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Improved core design of the high temperature supercritical-pressure light water reactor

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Abstract

A new coolant flow scheme has been devised to raise the average coolant core outlet temperature of the High Temperature Supercritical-Pressure Light Water Reactor (SCLWR-H). A new equilibrium core is designed with this flow scheme to show the feasibility of an SCLWR-H core with an average coolant core outlet temperature of 530 °C.

In previous studies, the average coolant core outlet temperature was limited by the relatively low temperature outlet coolant from the core periphery. In order to achieve an average coolant core outlet temperature of 500 °C, each fuel assembly had to be horizontally divided into four sub-assemblies by coolant flow separation plates, and coolant flow rate had to be adjusted for each sub-assembly by an inlet orifice. However, the difficulty of raising the outlet coolant temperature from the core periphery remained.

In this study, a new coolant flow scheme is devised, in which the fuel assemblies loaded on the core periphery are cooled by a descending flow. The new flow scheme has eliminated the need for raising the outlet coolant temperature from the core periphery and removed the coolant flow separation plates from the fuel assemblies.

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1. Introduction

The concept of the High Temperature Supercritical-Pressure Light Water Reactor (SCLWR-H) has been being developed at the University of Tokyo since 1989 and it has been selected as one of the Generation IV reactors. It is a thermal reactor, cooled and moderated by supercritical-pressure light water.

The supercritical-pressure light water does not exhibit a phase change from liquid to gas, so the coolant flow in this reactor is single phase. As a result, the SCLWR-H has a high economic potential that is beyond the reach of current LWR technology, due to its low capital cost and high plant thermal efficiency.

The plant system of this reactor is simpler and more compact compared to that of existing BWRs and PWRs, and it is similar to that of a supercritical fossil-fired power plant (FPP) as shown in Fig. 1. The plant system has a once-through direct cycle. The coolant directly circulates from the core to the turbine, and back to the core without the need for re-circulation or water–stem separation systems. The coolant can absorb a high enthalpy rise with a low core flow rate (about 1/10th of that in LWR) in the core and efficiently drives the turbine. Hence, both the core and the balance of plant (BOP) become compact.

The high enthalpy coolant from the outlet of the core results in a high plant thermal efficiency of about 44%. This is higher than that of a supercritical FPP for the same turbine inlet temperature, because there is no heat loss associated with the exhaust gas.

The SCLWR-H concept is being developed by applying existing technologies and operating experiences from LWR and supercritical FPP plants, thereby minimizing the need for large-scale developments. The application of major components, such as the reactor containment vessel, pumps and turbines, are all within the operating temperature range experienced by existing technology. The safety system is similar to that of the LWR. However, the core is expected to be a design element, which will require a relatively large-scale development effort.

One of the most important parameters of the core design is the average coolant core outlet temperature, because it directly affects the plant thermal efficiency. Un-

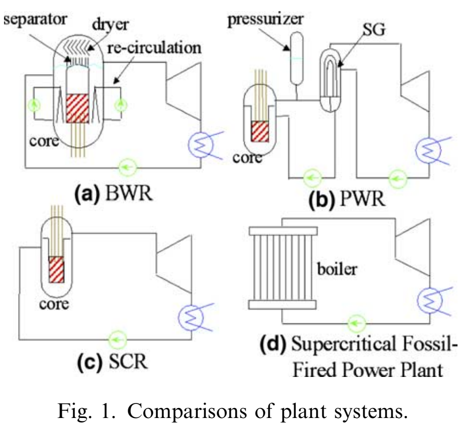

Fig. 1. Comparisons of plant systems.