KENS TARGET STATION

N. Watanabe, S. Ikeda
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki 305 Japan
and
Y. Ishikawa
Department of Physics, Tohoku University, Sendai, 982 Japan

1. Description of the KENS Target Station

The complete KENS target assembly consists of the target, two kinds of moderator with decouplers and a neutron reflector. The present target element is composed of two blocks of tungsten 6 cm thick as shown in Fig. 1. The target is cooled by circulated light water. The cooling channels which are only 1.4 or 2 mm in width are positioned at both sides and ends, and between the two target blocks, although not on the top and the bottom.

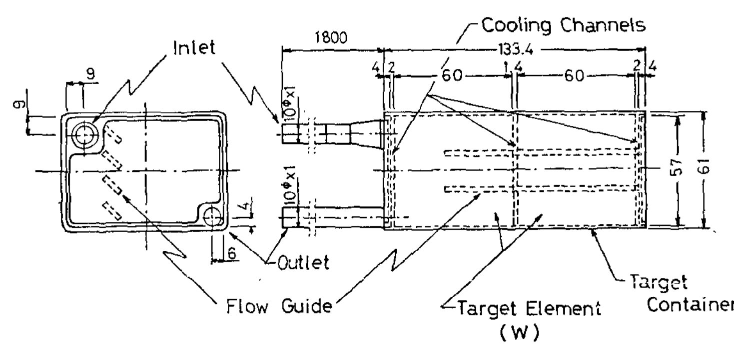


Fig. 1 KENS tungsten target

Several studies have been made in order to optimize the coupling efficiency of the target-moderator system. Figure 2 shows a cross sectional view of the KENS target-moderator-reflector assembly. A target of rectangular shape was adopted to increase the leakage of fast neutrons in the vertical direction towards the moderators. A target height of 5.7 cm was chosen on the basis of the size of the proton beam at the target and the stability of its position. The full width of the beam in the vertical sense was estimated to be about 2.7 cm and the maximum fluctuation of the beam spot position was assumed to be less than 1 cm. In addition, a small margin is necessary to limit the secondary escape particles to a tolerable level in the bottom of the cold moderator.

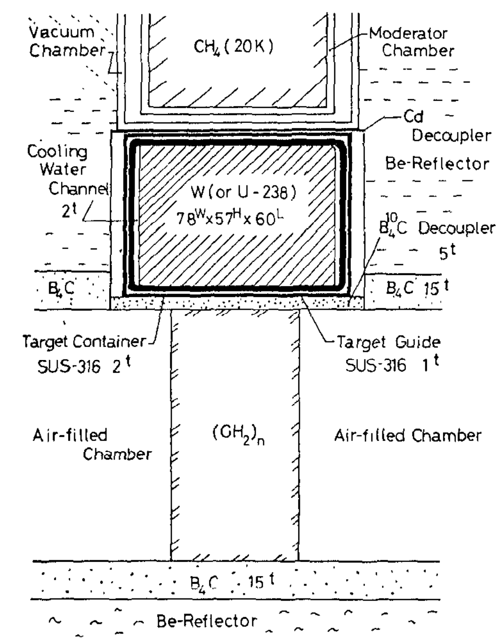


Fig. 2 Target-moderator configuration

A polyethylene moderator of dimensions 10 cm^{W}x 10 cm^{H}x 5 cm^T was located below the target. A sintered plate of $^{10}B_4C$ was adopted as a decoupler between the target and the polyethylene moderator and its thickness was limited to 0.35 cm in order to minimize the distance between them. In our design there are no cooling water channels between the target and the moderators and the distance between the center line of the target and the top of the polyethylene moderator is only 3.6 cm including the widths of the target container and a guide pipe used during target installation. A solid methane moderator of dimensions 12 cm^{W}x 15 cm^{H}x 5 cm^T is installed above the target, decoupled by a 0.5 mm thick cadmium sheet. The distance from the target center to the bottom of the solid methane is only 4.6 cm including the thickness of the walls and the vacuum gap required for thermal insulation.

