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SNS MODERATOR PERFORMANCE

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INTRODUCTION

The SNS moderators are designed to optimise the production of a wide variety of beams with spectral and resolution characteristics which are matched to the envisaged suite of neutron scattering instruments [1]. Four independent moderators are used in reflected wing geometry, two above and two below the target (see Figure 1). The reflector is D_2O cooled beryllium. To facilitate heat removal and to minimise radiation damage, the moderator materials are fluids. The four moderators are a 4.5cm thick liquid methane moderator at 95K poisoned with gadolinium at a depth of 2.25cm; a 4.5cm thick ambient water moderator asymmetrically poisoned with gadolinium to give 1.5cm and 3.0cm effective thicknesses; an 8cm thick supercritical hydrogen moderator at 25K; and a 4.5cm thick ambient water moderator poisoned with gadolinium at a depth of 2.25cm. Important aspects of the physical design of the moderators are summarised in Table I. Further details may be found in references [2,3], and predictions of their neutronic performance in reference [4].

In its initial configuration SNS has

-seven beams viewing the high intensity, high resolution liquid methane (CH_4) moderator, which is optimised for pulse structure;

-three beams viewing a very high intensity face (A) and three beams viewing a high intensity, high resolution face (AP) of an ambient moderator;

-three beams of long wavelength neutrons from the liquid hydrogen (H_2) moderator, which is optimised for intensity;

-and the remaining two beams viewing an intermediate resolution ambient moderator (D).

During the initial commissioning run of SNS in December 1984, six neutron beamlines viewing four different moderator faces were specially instrumented to obtain the maximum amount of information from the limited experimental run. In addition to measuring the performance of the moderators, several other experiments were performed simultaneously on each beamline, and the results from these are described in reference [5].

SPECTRAL PROPERTIES OF THE MODERATORS

The spectral distribution of the SNS moderators was measured using the primary time-of-flight monitors on each beamline. Physical parameters of these monitors are described in reference [5] and details of the analysis given elsewhere [6]. The monitor spectra were corrected for detector efficiency and residual air attenuation and transformed to an energy scale. The spectra were then described [4] as the sum of a Maxwellian term

$$\phi_{max}(E) = J \frac{E}{T^2} \exp\{-E/T\} \qquad (1)$$

where J is the Maxwellian integral, E the energy in eV and T the Maxwellian temperature in eV, and a slowing down term

$$\phi_{epi}(E) = \frac{1}{E^A} \qquad (2)$$

where A is a leakage parameter. These parts are combined using a switch function $\Delta(E)$, and multiplied by a constant ϕ_0, the differential neutron current at 1 eV, to give the absolute value (discussed below)

$$\phi(E) = \phi_o\{\phi_{max}(E) + \Delta(E)\ \phi_{epi}(E)\} \\ = \phi_o \cdot \phi_{tot}(E) \tag{3}$$

Typical fits for each of the three types of moderator are shown in Figure 2. Data rate problems on the SXD beamline viewing the ambient water moderator (A) prevented a quantitative analysis being performed on data from this moderator.

These parameters are given in Table II and compared with the design values taken from Table II of reference [4]. The agreement is excellent for the major parameters such as J, T and A and in good accord for the somewhat empirical switch function.

ABSOLUTE NEUTRONIC PERFORMANCE OF SNS

The absolute neutronic performance of SNS was determined by white beam activation of thick gold foils on each beamline. These data were then analysed using the appropriate spectral distribution measured by the time-of-flight monitor and corrected for multiple interactions by a numerical technique [6]. The absolute performance of the moderators, taken from reference [6] and corrected for viewing angle, is compared in Table III with the predicted performance [4], appropriate to 550 MeV. An independent measure of ϕ_o for each beamline may also be obtained from the time-of-flight monitors by assuming their calibrated efficiencies. These parameters again corrected for viewing angle are also presented.

