Beam hole design

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The main problem in collimating the primary neutron beam is that the neutrons of interest for the instruments are of high energy (∿ eV) compared with reactors and the normal absorbing materials used in reactor instruments are ineffective in absorbing these higher energy neutrons and may even have a substantial scattering contribution. A scheme has therefore been devised, based on ray diagrams, to minimise the scattering from the collimating surfaces. The system involves a series of apertures separated by longer regions of wider aperture in which surfaces viewed by the moderator are not seen by the sample and vice versa. This scheme is also useful in determining how a collimating system interacts with other constraints, such as beam shutters and choppers, and can indicate possible problem areas such as insufficient shielding of the target in wing moderator arrangements for high energy (MeV) neutrons.

A fuller account of the scheme may be found in the Rutherford Laboratory Report RL-80-054, 'Primary Neutron Beam Collimation on a Pulsed Source' by W S Howells.

Then λ was determined using eq. 3 for various angles and is about 123g/cm^2 for the forward direction and 90g/cm^2 for the transverse direction.$^{(2)}$

3. Results

The vertical view of KENS shield is shown in fig. 2. Its overhead shield is made of iron and heavy concrete. The former is 165 cm thick and the latter 80 cm thick. Dose equivalent rates outside the shield is expressed as follows,

$$H = H_0 \cdot \exp(-d/\lambda) \cdot r^{-2} \qquad (4)$$

and these shielding parameters estimated from above preliminary experiments are shown in table 2. There was not additional information for heavy concrete, it is assumed that it is the mixture of iron and concrete so its attenuation length was obtained by interpolation. These design values$^{(1)}$ are also shown. Next neutron flux was measured using C(n,2n) activation detectors on the top of the overhead shield. It is assumed that the conversion number, 3 neutron (>20 MeV) cm^{-2}s^{-1}/mrem h^{-1} would give the total dose equivalent rates due to neutrons. This results is also shown in table 2. Design values and estimated ones are different with each other, but the calculated dose equivalent rates using eq. 4 are in agreement with the measured value within factor 2 or 3.

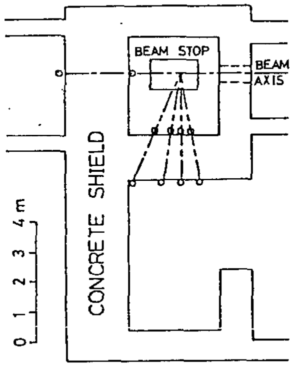
References
(1) R.H. Thomas et al., KEK-78-7 (1978)
(2) S. Ban et al., to be published

Table 1. Neutron yield from tungsten target measured using activation detectors.

Reaction	Threshold Energy	0°	90°
S(n,p)^{32}P	3 (MeV)	1.7E-26	/sr/p
Al(n,α)^{24}Na	6	3.7E-27	2.0E-27
C(n,2n)^{11}C	20	1.6E-27	5.4E-28
Al(n,spal)^{22}Na	30	8.8E-28	
C(n,spal)^{7}Be	40	5.5E-28	
Al(n,spal)^{18}F	50	3.7E-28	4.1E-29

Table 2. Vertical shielding paramaters.

	Evaluated Value	Design Value
H_0 (rem/h)m^2/(p/s)	8.2E-10	3.1E-10
λ(Iron) g/cm^2	116	145
λ(Heavy Concrete)	96	129
H (rem/h)/(p/s)	8.6E-17	6.2E-16
H(Measured Value)	1.8E-16	



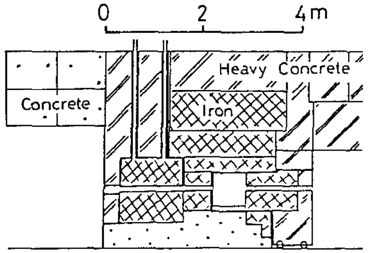


Fig. 2. Vertical view of KENS shield. Right hand side is upstream.

Fig. 1. Plane view of beam dump room. Open circles denote measurement points.

KENS Radiation Shield

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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,

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

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

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

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 $Al(n,\alpha)^{24}Na$).

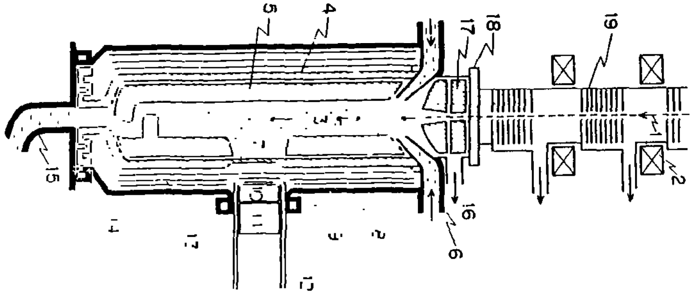

Fig. 1. Schematic Figure of MSINS (Molten-Salt Intense Neutron Source)

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.