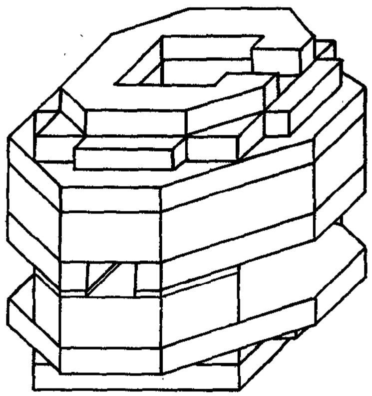


Fig. 3 Be reflector assembly

The target and the two moderators are enclosed within a reflector system composed mainly of beryllium but with graphite as an auxiliary. The beryllium reflector consists of approximately

120 beryllium blocks (about 220 Kg in total weight) which are assembled as shown in Fig. 3. More than 30 graphite blocks are added to the beryllium to complete an octagon and the reflector assembly is then haused within an aluminium vessel (see Fig. 4).

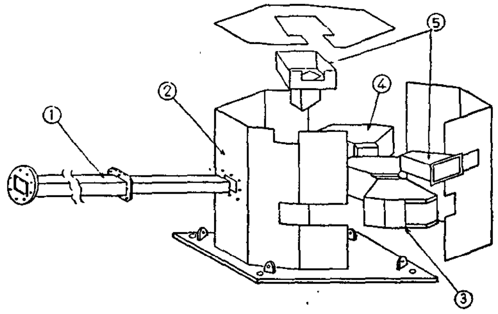


Fig. 4 Target-moderator-reflector assembly:
1) target guide/proton beam drift tube
2) assembly vessel made of aluminium
3) B_4C decoupler
4) polyethylene moderator at room temperature in a drawer
5) Cd decoupler for cold moderator

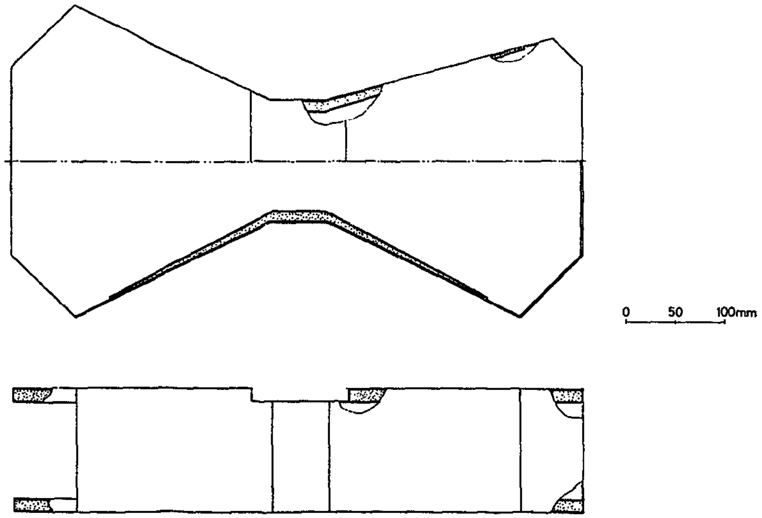


Fig. 5 B_4C decoupler for polyethylene moderator at ambient temperature

The ambient temperature polyethylene moderator is decoupled from the reflector by a B_4C plate as shown in Fig. 5. The moderator fits into an alminium drawer in the B_4C decoupler. The cryostat which accomodates the cold moderator is installed within a cadmium decoupler with an air gap of only 2 mm.

Finally the whole assembly is attached to a movable shield plug (see Fig. 6). The target station is inserted into the biological shield as illustrated in the photo picture. After the target station has been inserted in the center of the biological shield, the target itself is introduced through the proton beam tube (target guide), using the device described in section 5.

