KENS Radiation Shield

S. Ban and H. Hirayama

National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki, 305, Japan

1. Introduction

To prove the adequacy of the KENS radiation shield, several preliminary experiments were performed. Fast neutron yield from the target bombarded by 500 MeV protons was measured using activation detectors. Attenuation lengths of fast neutrons were evaluated for iron and concrete shields. And dose rates outside the KENS shields were estimated using these parameters. After that, KENS began to be operating and dose rates above the KENS overhead shield were measured. They were rather in agreement with above estimation.

2. Preliminary experiments

KENS neutron production target[1] is made of tungsten and 7.8 cm(W)×5.7(H)×12(L). Secondary fast neutron yields were measured using several activation detectors. Saturated activities of these detectors for 0° and 90° directions are shown in table 1. They are expressed as follows,

$$A = \int_{E_t} \sigma(E)\,\phi(E)\,dE = \bar{\sigma}\int_{E_t} \phi(E)\,dE$$

where σ is the microscopic reaction cross section, E_t is threshold energy and ϕ is neutron flux. For $C(n,2n)^{11}C$ reaction, the average cross section ($\bar{\sigma}$) is 22mb and E_t is 20 MeV. Then, integral flux above 20 MeV was determined.

Neutron flux outside the shield is expressed as follows,

$$N_o = N_i \cdot \exp(-d/\lambda) \cdot r_o^{-2} \quad (2)$$

So first N_i and N_o were measured then, the attenuation length (λ) is determined as follows,

$$\lambda = d/\ln\,(r_i^2/r_o^2 \cdot N_i/N_o) \quad (3)$$

where N_i and N_o is the neutron flux inside and outside the shield, r_i and r_o are the distance from target to each measurement points and d is the thickness of the shield.

To determine the attenuation length of iron for 90° direction, KENS target was put in the iron beam stop and bombarded by 500 MeV protons. The beam stop is 30 cm thick for the transverse direction. Neutron leakage fluxes were measured by activation detectors using C(n,2n) reaction. Then using eq. 3, the value of λ turned out to be 116g/cm^2.

Next to know the attenuation length of concrete for various directions, the iron beam stop was put in the beam dump room and irradiated by 500 MeV protons. Both inside and outside the concrete shield surrounding the beam stop, neutron fluxes were measured for 0° - 100° directions as shown in fig. 1. Measurements were done using activation detectors ($Al(n,spal.)^{18}F$, $C(n,2n)^{11}C$ and $Al(n,\alpha)^{24}Na$).

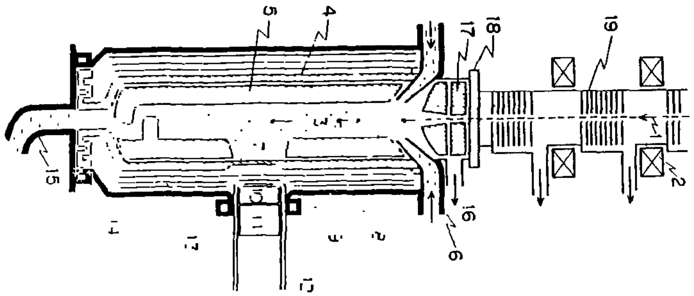

Fig. 1. Schematic Figure of MSINS (Molten-Salt Intense Neutron Source)
1 proton beam, 2 quadrupole magnet, 3 molten salt, 4 graphite vessel,
5 graphite inner cylinder, 6 inlet nozzle, 7 holes, 8 metallic container,
9 BN (decoupler), 10 polyethylene, 11 Be (BeO), 12 B_4C, 13 thermal shield,
14 freeze seal, 15 outlet, 16 vacuum line, 17 neutron shield, 18 beam shutter,
19 differential pumping system.