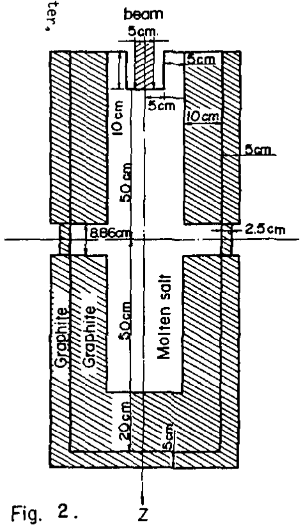

Fig. 2. Cylindrical Target Model for Neutronic Calculations of MSINS (Molten-Salt Intense Neutron Source)

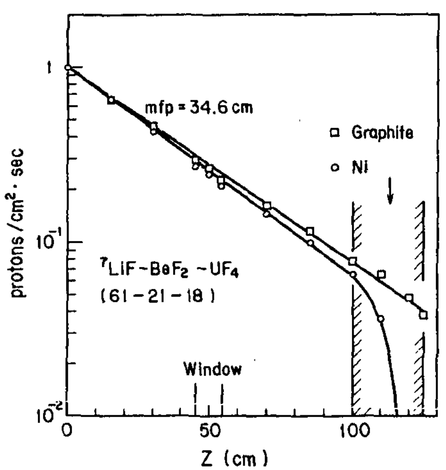

Fig.3 Axial distribution of primary protons

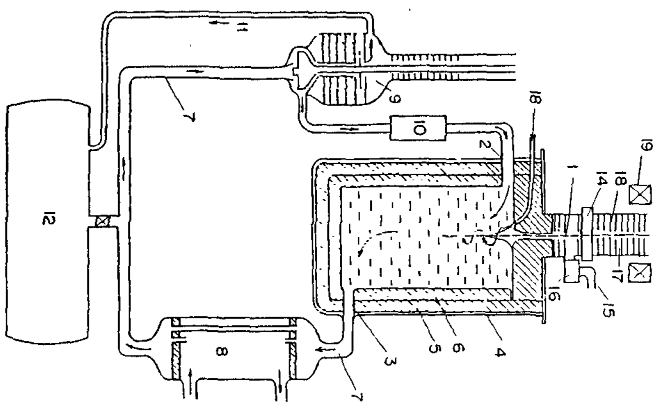

Fig. 4 Schematic Figure of Single-fluid-type Accelerator Molten-Salt Breeder

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.

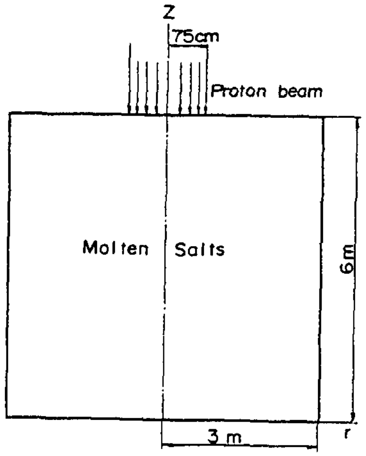

Fig. 5

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

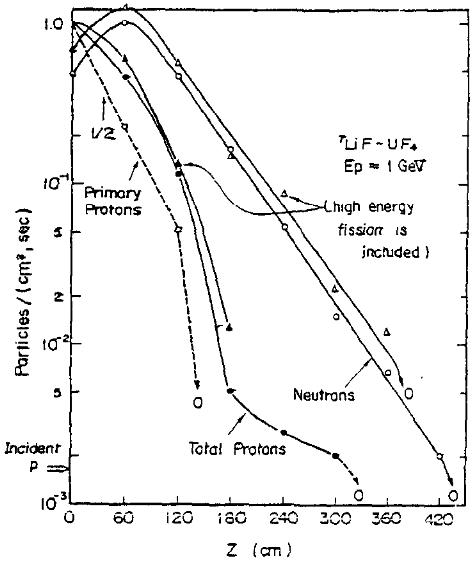

Fig. 6. Flux Distributions of Protons and Neutrons in the Direction of Incident Proton Beam. [>15MeV] (Cascade-Evaporation Only)