FAST REACTORS AND NONPROLIFERATION

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БЫСТРЫЕ РЕАКТОРЫ И НЕРАСПРОСТРАНЕНИЕ

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1. Three aspects of nonproliferation relevant to nuclear power are:
   - Pu buildup in NPP spent fuel cooling ponds (~ 104 t in case of consumption of ~107 t of cheap uranium). Danger of illegal radiochemical extraction of Pu for weapons production;
   - Pu extraction from NPP fuel at the plants available in nuclear countries, its burning along with weapon-grade Pu in NPP reactors or in special-purpose burners;
   - increased hazard of nuclear weapons sprawl with breeders and closed fuel cycle technology spreading all over the world.

2. The latter is one of major obstacles to creation of large-scale nuclear power capable of substituting for a substantial part of conventional fuels for solving the problems confronting the world:
   - depletion of cheap hydrocarbon fuel resources, rise in their prices, international conflicts around oil and gas sources;
   - releases of combustion products reaching hazardous limits.

That was the reason for termination of research involving breeders and closed fuel cycle in the USA. Other obstacles lie in the high cost of fast reactors and the failure to solve the problems of NPP safety and radioactive waste, as applied to large-scale power generation.

3. Nuclear power of the first stage using U-235 will be able to meet the demands of certain fuel-deficient countries and regions, replacing ~5-10% of conventional fuels in the global consumption for a number of decades. Nonetheless, without a prospect of large-scale development using breeders it loses its initial motivation and basic arguments, while the world will be deprived of one of the most realistic opportunities discussed to solve the arising energy problems.

4. Fast reactors of the first generation and the currently employed fuel technology are far from exhausting their potential for solving economic problems and meeting the challenges of safety, radioactive waste and nonproliferation. Development of large-scale nuclear power will become an option accepted by society for solving energy problems in the following century, provided a breeder technology is elaborated and demonstrated in the next 15-20 years, which would comply with the totality of the following requirements:
   - full internal Pu breeding (BR= CBR ~1);
   - deterministic elimination of severe accidents involving fuel damage and high radioactivity releases: fast runaway, loss of coolant, fires, steam and hydrogen explosions, etc.;
   - reaching a balance between radioactive wastes disposed of and uranium mined in terms of radiation hazard;
   - technology of closed fuel cycle preventing its use for Pu extraction and permitting physical protection from fuel thefts;
   - economic competitiveness of nuclear power for most of countries and regions, i.e. primarily the cost of NPPs with fast reactors is to be below the cost of modern LWR plants.

5. The main growth in demand for energy in the next century will fall on developing countries, which are therefore most interested in the development of a new power technology. It is on their initiative that the development depends now. No doubt the initiative will be supported by specialists from Russia and other nuclear states and their governments, provided the technology to be developed meets the requirements of nonproliferation.

6. The basic aspects of reactor concepts, which have been mastered in civil and military nuclear engineering and are studied for future use, are clear enough to decide on a certain option for the next stage. Fast reactors with UN-PuN fuel of moderate power density, which do not contain uranium blanket with BR= CBR ~1 and have a small reactivity margin $\Delta K_{tot} < \beta_{eff}$, optimal feedbacks, which are cooled with liquid lead at a low pumping rate (< 2 m/s) and assure a high level of natural circulation, seem to meet the requirements made.

7. If there is no uranium blanket in the reactor, it will not produce a surplus of weapon-grade plutonium. The value $\Delta K_{tot} < \beta_{eff}$ does not permit loading in the reactor fuel assemblies with source material for the production mentioned. At CBR~1 the fuel has a near-equilibrium composition and its reprocessing does not require either extraction or addition of Pu (the composition is corrected by adding U-238 to compensate for burn up). Various modes of refueling are possible-

up to quasicontinuous on-lead refueling (in the periods of load reduction). To avoid long-distance transportation of the fuel and radioactive materials it is appropriate to arrange the fuel cycle processes at large NPPs.

The above-mentioned factors open up possibilities for employing a simplified technology of fuel reprocessing, which excludes Pu extraction and its off-pile storage, and amounts essentially to removal of fission products from spent fuel.

8. The currently employed and investigated technologies of fuel reprocessing involve Pu extraction. The search of a new technology or improvement of the currently used ones are required. Physical methods of fuel purification from fission products, making use of approximately double difference in atomic weights, are of particular interest.

9. Primary reprocessing of today's reactor fuel and fabrication of the first loads for breeders may be performed at the plants of the nuclear states or at nuclear technology centers set up on their basis under international jurisdiction.

10. The scheme outlined above suggests simultaneous solution of two major problems:

- profitable involvement of accumulated plutonium into nuclear power fuel cycle, reducing the risk of its utilization for weapons production purposes, without special-purpose burners; and
- development of large-scale nuclear power.

Obviously, no new fuel technology can either rule out the illegal use of the available technologies for Pu extraction or uranium enrichment for weapons production. The problem may be solved solely by improving the measures of protection and control, international political regime of nonproliferation, and it is to be solved irrespective of a particular course of nuclear technology and power development.