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SODIUM COOLED SMALL FAST LONG-LIFE REACTOR "4S"

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ABSTRACT

CRIEPI and Toshiba Corp. have been exploring to realize a small-sized nuclear reactor for the needs of dispersed energy source and multi-purpose reactor. A conceptual design of 4S (Super-Safe, Small and Simple) reactor is proposed to meet the following design requirements: (1) All temperature feedback reactivity coefficients including whole core sodium void reactivity are negative; (2) The core integrity is secured against all anticipated transient without reactor scram; (3) No emergency power nor active mitigating system is required; (4) The reactivity core lifetime is more than 10 years. The 4S reactor is a metallic fueled sodium cooled fast reactor. A target of an electrical output is 10-50 MW. A remarkable feature of 4S is that its reactivity is not controlled by neutron absorber rods but by neutron reflectors to cope with a long core lifetime and a negative coolant void reactivity.

This study includes a design consideration of 4S. Design discussions are mainly focused on various core designs to meet above requirements. A tall core active height is adopted to gain long core lifetime. An averaged fuel burn-up is tried to be increased up to 100 GWd/ton from a point of economic view. The reference 4S designs are 10 MWe (30 years core lifetime) and 50 MWe (10 years core lifetime).

KEYWORDS

Small Reactor; Long-life core; Fast Reactor; Metallic Fuel; Passive Safety

1. INTRODUCTION

The 4S reactor is a small-sized sodium-cooled fast reactor in which intensive efforts has been concentrated with an aim at meeting the global energy source market. An economical disadvantage is pointed out as the principal hurdle to realize small reactors. Higher safety is also required, because the number of nuclear power plants increases in case small reactors are developed to all over the world. The economics tends to be incompatible with the safety in the classical nuclear reactors. Introduction of the passive system is expected to make coexistence between the economics and the safety. To correspond to above requirements, the 4S reactor design study started in accordance with the principle of higher safety, improved economic features, simple operation, simplified maintenance and proliferation resistance without scheduled refueling (Ueda *et al.,* 1991). More specific design policies for the 4S reactor are listed as follows;

1. no refueling more than 10 years (30 years, if possible),
2. simple core burn-up control without control rod and its rod driving mechanism,
3. removal of control and adjustment components from the reactor system,
4. quality assurance and short construction period based on shop fabrication,
5. load following without operation of reactor control system,
6. minimum maintenance and inspection of reactor components,
7. negative reactivity temperature coefficients including coolant void reactivity,
8. no core damage in any conceivable initial events without reactor scram,
9. safety system not dependent on the emergency power and active decay heat removal system,
10. complete containment of reactivity under any operational conditions and decommissioning.

Items from 1 through 6 relate simplification of system and maintenance. Items from 7 through 10 relate safety. The 10 years core lifetime means that the primary system has been closed for 10 years because a reactor vessel is not required to be opened for refueling. This 10 years sealed core and fuel system may have a great advantage to the proliferation resistance.

Based on above design requirements, 4S reactor has been embodied with higher safety and passive characteristics. Enhanced passive safety features can realize higher safety and can greatly reduce the auxiliary systems, which are required to support the safety function system. The system reduction and simplification also reduce the maintenance works.

The negative coolant void reactivity during core lifetime greatly helps to carry out the passive shutdown in unprotected transients of which typical events are ULOF (unprotected loss of flow) and UTOP (unprotected transient overpower). A fully passive heat removal system is employed in the 4S so that the auxiliary support system can be eliminated. The safety of 4S can easily be demonstrated in full-scale test because of its small size. The design status of the passive safety feature of the 4S was described and the passive safety capability was estimated through safety analyses.

The key technology introduced to the 4S reactor is the reflector controlled metallic fuel core to realize both the 10-30 years core lifetime and the negative coolant void reactivity. In general, a good neutron economics (in other words, a good internal conversion) is required for longer core lifetime. Also, large neutron leakage is required to make a coolant void reactivity negative in sodium coolant and plutonium fuel system. In the 4S reactor, these opposed characteristics are compromised by the reflector controlled longer metallic fuel core. The core design approach and reactor designs are presented in this study.