REMARKS ABOUT THE REACTOR SYSTEM DRIVEN BY AN ACCELERATOR FOR NUCLEAR WASTE TRANSMUTATION

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ABSTRACT

The long-lived waste transmutation system is analysed with the grid of the actual technological applicability. Specific questions in reactor, accelerator, interface between them and radioprotection difficulties are formulated for clarify the complexity of a burning waste system. Some remarks are based on the results of two OECD Benchmarks (simulation of energetic proton collision on heavy target).

1. Introduction

The purpose of this paper is to pose the problems of the driven accelerator system with a simple-minded but global approch.

2. The reactor

Criticity: in pressurized water reactor (P WR), variation of neutron flux density happens, caused by statistical fluctuations of fission process. If an energetic proton beam initiates fission near the critical threshold (k_{eff} value, the effective multiplication factor, is often chosen as 0.95), local divergences are foreseeable in the core. Changes with the time inside core and targets reduce the homogeneity of the system and aggravate the probability of hot spots. The managing of the reactor becomes then more and more difficult even with molten salt reactor.

Radioactivity control: this control depends first on the structure of reactor. The heat coefficient $\alpha = dk_{eff}/dT$ (T is the temperature) must be negative i.e. when the core temperature increases, neutron flux production would decrease. For the russian RBMK reactor, α is positive.
The assumption that after the beam shut down, fission reaction would stop instantaneously, ia not proved because the after-heat can involve partial or complete core fusion in an accidental case.
The control problem still awaits answer. What are really the means for avoiding critical and supercritical divergences, power exersion? How could be the tools for absorption control, configuration control, spectral shift control, fuel control, moderator control, reflector control, fluid poison control?

Accessibility: the access to the different parts of the reactor system are very important for safety. At the beginning of design, we have to integrate into some special places, control detectors and neutron absorber.

Delayed neutrons and ***approach to criticality:*** delayed critical neutron are useful to manage fission reaction in a P WR; in our case, less fission products would release less delayed neutrons.

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The space phase of neutron production is larger with a reactor driven by an accelerator than in the PWR. The main difficulty about neutronic control is the approach to criticality with prompt neutrons.

Coolant: the viscosity of coolant must be in such a way that heat is evacuated quite fast from the core. Heavy pressure of cooling is a condition for this system.

Safety device: **all** of these system driven by accelerator do not use fuel clads for stopping any radioactive leakage. However, it is an important safety device in usual PWR. The safety of the reactor vessel is also weakened by the opening of window into the wall thickness.

Efficiency and *optimization:* the efficiency estimations and parameter optimization depend on the waste concentration and mass, k_{eff} value, sise and geometry of reactor, the operating cycle of the system; chemical reprocessing and separation possibilities limit the waste burn-up.

Diversion: if we use this system with other aims than the planned one, we could make enriched **fissile** fuel. We have to take appropriate action and to avoid technological diversion of this system.

Ignorances: for the understanding of collisions at intermediate energies between hadron and heavy nuclei, experimental data and **unified** theoretical models are missing.

3. The accelerator-reactor interface

Thickness: if the window is thin (for instance, 5 mm with a radius of 460 mm in **japanese** projects), energetic proton beam passes through it without any appreciable intensity change. But pressure **difference** between reactor **vessel(155** bar) and accelerator, overheating of the window (A 1 **GeV** beam lets 0.7 **MeV** in a steel window i.e. 4 **kW/mm)** lead to its mechanical break even with an additional cooling.
If the window is thick (for instance, **5cm),** neutron absorption is high. Half the beam intensity **(10mA** to 300 mA) can be lost in this interface; this is balanced by a best mechanical resistance.

4. The accelerator

Neutron back-scattering: more the window is thin and the proton energy low, more back scattering neutrons produced in the window could ***damage*** the accelerator running. Every incident proton produces no less than one **bs** neutron. 1 **mA** gives 0.161016 **bs** neutrons.

Energy: what is the best energy of incident protons for nuclear waste transmutation? We must watch over all parameters for a acceptable optimization.

Halo: This valuation of the halo has to be taken account. Interactions between residual gas and the incident particles beam reduce the **efficiency** of the accelerator.

6. Conclusion

Principal argument of the system is the impossibility of criticity accident but no demonstration has been done of this assumption. Our computer simulations demonstrate the existence of local divergences induced by the chain reaction and show the back scattering neutron production. Every question has to be solved before the construction of any prototype.

References

[1] J. Maillard - Conference “Commentaires, **réflexions** et propositions **sur** les **systèmes** de transmutation des **déchets nucléaires à** vie **longue”,** Orsay (22 **février** 1994)

[2] International code comparison for intermediate energy data NEA OECD (1994)

[3] F. **Bacha,** J. **Maillard** - Specification for an International Code and Model **Intercomparison** for Intermediate Energy I & II (1993)