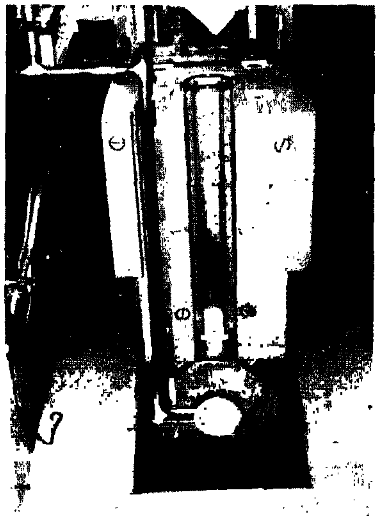


Fig. 6 Target-moderator-reflector assembly on movable shield plug

2. Proton Beam Profile

The first beam of 500 MeV protons from our booster accelerator was successfully delivered to the KENS target on June 18, 1980. The final position and profile of the proton beam at the front of the target were measured by an activation detector of sectioned paper which utilizes $^{12}C(P, P'n)\ ^{11}C$ reaction. After irradiation the paper was cut into small pre-determined sections and the beta activity of each piece was measured by a GM counter with aid of a sample changer. This method has been found to be both precise and convenient. The measured profiles of the proton beam at the target are illustrated in Fig. 7 (in this case, the horizontal position deviated somewhat from the center of the target). A contoured picture of the beam spot may also be seen in Fig. 6 of Ref 1. The beam spot is quite large due to emittance degradation at a beam window located at about 5 m up-stream from the target. The full width of the beam was 3.6 cm in horizontal direction and 3.1 cm in vertical direction, which is somewhat larger than expected.

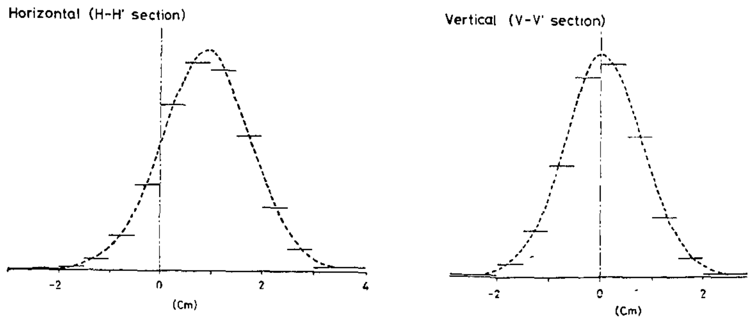


Fig. 7 Proton beam profile in front of neutron target

3. Performance of the KENS Target-moderator-reflector System

3.1 Energy Spectra

The energy spectra of neutrons emanating from both the ambient and cold moderators were measured at the exits of the beam tubes by means of the scattering from vanadium. Figure 8 shows the measured spectrum for neutrons from the polyethylene moderator at ambient temperature. The epithermal region exhibits $E^{-0.88}$ rather than 1/E behaviour because the moderator is heavily decoupled.

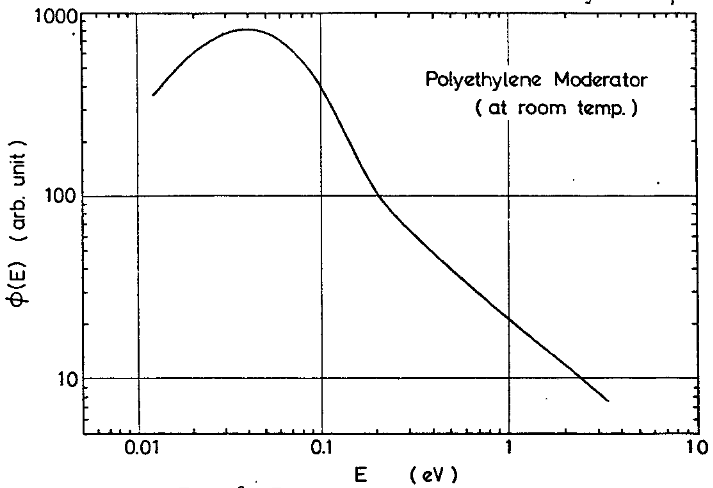


Fig. 8 Energy spectrum of neutrons from KENS polyethylene moderator at ambient temperature

The measured neutron spectrum from the solid methane moderator at 19.7 K is displayed in Fig. 9 in comparison with the results for a similar cold moderator at Hokkaido University[2). The latter has dimensions 25 cm^W x 25 cm^H x 5 cm^T and is embedded in a graphite reflector decoupled by cadmium. The build-up of cold neutrons in our moderator is less than in that at Hokkaido by a factor of about 1.5 due to higher backling of our cold moderator.

