Characteristics of KENS Cold Neutron Guide Tube

J. Mizuki, Y. Endoh, Y. Ishikawa and S. Ikeda*
Tohoku University
Sendai, Japan
* National Laboratory for High Energy Physics
Tsukuba, Japan

In the KENS facility three guide tubes view the cold neutron source and transport cold neutrons to the cold neutron experimental area. The spectrometers SAN and TOP have been positioned at the end of guides C_1 and C_3 and a high resolution spectrometer will be soon installed at the exit of guide C_2.

As has been previously noted in KENS Report I1), these guide tubes consist of two parts. A straight section, 3.5 m long and with a cross section of 3×5 cm^2 is installed inside the biological shield. There is then a long curved section of radius of 830 m and cross section 2×5 cm^2 which is followed by a straight tube with about 0.4 m gap. The curved sections of guides C_1 and C_3 are 11 m long, while that of C_2 is 18 m. The curvature corresponds to a cut-off wavelength of 4 Å. The direct view distance is 14.47 m for each guide tube. A tail cutter is situated in the gap between the straight and curved sections of each guide tube in order to prevent the passage of neutrons with wavelengths longer than 12 Å. A film of Ni metal about 2000 Å thick evaporated onto 3 mm thick float glass was used as the neutron reflector.

The spatial distribution and the energy dependence of the flux of cold neutrons at the guide exits were directly measured. The transmittance of the guide tube was also determined and the results of these measurements are briefly outlined below.

§2. Measurement of $I(\lambda)$

The neutron spectrum or the wavelength dependence of the neutron intensity, $I(\lambda)$, was determined at the exit of guide tube C_3 by measuring the incoherent scattering from vanadium metal. The result is shown in Fig. 1. A two dimensional Monte-Carlo calculation had suggested that the wavelength dependence of the neutron intensity, $I(\lambda)$, would be given by $\frac{1}{\lambda^4}\exp\left(-(\lambda_T/\lambda)^2\right)$ as shown by the broken line in the figure. The observed intensity distribution, however, is significantly lower than that calculated over whole wavelength range, suggesting that the two dimensional calculation is an oversimplification.

The intensity distribution, $I^0(\lambda)$ at the cold neutron source was measured at the exit of the beam tube C_4 which views the cold moderator source directly, and the result is plotted as a dotted line in Fig. 1. The triangles in the figure represent the intensity distribution at the exit of the straight guide tube estimated from $I^0(\lambda)$ by taking into account only the geometrical configuration of the guide tube. The estimated values agree approximately with the experimental value despite the simplified nature of the calculation.

The spatial distribution of the neutron intensity along the horizontal axis was also measured at the exit of the C_3 guide tube using a small (0.5×60 mm^2) slit in a Cd metal shied before a He^3 counter The results measured at four different position are displayed in Fig. 2. Our results show that the spatial distribution is practically uniform for wavelengths longer than 6 Å, but the intensity of neutrons at shorter wavelengths is significantly reduced at the inner side of the curved guide. These results are in accord with our previous calculation.

§3. Absolute neutron intensity at the guide exits

3-1. Measurement by the activation of Au foils

The absolute intensity of cold neutrons at both the entrances and exits of the guides were determined by the activation of Au foils. The size of these foils was 10×10×0.1 mm^3. The Au foils were exposed for ten minutes, and absolute incident neutron intensity was then given by the saturation activity of Au divided by the absorption cross section, σ_a. The average absorption cross section $\langle\sigma_a\rangle$ was estimated from the experimental result of $I(\lambda)$, according to

$$\langle\sigma_a\rangle = \frac{\int_2^{16}\sigma_a(\lambda)I(\lambda)d\lambda}{\int_2^{16}I(\lambda)d\lambda}.$$

The value $\langle\sigma_a\rangle$ thus calculated was $317\times10^{-24}\,cm^2$. The derived value for the absolute neutron intensities are given in Table 1.

Table 1 Absolute Neutron Intensities I_0

Guide tube	I_0 (n/cm^2·sec)
C_1	0.78×10^5
C_2	0.91×10^5
C_3	0.91×10^5

These values correspond, in the case of a repetition rate of 16 pulses per second, to a neutron intensity per pulse of 5×10^{11} n.

3-2. Measurement of vanadium incoherent scattering

The absolute neutron intensities were also determined by the measurement of the vanadium incoherent scattering. Vanadium samples of three different shapes were employed; a cylinder 10 mm in diameter and 110 mm long, and two plates of respective dimensions 100×6.5×1 mm^3 (Plate 1), and 110×38×1 mm^3 (Plate 2). The measured intensities were corrected for absorption by the sample and by air, and the final derived intensities are summarized in Table 2.

