Programme in the Republic of Korea

In Korea, an accelerator driven system (ADS), named HYPER (HYbrid Power Extraction Reactor), is being developed at KAERI within the framework of the national mid- and long-term nuclear research plan. The basic mission of HYPER is the transmutation of both transuranic elements (TRUs) and long-lived fission products (LLFPs). The minimum required sub-criticality of the HYPER core is set to k_{eff}=0.97, and the rated power is 1000 MW_{th}. Lead-bismuth is used as the coolant due to its benign chemical characteristics. A proton current of 1 GeV impinges on a lead-bismuth target in the core center and generates about 29.3 spallation neutrons per proton. Transmutation of the radioactive nuclides, in general, is based on a closed fuel cycle. Consequently, the related fuel cycle should have a high proliferation-resistance. In HYPER, a simple fuel cycle is assumed, in which spent fuels from commercial reactors are reprocessed with a highly proliferation resistant pyroprocess, such as electro-refining. The TRU fuels contaminated with a significant fraction of lanthanides are incinerated in the HYPER core. The spent fuel of HYPER is also recycled after undergoing a similar proliferation resistant reprocessing. It is claimed that the fuel cycle for the HYPER system has an excellent compatibility with the non-proliferation requirements.

Currently, R&D activities are mainly focused on the core and beam window designs. The HYPER core adopts a hexagonal type fuel array to render the core compact and to achieve a hard neutron energy spectrum. In order to keep the radial power peaking within the design target value of 1.5, the blanket region is divided into three TRU enrichment zones. A low TRU fraction fuel is loaded in the innermost zone and a high TRU fraction fuel in the outermost region. The refuelling is to be performed based on the scattered loading with 3 batches for each zone. Target cycle length at the equilibrium state is 1 year with a 75% capacity factor. In order to minimize the reactivity swing of the HYPER core loaded with TRU fuels, two types of burnable absorbers are under investigation, one is B_4C-coated cladding and the other one a mixture of B_4C and ZrH_2. Preliminary studies show that B-10 can be effectively used as a burnable absorber, especially the mixture of B_4C and ZrH_2 can reduce the reactivity swing by a factor of 2, with only a little compromise of the transmutation quality. An important research area is the maximization of the spallation neutron multiplication, in other words, minimization of the proton current. The overall optimization of the core is in progress such that the source multiplication can be maximized.

A unique feature of HYPER is the transmutation of ^{99}Tc and ^{129}I in a locally thermalized neutron spectrum six fission product containing assemblies are loaded in the middle ring of the core in order to make the support ratio of the fission products similar to that of TRU (4 - 5). In the fission products target region, metallic ^{99}Tc is loaded as a plate in the periphery and NaI or CaI_2 rods are placed in a staggered manner with CaH_2 moderator rods, inside the Tc plate.

Either TRU-Zr metal alloy or (TRU-Zr)-Zr dispersion fuel is being considered as a blanket fuel for the HYPER system. In spite of the successful application of the metal fuel in the conventional LMRs, it is not easy to control the vaporization of americium nuclides in the fabrication process of an alloy type fuel rod. In the case of the dispersion fuel, the particles of TRU-Zr metal alloy are dispersed in the Zr matrix. The cladding material is ferritic-martensitic steel, HT-9. It is expected that the dispersion fuel will generally withstand significantly higher burnup than the alloy fuel.

The proton beam is delivered into the core central region through a beam tube and the target zone is separated by a 2 mm-thick window of 9Cr-2WVTa. Related research work is focused on the lifetime analysis of the window. The target lifetime of window is at least one year. Preliminary results indicate that, as far as the mechanical integrity is concerned, the window seems to withstand 6 mA current of 1 GeV protons. Currently, more detailed analyses are ongoing. In HYPER, a 3-loop heat transport system is adopted in order to keep the coolant speed below the maximum value of 2 m. The p/d (pitch-to-diameter) ratio of the HYPER core is 1.5, and the corresponding Pb-Bi velocity is 1.1 m/s. Instead of wire spacer commonly used for tight lattices, grid spacers are suitable to ensure proper separation of the fuel rod. Thermal hydraulics analyses are being performed with a modified SSC code. In the next phase of R&D, the research will be tuned to the core thermal hydraulic analysis including the target area.

The whole development schedule for the HYPER system is divided into three phases. The basic concept of the system and the key technical issues are identified in Phase 1 (1997-2000). In Phase 2 (2001-2003), core design optimization will be performed to maximize the HYPER economics. Also in phase 2, some experiments will be conducted to confirm the key technical issues. A thermal hydraulic test for Pb-Bi, an irradiation test for the fuel, and a spallation target test are the major experiments that KAERI is considering. In Phase 3 (2004-2007), a conceptual design for the HYPER system will be finished by completing the development of design tools based on the experiments.