IAEA-SM-332/I.3

# DESIGN TRENDS AND MAJOR TECHNICAL ISSUES OF ADVANCED NON-WATER COOLED NUCLEAR REACTORS

Shunsuke Kondo
JAPAN

Advanced nuclear reactors are under development in various countries as successors to or companions of present day nuclear power plants. Some of these advanced reactors, liquid metal cooled fast reactor and high temperature gas (helium) cooled reactor, in particular, are being developed, among other things, to contribute to the expansion of nuclear energy use for the protection of the environment of our planet earth since the former can significantly expand the fissile resource basis for nuclear energy by breeding and the latter can significantly broaden the application of nuclear energy in non-electric sectors.

The major design trends for these advanced non-water reactors are, responding to the increasingly demanding safety requirements, economic competitiveness and public acceptance, to employ the core with improved characteristics such as smaller positive component of reactivity coefficients, higher outlet coolant temperature, higher fuel burn up, etc. for safer and more competitive plants, to pursue compact design for competitiveness, to simplify the plant design for higher reliability, facilitating inspection, maintenance, repair and replacement of equipment, to wisely apply passive and active safety systems for safer plants, to increase in robustness against beyond design bases events, to pursue more thoughtful design of man-machine interface for operators, to reduce on-site construction work so as to shorten the construction schedule, etc.

Major technical issues under discussion are development and validation of analysis codes for both nuclear characteristics and thermal hydraulics of advanced core and plant systems in normal and transient conditions, understanding of severe accident phenomenon and the possibility of its management by non-safety grade systems, code for high temperature structural design, feasibility of alternative fuels and coolants for safer plant, feasibility of integration of components or modular system for more compact and economical plant, feasibility of transmutation of hazardous nuclei like Np, Am, Cm or minor actinides in fast reactors for expanding its strategic role, application of probabilistic safety assessments (PSA) for evaluation and rationalization of safety design, numerical safety goals for advanced nuclear plants etc.

In addition to these piecemeal issues, there are several strategic issues on the long road to the commercialization of these advanced non-water reactors. Key items are competitiveness, first of a kind cost, technology demonstration and plant licensing, and compatibility with fuel cycle system utilized or under development. As for the employment of new technology, there is a tendency to pursue it in an evolutional way, seeking improvements in components and systems and construction and operation based on the experience gained with presently operating experimental or prototype plants, although incorporating several innovative features such as passive systems to assure higher safety. In the case of incorporating innovative components or systems for which a large experience base is lacking, it is stressed that they should undergo thorough testing and demonstration before they are used in real plants in order to achieve high reliability.

In the case of fast reactor, the key issue has been the competitiveness. For example it is claimed that the European Fast Reactor (EFR) has been designed with objectives that 1) it must be regarded as the lead plant of a commercial series ordered from 2010 onwards; 2) it must be an advanced design that is still valid in 2010 without substantial extrapolation of the currently available fast reactor technology; 3) the design must be underwritten by a well-focused and comprehensive R&D program; 4) EFR must be an economically acceptable alternative to contemporary thermal reactor plants; 5) It must be licensable in any participating countries with minimum adjustment that might be necessary to cope with particular national requirements. The view of utilities is, however, cautious: they stated that although fast reactor will become necessary in future, when it will become so is an open question today, one of the major parameters being the total demands for nuclear energy, and therefore, it will be used meanwhile to burn more Pu than they produce in parallel with the demonstration of its technology from the viewpoints of reliability and maintainability.

In the case of actinide burning, it has been shown that a reduction of the actinides can be possible by burning in fast reactors to a reasonable degree. This holds also for thermal reactors if the high mass number minor actinides beyond Am or Cm are not recycled. Whether we can use this approach, however, depends on the possibility that we can solve the problems of reprocessing and fabrication processes caused by the actinides with their high neutron emission and heat release. The Integral Fast Reactor (IFR) which is an innovative fast reactor concept developed by the USA is the most promising candidate for this purpose since it uses a metallic fuel and a pyroprocessing for reprocessing. However, the IFR demonstration effort is now faced with a setback due to a change of priority in formulating energy R&D budget in the USA.

The hurdles on the road to the commercialization of HTGR are similar. It is said, for example, that the scale up of the modular HTGR to 4x350MW(t) module would be necessary for attaining the competitiveness with similarly sized fossil and nuclear station, although the flexibility in the selection of plant capacity, in addition to a new quality of safety, has been a merit of this kind of reactors.