The overall agreement is excellent for all three moderators. The error is almost entirely due to proton normalisation and is not present in relative measurements, such as a comparison of two beamlines viewing the same moderator, where only random errors of a few percent are important. The discrepancy between the TFXA and HET measurement of the ambient poisoned moderator referred to in [6] resulted from an error in the location of the gold foil (11.5m rather than 10m). The discrepancy between the LAD and HRPD measurements of the liquid methane moderator, seen by both the gold foil and time-of-flight technique, may still be significant. Possible explanations are a misalignment of the shutter-collimator system or an angular flux distribution from the moderator face which is more strongly peaked than the anticipated cosine-like distribution.

TIME STRUCTURE OF THE NEUTRON PULSE

Detector saturation problems on TFXA and IRIS prevented a full pulse shape analysis from the ambient water and liquid hydrogen moderator and the purposely large beam on HRPD led to sample geometry contributions to the methane data. However, long time decay constants were obtained from all three moderators (see Table II) which were in excellent agreement with the predictions from reference [4]. Additional confirmation of the quality of the pulse shape came from the low data rate (but correspondingly poor statistics) run on TFXA and the fact that HRPD achieved its design resolution of $\Delta d/d = 0.0004$ (see reference [5]). An additional long time decay constant ($\sim 35\lambda$ Å-μs) was observed in the pulse from the non-decoupled liquid hydrogen moderator and this led to the decision to decouple the hydrogen moderator with cadmium for subsequent operation.

CONCLUSION

The neutron intensity and spectral properties of the SNS moderators have been measured and were found to be in excellent agreement with the design values.

REFERENCES

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[2] A Carne, 'Review of the SNS Target Station', in Proceedings of ICANS-IV (1980), p136, KENS Report-II (1981).

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[5] A J Leadbetter et al 'First Neutron Results from SNS', Rutherford Appleton Laboratory Report RAL-85-030 (1985).

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TABLE I

MODERATOR	Front Ambient		Liquid Methane		Liquid Hydrogen	Rear Ambient
Mnemonic	AP	A	CH_4		H_2	D
Material	H_2O		CH_4 (4 atm)		p-H_2 (15 atm)	H_2O
Temperature (K)	316		95		25	316
Position	Top Front		Bottom Front		Bottom Rear	Top Rear
Height (cm)	12		11.5*		12*	12
Width (cm)	12		12*		11*	12
Thickness (cm)	4.5		4.5*		8*	4.5
Poison	0.05 mm Gd		0.05 mm Gd		--	0.05 mm Gd
Poison Depth (cm)	1.5	3.0	2.25	2.25	--	2.25
Beam Lines (Angle to Moderator Normal)	N7(0) N8(14) N9(27)	S1(14) S2(1) S3(12)	N1(14) N2(1) N3(12)	S6(13) S7(0) S8(14)[+] S8(14)[+] S9(27)	N4(13) N5(0) N6(13)	S4(13) S5(0)
Decoupler	Boron[x]		Boron[x]		None	Boron[x]
Void Liner	Boron[x]	Boron[x]	Boron[x]	Boron[x]	Boron[x]/Cd	Boron[x]

Notes: * Maximum dimension. Moderator containment is a pressure vessel whose faces have radii of 25 cm.

\+ S8 beam line is multiplexed with two guides.

x 1/e transmission of boron layer at 3.6 eV.