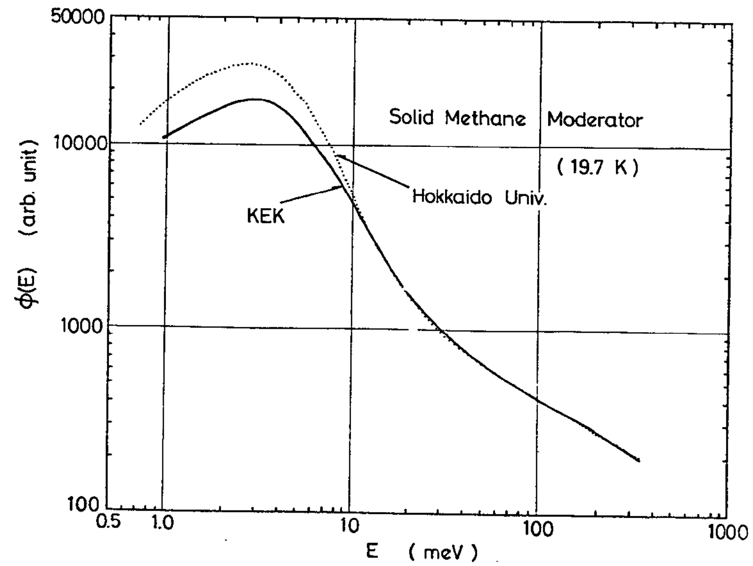


Fig. 9 Energy spectrum of neutrons from KENS cold moderator

3.2 Conversion Efficiency, Coupling Efficiency

The conversion efficiency of protons to thermal neutrons ($n_{th}\cdot str^{-1}\cdot p_f^{-1}$) and the coupling efficiency between target and moderator ($n_{th}\cdot str^{-1}\cdot n_f^{-1}$) in the target-moderator-reflector system are the two most important parameters of pulsed neutron source. The absolute intensities of the KENS neutron beams were measured by the activation of gold foils with and without cadmium covers[3). The results are summarized in Table I in terms of the conversion and coupling efficiencies and in comparison with the results from other laboratories. The measured values for our compact system turned out to be fairly high. For example, the coupling efficiency of our 300 K polyethylene moderator is almost 2 times higher than that of a system of similar scale at ZING-P'[4). The value of the

Table I Comparison of Conversion Efficiency and Coupling Efficiency of the Pulsed Spallation Sources

	Ep	Target/ Coolant	Reflector	Decoupler	Solid Methane (20 K)		Polyethylene Moderator (300 K)			
					I^{th}		I^{th}		$EI(E)\|_{1eV}$	
	MeV				$n{\cdot}str^{-1}{\cdot}p^{-1}$	$n{\cdot}str^{-1}{\cdot}n_f^{-1}$	$n{\cdot}str^{-1}{\cdot}p^{-1}$	$n{\cdot}str^{-1}{\cdot}n_f^{-1}$	$n{\cdot}str^{-1}{\cdot}p^{-1}$	$n{\cdot}str^{-1}{\cdot}n_f^{-1}$
KENS	500	W/H_2O	Be							
Cold				Cd	3.1×10^{-2}	3.9×10^{-3}				
Normal				B_4C			2.2×10^{-2}	2.7×10^{-3} *	5.26×10^{-3}	6.6×10^{-4} *
ZING-P' (ANL)	500	W/H_2O	Be	B_4C					2.62×10^{-3}	3.3×10^{-4} *
SNS Mock-up (Rutherford)	720	U/D_2O	Graphite	B_4C			1.74×10^{-2} **	7.4×10^{-4}	2.9×10^{-3} **	1.21×10^{-4}

* Assuming 8 neutrons per proton

** Assuming 23.5 neutrons per proton

coupling efficiency appears even more favourable when compared with larger systems such as the SNS Mock-up[5]. The coupling efficiency for our cold moderator is higher by a factor of 1.4 than that for the 300 K polyethylene moderator because the decoupler for the former is made of cadmium. The distance between the center line of the target and the bottom of the solid methane moderator is 4.8 cm, while the corresponding distance for the 300 K polyethylene moderator is 3.6 cm. The emanating surface of the solid methane moderator is only 87 cm^2 because the beam window of the beryllium reflector which views the brightest part of the moderator surface is 10 x 8.7 cm^2. The present value of the coupling efficiency was as expected from our mock-up test.

