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PRODUCTION REACTOR CHARACTERISTICS (U)

by

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A paper for presentation
American Nuclear Society 1990 Annual Meeting
Nashville, TN
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Introduction

Reactors for the production of special nuclear materials share many similarities with commercial nuclear power plants. Each relies on nuclear fission, uses uranium fuel, and produces large quantities of thermal power. However, there are some important differences in production reactor characteristics that may best be discussed in terms of mission, role, and technology.

Production and power reactors have different primary missions.

Production reactors produce excess neutrons to irradiate specific materials and transform them into new materials. These special nuclear materials are the main product, and production reactors are optimized to provide them in a specific form suitable for their end application. Power reactors, in contrast, utilize the thermal power from the nuclear chain reaction to produce steam at high temperature and pressure. Performance of a power reactor is optimized to obtain an economic supply of steam for the production of electricity. The difference in primary mission is reflected in the instrumentation and control systems designed to support the reactors.

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Production and power reactors have different roles.

Since there will be very few production reactors, they must be very reliable and have a high availability. The product isotopes should be readily recoverable and meet a variety of rigid specifications dictated by the ultimate use of the product. The fuel used in the production reactor is highly-enriched uranium obtained from available DOE feed stockpiles. The fuel is reprocessed and recycled in established fuel cycles. Some valuable products come from the reprocessed fuel; for example, Np-237 used to make Pu-238 for space vehicle power sources.

A power reactor is usually part of an electric distribution grid; one of many generating stations that must operate reliably to provide dependable low-cost power. The core designs of light water power reactors use low-enriched fuel that , after use, is stored and not reprocessed.

Production and power reactors have different technology.

The mission to produce special nuclear materials by neutron induced transmutation of target materials has a major impact on the design of the reactor core and the reactor operating systems.

Fuel and Target Fabrication and Reprocessing. Five properties of critical importance to the production goals and material throughput requirements of a production reactor are: ease of fabrication, acceptable neutron economy, containment retention for tritium and reactive target metals, ease of disassembly and processing, and minimal solid waste generation for disposal. At SRS, these objectives led to the development and use of aluminum technology and, as a consequence, low temperature operation. The use of

aluminum cladding for lithium targets for the production of tritium provides the following attributes: low permeability to tritium at reactor operating temperatures, low neutron absorption cross section, low tritium solubility, excellent fabrication characteristics, controlled purity, mechanical strength, and corrosion resistance.

Neutron Economy. The HWR Production Reactor is based on the use of heavy water (D_2O) as the neutron moderator. The low mass of deuterium, coupled with a low absorption cross section, provides an excellent thermal neutron environment, compared with other proven thermal reactors using other moderators. The net result is the ability to meet production goals with a smaller fissile mass and less power than other thermal reactor choices. The long migration length of neutrons in D_2O also allows a wide spacing of the fuel lattice, which translates into opportunities for less complex mechanical design. This includes room for interstitial safety and control rods, instrumentation, and improved space for using through-the-head penetrations for refueling.

Versatility from Extensive Reactor Core Control and Instrumentation. Tritium is the primary product of the HWR Production Reactor. However, DOD-DOE product requirements have a long history of being subject to change. The potential exists for future demands for other heavy isotope production (i.e., Pu-238,-239). The design of the HWR Production Reactor must be flexible to conform to changing programmatic demands in the type and quality of products other than tritium.

Flux flattening improves uniformity of isotope production and purity in batch loads, especially for heavy isotope production. In-core instrumentation is needed to properly control the axial flux shape in control rod regions, and to direct control changes. Axial

power monitoring, when coupled with individual assembly flow and temperature monitoring, provides complete production exposure information.

Cladding penetrations can potentially occur in fuel and target assemblies, so instrumentation is needed to recognize the type and location of the failure. There is also a need for sensors at each reactor core position to monitor fuel and target exposure to comply with safeguard rules. These rules require that radionuclides be accounted for from their genesis and separation to the time of shipment.

Efficient Refueling. Refueling includes the introduction of fresh driver fuel and targets into the reactor, and removal of irradiated fuel and targets after their exposure cycles. SRS experience shows that it is important to open and close the reactor easily, and to refuel and restart rapidly to maintain high availability. The machines supplied to do the refueling operation must be capable of all head preparation for removal and insertion of fuel and targets reliably.

Summary

Several distinguishing characteristics have been emphasized to contrast production and power reactors: mission, role, technology considerations for fuel and target fabrication and reprocessing, neutron economy, versatility of reactor core control and instrumentation, and rapid refueling. For either production or power reactors, however, safety and reliability are paramount.

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