TABLE II

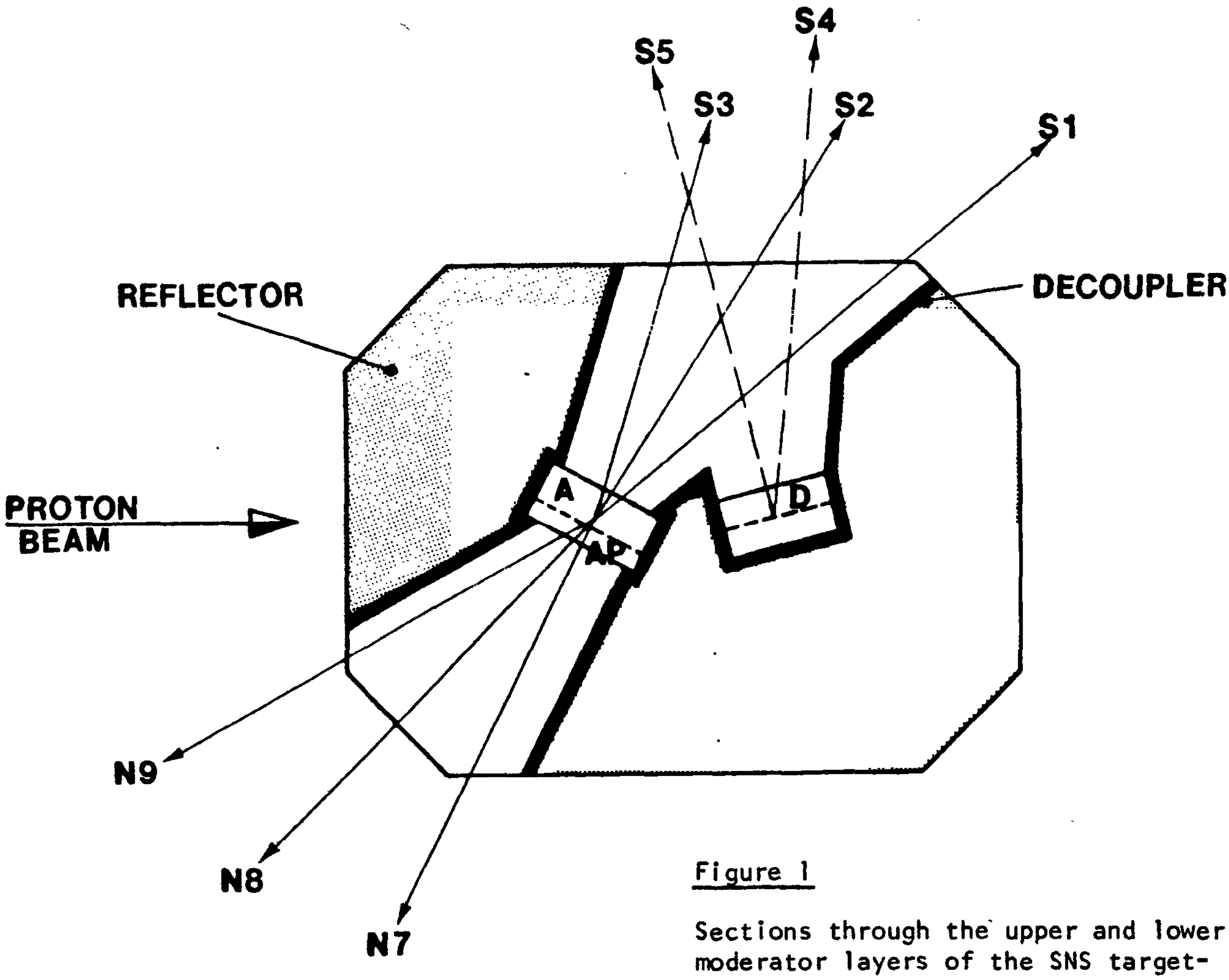
MEASURED SPECTRAL DISTRIBUTION PARAMETERS FOR THE SNS MODERATORS (DESIGN VALUES IN PARENTHESES)

Moderator:	AP	A	CH_4	H_2
Maxwellian parameters				
J	2.3 (2.4)	--	2.1 (1.8)	2.4 (2.6)
T (meV)	32 (33.9)	--	11 (11)	2.1 (2.8)
Epithermal parameters				
A	0.95 (0.9)	--	0.92 (0.9)	0.95 (0.9)
Joining function parameters				
W1	120 (90)	--	55 (54)	15.5
W2	10 (8.9)	--	7 (6.7)	3.1
W3	--	--	--	11
W4	--	--	--	0.254
W5	--	--	--	0.0275
Time structure parameter: μs	22 ± 5 (20)		31 ± 2 (32)	23λ ± 2λ (25λ)

TABLE III

COMPARISON OF DESIGN VALUES OF ϕ_0 WITH GOLD FOIL AND MONITOR MEASUREMENTS.
Units: 10^{10}n/eV.sr.100cm^2.μA.s

		Gold Foil	Design	Monitor
Ambient Poisoned Moderator	TFXA(13°)	2.8 ± 0.5	2.3	2.9
	HET(27°)	2.7 ± 0.4		2.4
Liquid Hydrogen Moderator	IRIS(13°)	1.9 ± 0.4	2.1	2.0
Liquid Methane Moderator	LAD(0°)	2.6 ± 0.4	1.9	2.3
	HRPD(14°)	1.1 ± 0.3		1.1