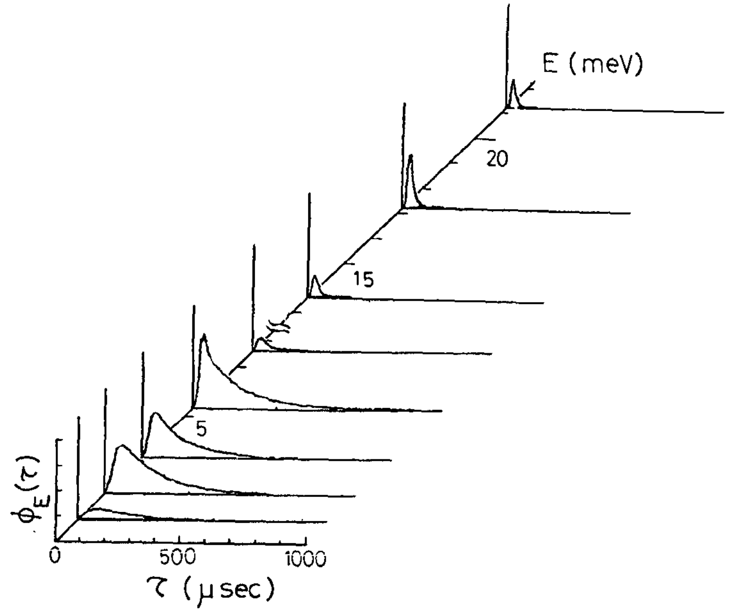


Fig. 10 Time distribution of neutrons from solid methane moderator at 19.7 K

3.3 Time Distribution of the Neutron Pulse

The time distributions of neutrons at various energies were monitored by Bragg diffraction from a mica single crystal in back scattering mode. A typical result obtained for the solid methane moderator at 19.7 K is displayed in Fig. 10. We found that the FWHM of the pulse is approximately given by 22 λ(A) μsec. A preliminary measurement for the 300 K polyethylene moderator was also performed, but the accuracy of the data in the epithermal region were rather poor and an improved measurement is therefore required.

4. Biological Shield

The KENS biological shield was designed so as to satisfy the following two criteria

(1) The maximum dose equivalent rate at the surface of the bulk shield in the horizontal direction should be less than 0.8 mrem/hr.

(2) The annual dose equivalent at the nearest site boundary (about 350 m from the source) should be a small fraction of the natural background radiation, since existing facilities on the site has already produced an appreciable radiation intensity.

The design studies for the biological shield was reported in Ref. 6.

Horizontal and vertical cross-sectional views of the KENS shield as constructed are displayed in Fig's 11(a) and (b). It is composed of a fixed heavy concrete shield and several movable blocks made of iron and heavy concrete. The thicknesses of the bulk shield are 3.65 m (at least 1.25 m iron and 2.4 m heavy concrete (ρ = 3.5 g/cm^3))