Table 2 Absolute Neutron Intensities I_0'

	Plate 1	Plate 2	Cylinder (n/cm^2.sec)
C_1		7.3×10^4	5.5×10^4
C_2	1.2×10^4 2.6×10^4	4.8×10^4 5.1×10^4	4.6×10^4
C_3	1.5×10^5 0.95×10^5	0.99×10^5	0.65×10^5

Although the values in the table are somewhat scattered, those obtained for plate 2 are probably the most reliable because, as this plate has large width, missetting errors could be minimized. From the values given in the table, the relative ratios of the intensities at the exits of the three guide tubes are calculated as 0.7:0.5:1 for C_1:C_2:C_3.

4. Measurement of transmittance

4-1. Direct measurement

The transmittances of the guide tubes were estimated by two different methods; (i) direct comparison of the measured neutron intensities the entrances and exits of the curved guides and (ii) measurement of the transmittance a single section of the curved guide tubes.

In the former method, the neutron intensities in the C_1 and C_3 guide tubes were measured using a He^3 counter with a thin slit. The transmittance, T, is obtained from the ratio, I_{out}/I_{in}, of the intensities measured at the exit and entrance of the guide according to $T=C(\lambda)\cdot I_{out}/I_{in}$, where $C(\lambda)$ is a wavelength dependent correction factor arising from the different solid angles spanned by the counter. The calculation values are presented in Table 3. The average transmittances computed by assigning a weight of $I(\lambda)$ to each wavelength are 0.35 and 0.47 for guides C_1 and C_3 respectively.

Table 3 Transmittance of Guide Tubes C_1 and C_3

		4.5	5.3	6.0	6.7	7.4	8.0	8.9	9.6
C_1	I_{out}/I_{in}	.022	.022	.023	.025	.026	.032	.026	.026
	T	0.4	0.36	0.35	0.35	0.34	0.4	0.3	0.28

		4.5	5.3	6.0	6.7	7.4	8.0	8.9	9.6
C_3	I_{out}/I_{in}	.026	.029	.030	.033	.036	.046	.038	.039
	T	0.48	0.48	0.46	0.47	0.47	0.57	0.43	0.42

The ratio between that for C_1 and C_3 is about 0.75 which is in good agreement with that estimated from the absolute neutron intensities. The transmittance of guide C_2 was measured in a slightly different way. The incident neutron beams were collimated by inserting a 10" Soller collimator in front of the curved guide (This procedure is not possible for other guide tube.) in order to minimize the angular correction due to the beam divergence.

An average transmittance of 0.21 was obtained suggesting that the transmittance of guide C_2 is only 0.45 of that of C_1 which is also in good agreement with the results obtained from the absolute intensity measurement.

In order to determine the cause of the poor performance the transmittance of the 1 m long sections comprising the guide was estimated by monitoring the increase in intensity when the last two such sections were sequentially removed.

The ratio of the neutron intensity at the exit, A, to that at B (or C) which corresponds to the position of the end of the guide after the removal of one (or two) sections is plotted in Fig. 3. The measured average transmittance of a single 1 m section is approximately 92%. This gives rise to a transmittance of 0.2 ($\approx(0.92)^{18}$) for a guide composed of 18 similar sections, which is in good agreement with the aforementioned.

4-2. Estimation of the transmittance by absolute intensity measurement

The transmittance of guide tube C_2 was also estimated by comparing the total neutron intensities at the exit of the initial straight section with that at the exit of the curved section. The neutron intensity at the exit of the straight section was estimated by the Au foil method to be 4.4×10^5 n/cm$^2\cdot$sec. After correction for the divergence of the beam in the air gap between the straight and curved sections, the intensity at the entrance of the later section becomes 3.2×10^5 n/cm$^2\cdot$sec. This may be compared with the observed intensity at the exit of the curved section of 5×10^4 n/cm$^2\cdot$sec, yielding a transmittance of 15.6%. Allowing for the ambiguities in the absolute measurement this value agrees reasonably with the values estimated by other methods.

In conclusion, the KENS guide tubes have a maximum transmittance of about 50%. This low value is apparently due to low reflectivity in the mirror plates composing the guides, and to improve the guide performance further work should be directed towards increasing this reflecting.