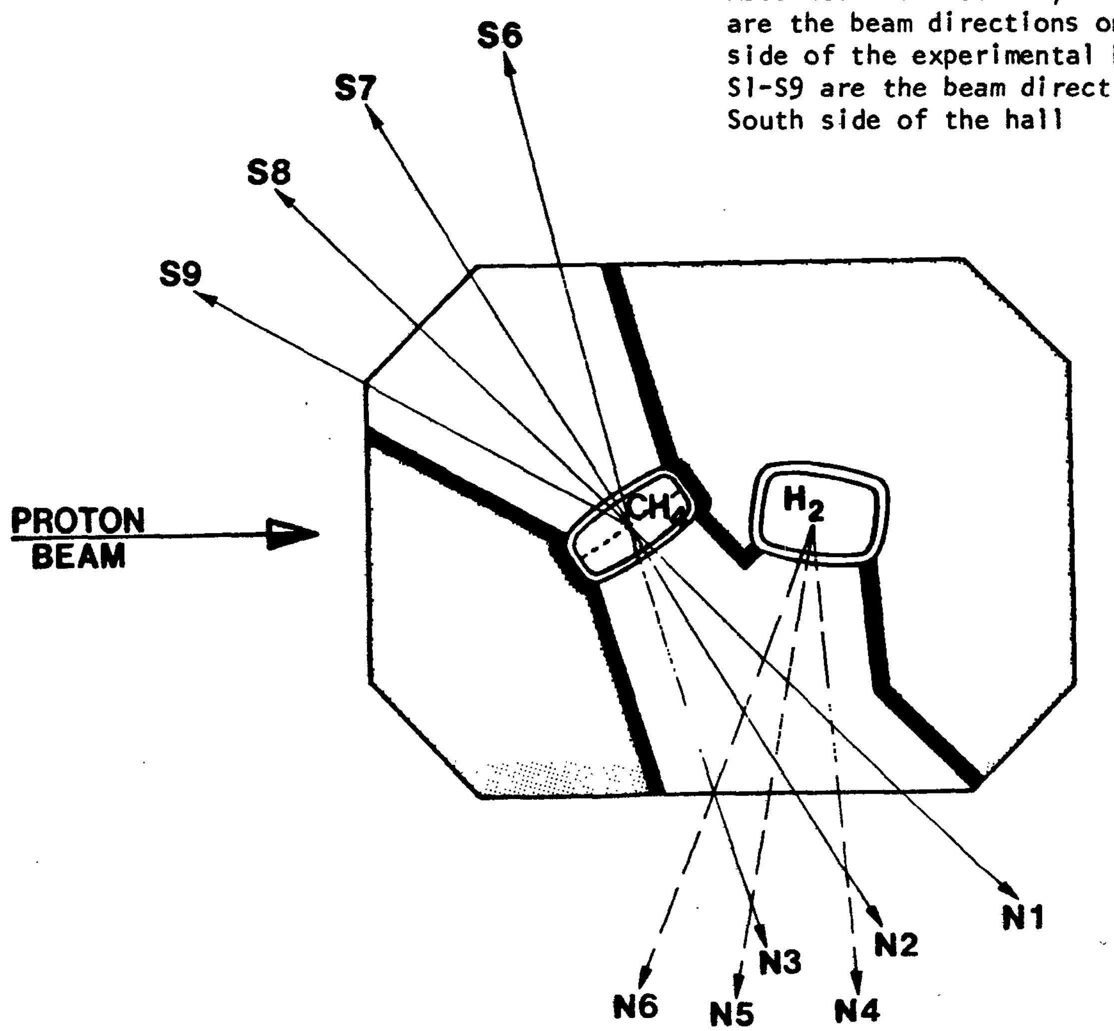


Figure 1

Sections through the upper and lower moderator layers of the SNS target-moderator-reflector system. N1-N9 are the beam directions on the North side of the experimental hall and S1-S9 are the beam directions on the South side of the hall