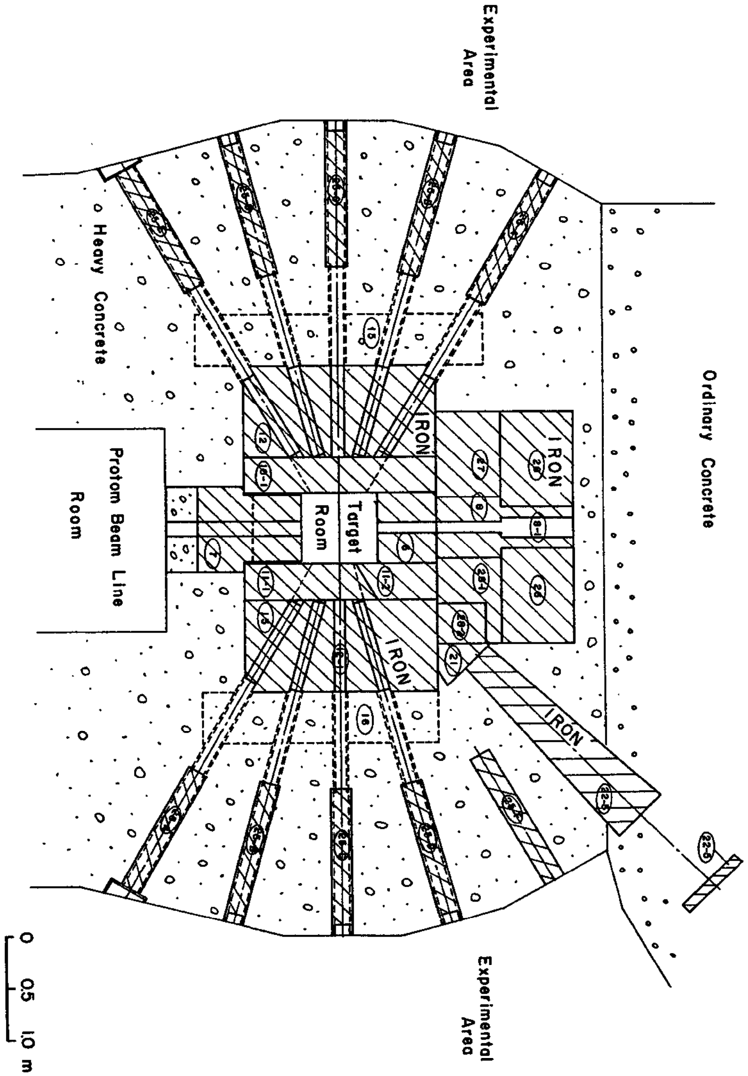


Fig. 11 (a) KENS biological shield (horizontal)
Iron blocks 12-1 are beam shutters

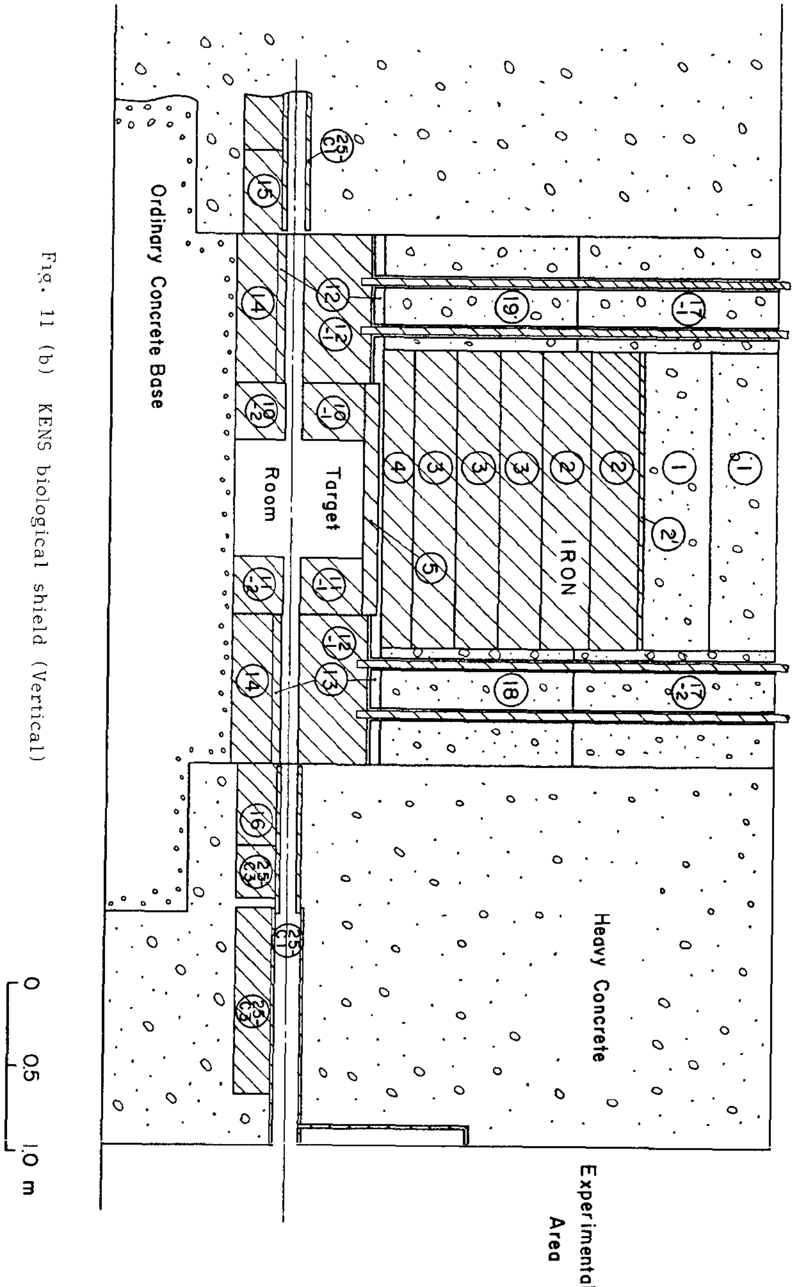


Fig. 11 (b) KENS biological shield (Vertical)

in the horizontal direction and 2.45 m vertically (inner 1.55 m of iron and outer 0.8 m of heavy concrete). These thicknesses correspond to 13 and 11 attenuation lengths for high energy neutrons respectively.

