TWO APPROACHES TO NEUTRON PRODUCTION FOR ACCELERATOR BREEDING AND RADWASTE TRANSMUTATION

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Production of intense fluxes of energetic neutrons using spallation reactions induced by the beams of accelerated charged particles is considered to hold certain promises as referred to the solution of specific problems of nuclear reactor fuel cycle (such as nuclear breeding and transmutation), utilization of weapon-grade plutonium, etc. Generally, the concept of accelerator driven target-blanket system is considered to be feasible. However, it was not yet clearly demonstrated that such system is practical. The reasons for this are following:

- the nature of neutron-producing reactions;
- high technological risk associated with inadequate research and development of components of the system in question;
- very high capital cost;
- inadequacy of nuclear data available at the moment.

The nature of spallation reactions envisaged as a neutron source is such that the maximum of neutron yield or minimum neutron production energy cost pertains to the energies of the order of 1 GeV per accelerated nucleon. We cannot go down with energies, build a smaller and less expensive spallation machine and project the results obtained on a large-scale device. On the other hand, even that minimum energy cost is high enough to make necessary the solution of the dilemma: either to increase drastically the beam current or to enhance fissions in the subcritical blanket. This disadvantage of spallation reactions is explained by the fact that almost forty per cent of the initial projectile energy is lost for ionization of the target medium while the projectile slows down before it undergoes inelastic collision with target nucleus[1].

Technological feasibility of the concept could be proven if there existed a less expensive and complex prototype device combining all the constituents of the system under operation. Taken apart, all these constituent parts exist or can be developed: high projectile energies were managed, RF sources to accelerate intense beams of charged particles exist, target-blanket assembly can be designed. However, technological risk associated with construction of such device is probably too high and the gain to be obtained is too uncertain for the project to get started.

Very high capital cost of accelerator based nuclear installation is probably a decisive

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argument in the complicated political and economical interplay involved in the realization of the concept.

More complete nuclear and neutron data are needed to clarify the potential of accelerator applications in nuclear energy.

The above arguments demonstrate that inexpensive, compact prototype accelerator device is necessary to prove the practicality of the idea and that spallation neutron source is not convenient for the purpose.

The answer to the questions raised above is to reduce projectile energy losses for ionization and to find a suitable nuclear reaction to produce neutrons at lower energies. Such neutron source can be provided if neutron stripping was used instead of nuclear spallation. The idea was initially suggested in[2] and was further elaborated in a number of publications[3,4]

A set-up of a suggested demonstration facility is shown in Fig. 1. A deuteron beam is initially accelerated in the deuteron linear accelerator and pierces transparent target. Neutrons are stripped from loosely-bound deuteron projectiles during inelastic collisions with target nuclei. Scattered deuterons are picked up, squeezed and shaped to form a focused beam. The trajectory is then bent twice with magnet structures to form a storage ring. Quadruple magnet lenses are positioned within the interval between the bending structures to shape the deuteron beam and minimize deuteron losses. RF resonators are installed within the space between bending magnets opposite to the target to compensate losses of deuteron energy on ionization. The dimensions shown in Fig. 1 are given in centimeters. Thus, the storage ring is a very compact structure. Neutron energies form a continuous spectrum with maximum corresponding to approximately one half of initial projectile energy. This spectrum can be adjusted for specific purposes. Neutron yield from stripping reactions is small as compared to that of spallation reactions. To achieve sufficiently high neutron fluxes it is envisaged to accumulate considerable beam currents within the storage ring.

The results given in Table 1 for beryllium target represent the extension of parameters of the device to the very extreme conceivable limit. Evaluation of neutron yields was performed based on the data from[5]. The impact of multiple scattering during deuteron propagation in the target is still to be clarified. The results shown in the table demonstrate that evaluated ionization losses of deuteron energy are equal to less than 2 per cent of initial deuteron energy which is ten times less than in the case of 1 GeV proton beam interacting with uranium target (circa 400 MeV or forty per cent). Despite the low neutron yield from deuteron stripping reactions the neutron production energy cost appears to be approximately equal to that in the case of 1 GeV protons stopped in the thick uranium target.

The structure integrating linear accelerator, storage ring and the target is much smaller and much less expensive than the 1 GeV linac. However such installation could demonstrate that we can handle the intense beams of charged particles, beam injection in and extraction from the target. Such installation could be a testing facility for accelerator breeder and transmute technology and provide a wealth of information for material studies, nuclear and neutron data measurements. Finally, the device would demonstrate that we can actually breed nuclear fuel and transmute hazardous nuclear waste, what are the expenses and risk associated with the process.

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Table 1

Evaluated parameters of the installation under investigation

Target	Berillium
Injection current	0.05 A
Accumulated current	7 A
Deuteron beam cross-section	4.1 cm
RF frequency (q=25)	125 MHz
RF amplitude	1.8 MV
Ionization losses	1.55 MeV/rev
Target thickness	0.8mm (10^{22}cm^{-2})
Heat generation	11 MW
Neutron flux	10^{17} s^{-1}
Neutron production energy cost	35 MeV/neutron

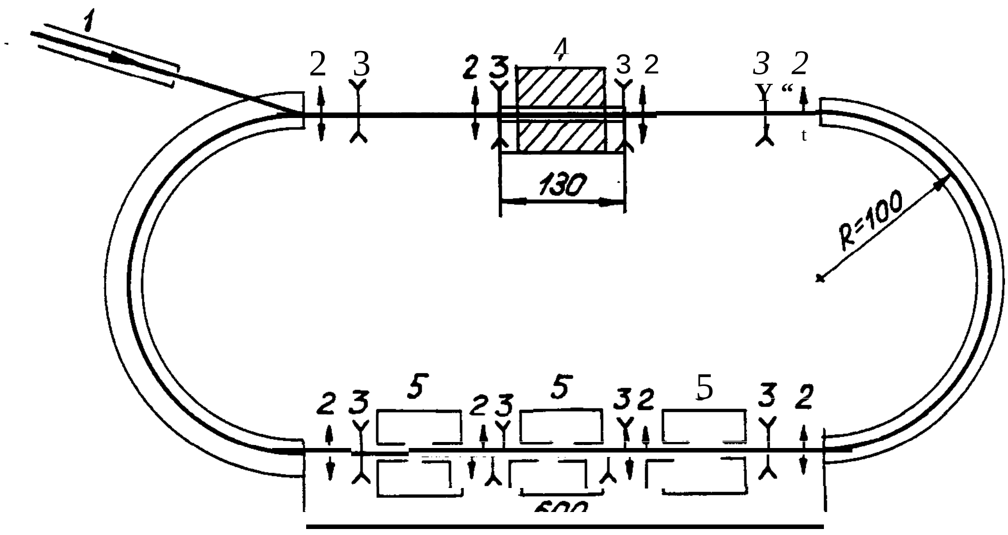

Fig. 1. Configuration of suggested demonstration facility. 1- deuteron linear accelerator; 2,3- magnet lenses; 4- target assembly; 5- RF resonators.