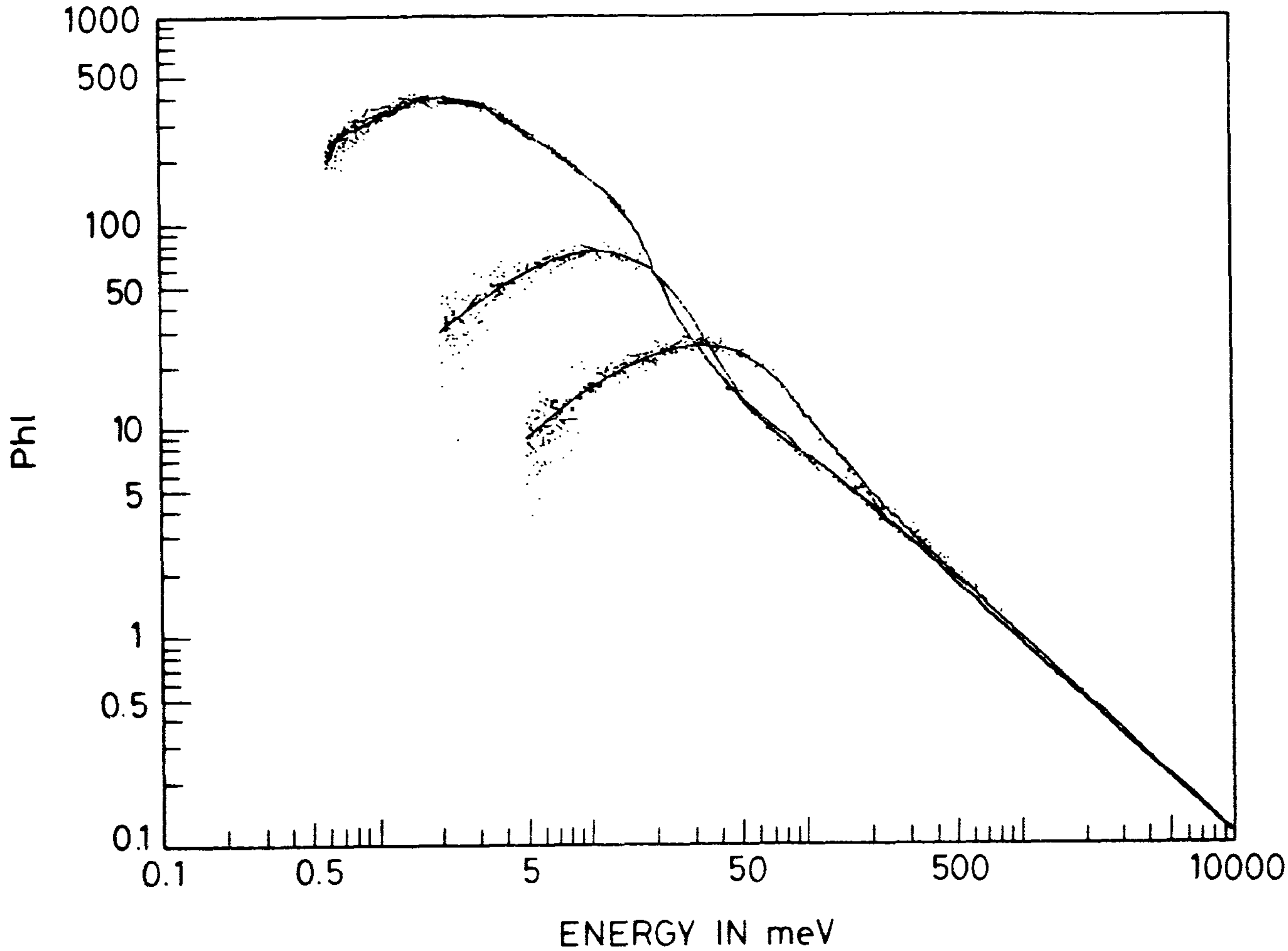


Figure 2 The observed (points) and fitted spectral distribution from (a) the ambient poisoned moderator (TFXA); (b) the 100K liquid methane moderator (LAD); and (c) the 25K liquid hydrogen moderator. The solid line is equation (3) and the fitted parameters are summarised in Table II.