The neutron beam pipes which are square in section and made of iron are embedded in the bulk of the shield just above and below the target level. In this configuration, an appreciable portion of the shield thickness around the beam tube is missing. Additional iron blocks are therefore embedded above or below the beam tubes which view the upper (cold) and lower (ambient) moderators respectively (block number 15, 16 and 25-c-3 in Fig. 11(b)).

A beam shutter is installed in the inner section of each beam tube to prevent the neutron beam from entering the experimental area when the beam is not used or when experimenters need to approach the beam line. The shutter consists of an iron block of dimension 12 cm^Wx 45 cm^Hx 90 cm^L haused within a shutter casing. The height of the shutter block was chosen such that the height of the air gap necessary to allow shutter movement would not cause a serious short-fall in the shield for people working around the bulk shield.

Square alminium pipes are mounted within the beam pipes to form evacuated paths and inner iron collimators are then inserted into these pipes.

The performance of the KENS shield was monitored during actual operation and the radiation levels were found to be very close to the design values. Further details of the measured performance of the shielding are given elsewhere in this proceedings (Ref. 7).

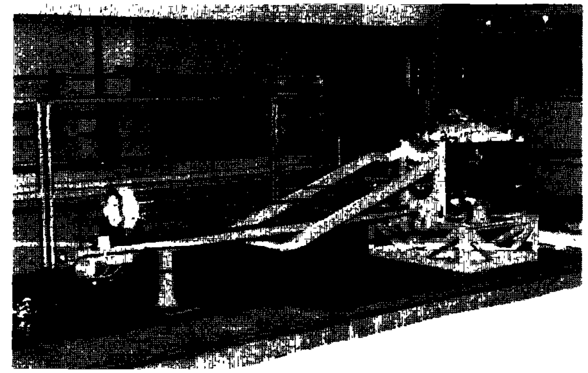
5. Handling Devices for Active Target and its Surroundings

5.1 Target Cask

A lead cask for remote target handling is located in front of the movable shield plug which accomodates the target-moderator-reflector assembly. The proton beam is fed to the target through a large rectangular hole in the cask. Photographs of the cask are shown in Fig. 12. For target removal, a section of the beam transport tube is removed, and the couplers for the target coolant are released. The target and part of the water cooling system may then be withdrawn under motor drive towards the up-stream direction. The cask is equipped with motor-driven shutters at each end of the hole. A special mechanism is installed in the cask so that the position of the target can be adjusted with respect to both the hole in the cask and the target guide pipe of the target-moderator-reflector assembly.

5.2 Handling Device for Cold Neutron Source

A remote handling device for the installation and removal of the cryostat for the cold neutron source was constructed as illustrated in Fig. 13. By this device the cryostat together with part of the helium transfer tube can be mounted (or removed) on the target-moderator-reflector assembly within an accuracy of 2 mm with the aid of the guide pins shown in the photo. The device will be handled by a remote crane which is currently under construction.



