

DEEP UNDERGROUND REACTOR (PASSIVE HEAT REMOVAL FROM A LWR WITH A HARD NEUTRON ENERGY SPECTRUM)

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ABSTRACT

In this paper, I discuss the advantages of siting deep underground a high-conversion reactor with a Pu-Th fueled tight-fueled assembly, wherein the fuel has a long burn-up period. By putting this reactor far under the ground, heat can be removed passively not only during a steady-state run and also in emergencies, such as loss of coolant and loss of on-site power; hence, the safety of the reactor can be much improved. Also, the reactor can be built near a consumer area, and the evacuation area around it accordingly minimized. This approach reduces the cost of generating electricity by eliminating the container building and shortening transmission lines.

INTRODUCTION

The concept of a high-conversion light water reactor using a high concentration of Pu-fuel tight-lattice was proposed in the Nuclear Energy Research Initiative (NERI) Program [1]. This reactor has a hard neutron-energy spectrum close to that of an Na-cooled fast reactor, so that a high burn-up of fuel can be obtained. A reactor with uranium fertile material has a positive water-coolant void coefficient; thus, to obtain a negative void-coefficient, a pancake-type flat core configuration is needed, or a fuel assembly with a neutron-streaming void section [2]. The latter option reduces neutron economy. The use of thorium fertile material, however, provides a negative void-coefficient without having a neutron-leaky core configuration; the neutron economy accordingly is improved and a higher burn-up of fuel attained compared with a reactor with uranium fertile materials. However, the pumping power required to circulate the water coolant has to be substantially increased to remove the high-density heat from a tight-lattice fueled core. During steady operation, the flow of the coolant can be maintained by increasing the pumping power several times above that of the regular LWR. But, during emergencies, such as an outage of on-site power or loss of coolant, heat removal becomes a serious problem. This accident scenario has been analyzed in detail, and an experimental study on heat removal from a tight lattice is planned in the Japanese research program.

PASSIVE HEAT REMOVAL

To withstand an emergency of loss of pumping power, a passive cooling system is needed to remove heat, such as using the natural circulation of the coolant. Here I propose using a tight-lattice water reactor embedded in a deep underground location, where it will be cooled by the natural circulation of the water. A high pressure difference between the inlet and outlet in the narrow water channel of the tight lattice is generated by the difference in gravity force between the low density of boiled water and the high-density water condensed after the steam passes through the steam turbine. To achieve such a high-pressure difference, the vacuum condenser must be located far above the boiling water reactor. The pumping-pressure difference needed to circulate water in a regular BWR and PWR are, respectively, 2 atm and 1.5 atm, equivalent to a 20-15 meter difference in water height. For our high conversion (HC) LWR with a tight lattice, the difference in pumping power is increased several times; a water height of more than 80-60 meters is needed to naturally circulate coolant water. By putting the reactor deep underground, there is enough space to get such a high pressure difference between the inlet and outlet, relying on the density difference between the steam section and the water which is condensed after passing through the steam turbine and condenser; in our configuration, both are located far above the reactor vessel. By locating the reactor even deeper, the pressure imposed on the pressure vessel is increased by the gravitational force of the surrounding earth. A water pressure of 100 atm and 150 atm for a BWR and a PWR can be provided, respectively, by the earth's pressure at a depth of 400- and 600-meters.

The passive cooling system using natural circulation conventionally proposed is operated in an