Reference

1) S. Ikeda, Y. Ishikawa, and Y. Endoh : KENS REPORT I 45-72 (1980)

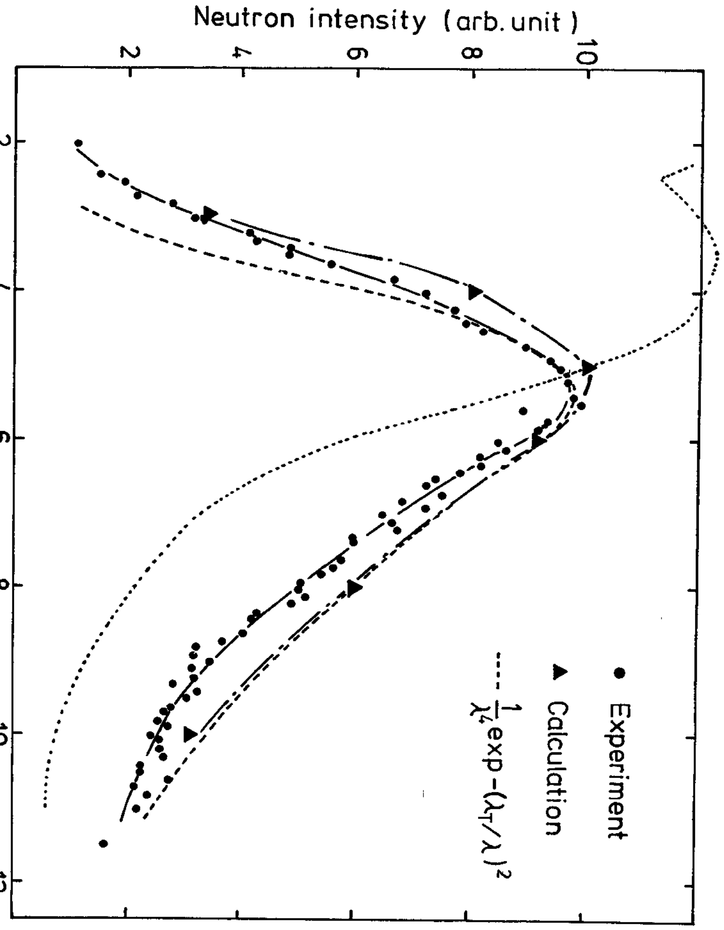

Fig.1 : I(λ) of guide tube,C_3.

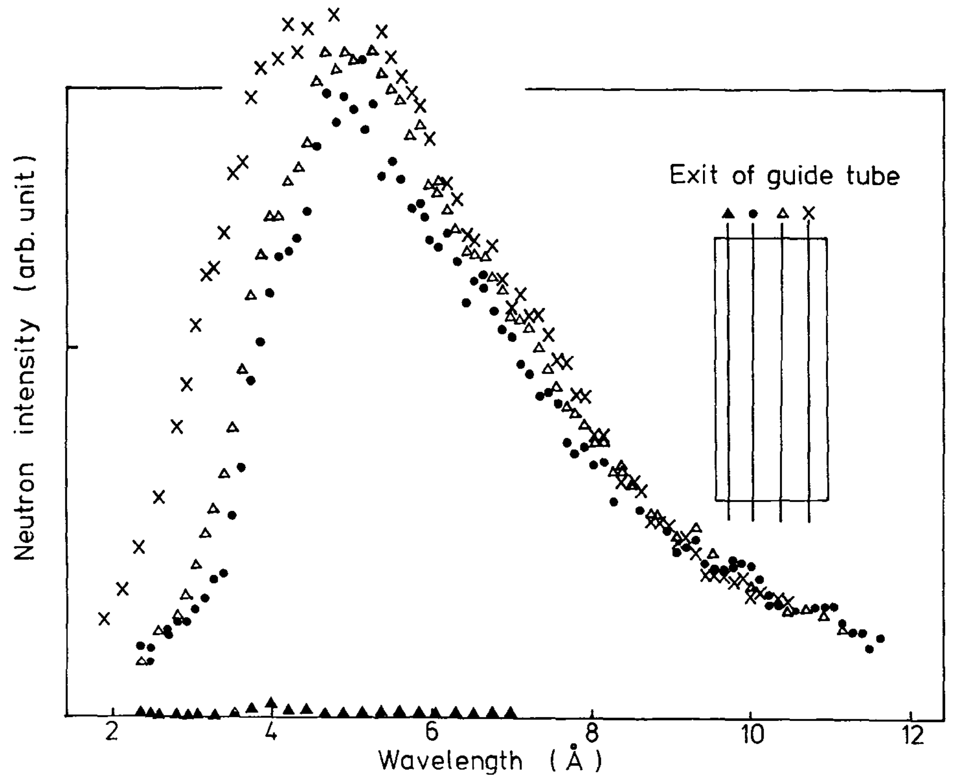

Fig.2 : The spatial distribution of the neutron intensity along the horisontal axis.