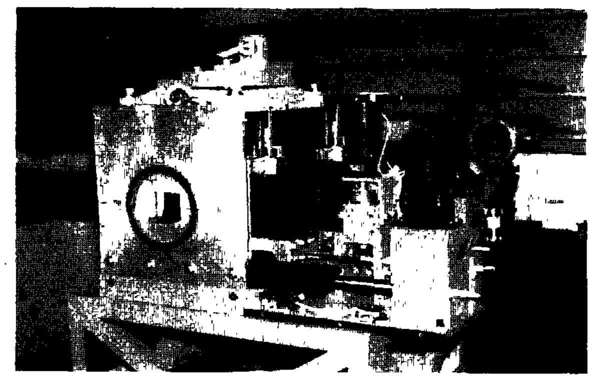


Fig. 12 KENS target cask

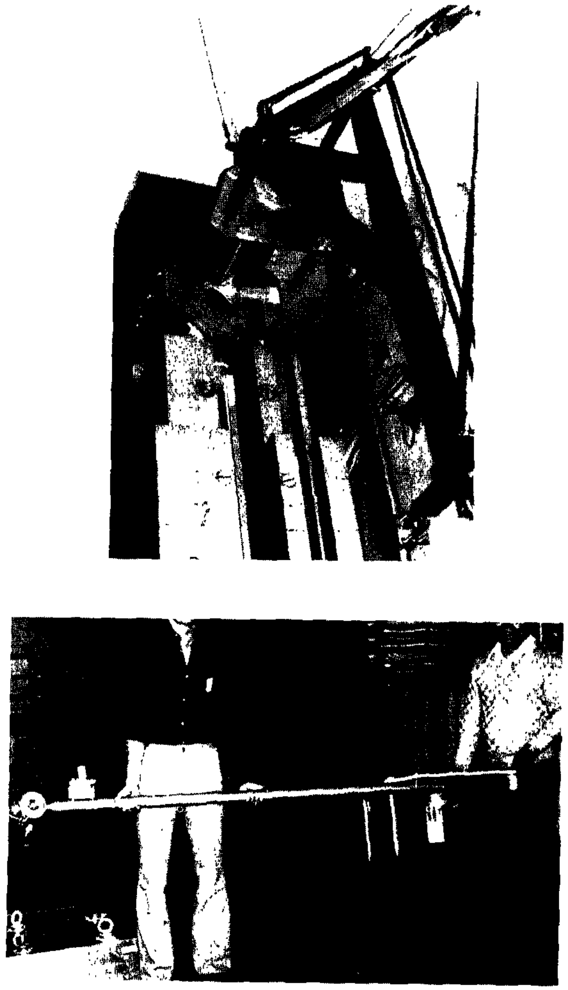


Fig. 13 Handling device for cold neutron source.
Lower photograph shows the cryostat with guide pins and helium transfer tube.

5.3 Handling Device for the Assembly

A photograph of the device which has been constructed to allow the target-moderator-reflector assembly to be mounted or dismounted from the movable target shield plug is shown in Fig. 14. The remote crane will also be used to handle this device.

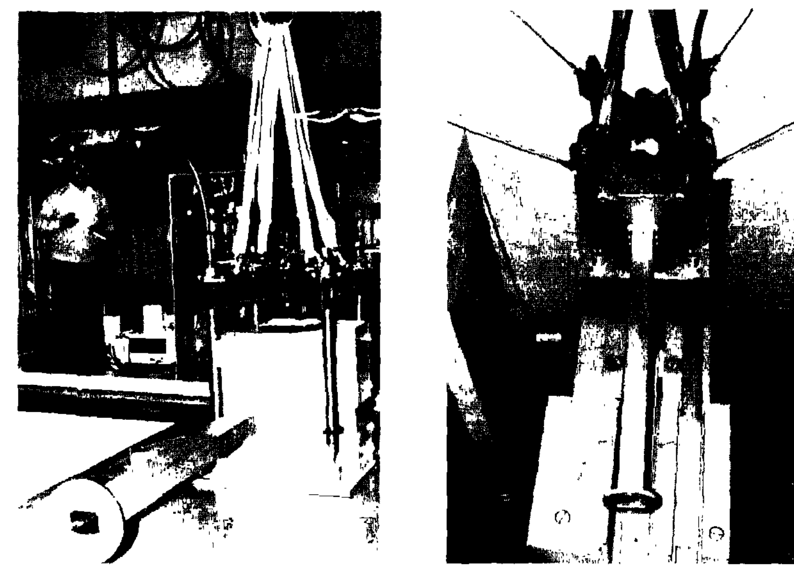


Fig. 14

Acknowledgments

KENS project required over three years to design and construct the target station and a large number of people made significant contribution to the project. The authors wish to acknowledge all the persons who contributed it. One of the author, N. Watanabe would like to express his sincere gratitude to Dr. M. Misawa, Dr. N. Niimura and Dr. K. Yamada for assisting with design of the target station, and his deepest thanks to Prof. K. Katoh, Dr. H. Hirayama and Dr. S. Ban for their sincere advices concerning the shielding design.

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