin supplies: primary coolant, emergency coolant, shielding, discharge water, spent fuel storage pool, and cask loading pit.

Results

The reactor concept developed in 1992 eliminates or reduces significantly most Design Basis (DBA) and Severe Accidents (SA) that plague other designs. Furthermore, it can use all the existing and proven (through 40 years) Savannah River Site (SRS) technologies for both fuel and target fabrication (the upstream, or feed process) and product recovery operations and fuel recycling (the downstream, or post irradiation activities). Especially important, the proven, current SRS tritium cycle remains intact. Production within the US of medical isotopes[2] such as Mo-99 would also be possible.

The reactor combines an arrangement of many proven technologies used successfully at SRS and other nuclear sites for many years. The concept's major safety features will be described. Operation during normal and accident conditions will be covered.

It is expected that a patent[3] for this concept will soon be granted to DOE.

References

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