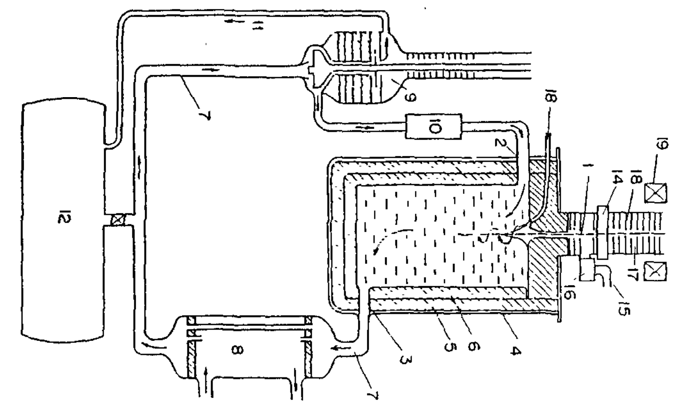

Fig. 4 Schematic Figure of Single-fluid-type Accelerator Molten-Salt Breeder
1 proton beam, 2 salt inlet, 3 salt outlet, 4 reactor vessel, 5&6 graphite,
7 primary loop, 8 heat exchanger, 9 main salt pump, 10 throttle valve,
11 overflow line, 12 storage tank, 13 high-pressure salt outlet,
14 gate valve, 15 vacuum line, 16 vapor trap, 17 duct, 18 orifice,
19 focussing magnet.

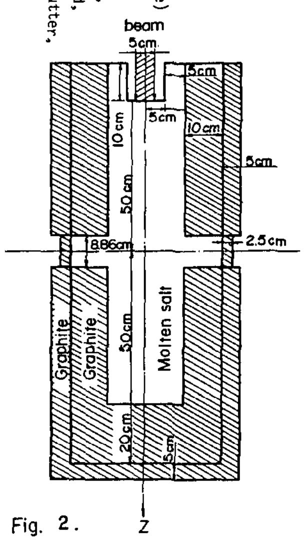

Fig. 2. Cylindrical Target Model for Neutronic Calculations of MSINS (Molten-Salt Intense Neutron Source)

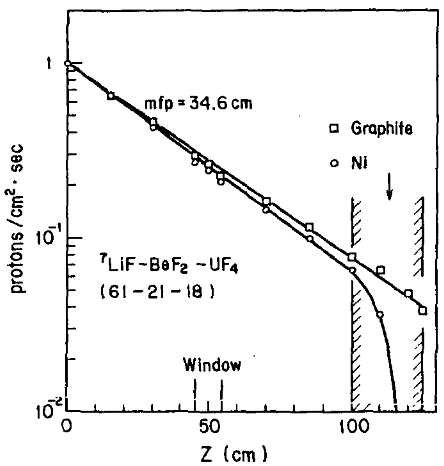

Fig.3 Axial distribution of primary protons

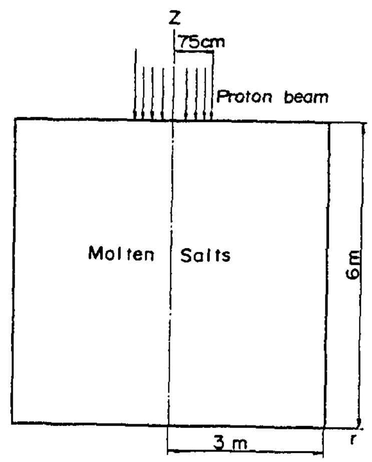

Fig. 5

Cylindrical target model for neutronic calculations of AMSB (Accelerator Molten-Salt Breeder)

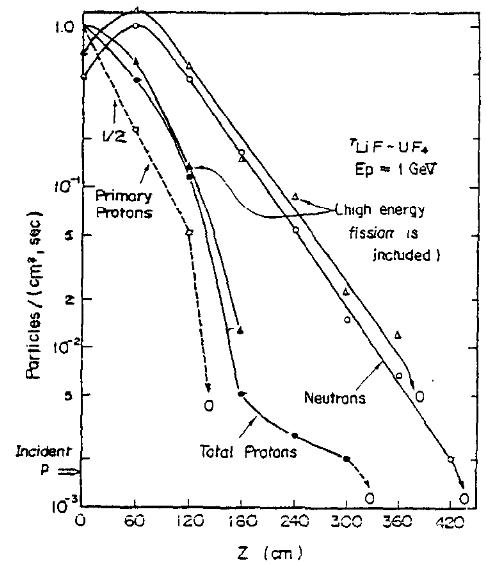

Fig. 6. Flux Distributions of Protons and Neutrons in the Direction of Incident Proton Beam. [>15MeV] (Cascade-Evaporation Only)