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Summary on a discussion on moderators with grooved surface

Results were presented by G.S. Bauer on experiments performed by the German study group at SIN and SATURNE* to increase the neutron leakage from hydrogeneous moderators by rearranging part of the moderator material near the surface in such a way that grooves of 1 cm width and up to 9 cm depth were obtained with a 50% ratio of void and material (Fig. 1).

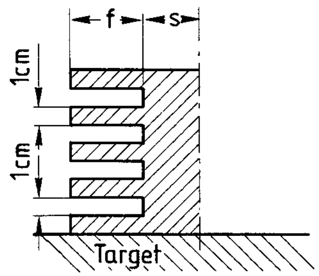

Fig. 1 Section through one half of a grooved moderator

The moderators were placed on a slab target of Pb 10 cm high 50 cm wide and 60 cm deep. The proton beam hit the target below the moderator centre plane. Table 1 summarizes results obtained for different moderator geometries with and without a reflector or lead shielding. The moderators were 20 cm long and 11 cm high. The thickness of the reflector, if in place, was 20 cm and the lead shield was 50 to 80 cm thick with a cavity to accept the reflector.

The gain obtained for a bare moderator due to the grooves is 1.8 (measurement 4 relative to 2) and in a well reflected geometry it is 1.35 (measurement 12 relative to 10).

Similar gains were also found in experiments performed at the CERN booster** for decoupled arrangements (Fig. 2).

The neutron current emerging from a moderator surface is determined by the neutron flux level ϕ_λ at a distance of one transport length (λ_{tr}) below the surface. The flux distribution inside the moderator has roughly the form of a cosine distribution going to zero at a distance $d = 0.7 \cdot \lambda_{tr}$ outside the moderator (Fig. 3a). A higher flux level than ϕ_λ could in principle be reached by a reentrant hole reaching inside the moderator. However, this hole's diameter should be only of the order of λ_{tr} in order to avoid creating a new outer surface. For H_2O λ_{tr} is only 4.5 mm and therefore such a reentrant

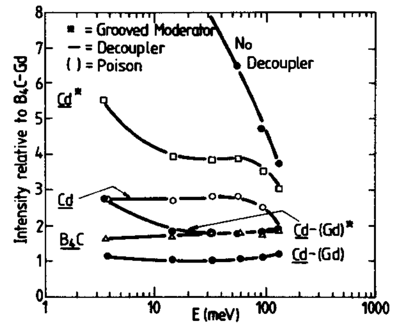

Fig. 2 Integrated intensities of reflections obtained from a pyrolytic graphite crystal as a function of neutron energy for various moderators with decouplers and heterogeneous poison. Moderator material was polyethylene. The systems are characterized by the symbol for the decoupler used with the poison set in parentheses. N stands for no decoupler, an asterix marks a moderator with 15 mm deep grooves on the surface.

hole can only be very small. In the experiments performed at the SIN by the German study group the leakage from the moderator surface could be considerably increased, if a large number of holes were introduced in the moderator surface. In order to avoid the collimating effect of these holes, horizontal grooves running over the moderator surface were used in later measurements. They were found to yield a similar increase in neutron leakage without the undesired collimating effect in the horizontal plane. Qualitatively the effect of these grooves which were arranged such as to yield a 50% material-to-void ratio can be understood as follows (Fig. 3b). Starting from a moderator of thickness L with a neutron flux distribution as indicated in Fig.3a the material contained in a surface layer of thickness F is rearranged thus as to yield a layer of thickness 2F with a macroscopic scattering cross

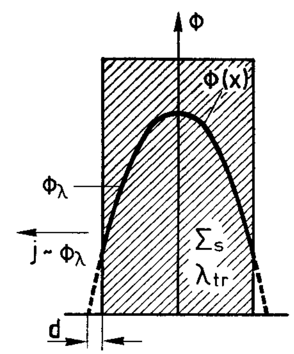

Fig. 3a

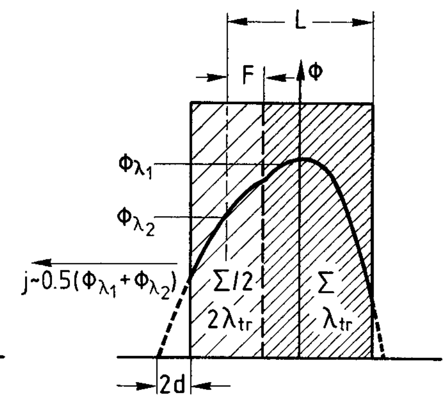

Fig. 3b

section $\Sigma_s/2$ and hence a transport length $2\lambda_{tr}$. The flux distribution then goes to zero at a distance $2d = 1.4\ \lambda_{tr}$ from the new moderator surface as indicated in Fig. 3b. Due to the fact that the material is distributed heterogeneously in the layer of thickness 2F, two flux levels will be significant for the neutron leakage perpendicular to the surface: $\phi_{eff}=0.5\cdot\phi_{\lambda_1}+0.5\cdot\phi_{\lambda_2}$. This value is obviously higher than the value ϕ_λ which determines the leakage from a solid moderator of the some amount of moderating material.

Experiments of this type have also been performed at ZING-P' with the goal of establishing the effect of the grooves on time structure. It was found that there was a slower rise and a faster decay of the neutron pulses resulting in an overall increase of the FWHM by 5%. In these experiments the grooves were running at right angles to the target surface which results in a decrease of the solid angle subtended by the moderator and hence a poorer target-moderator coupling. Correspondingly the intensity gain was only less than 20% yielding no change in the figure of merit $I/(\Delta t)^2$. However, since an arrangement of the grooves parallel to the surface of the target will not alter the time behaviour while improving the coupling, it was concluded that grooved moderators are also beneficial for pulsed sources as well as quasi-continuous ones.

#	Moderator	Dimension	Reflector	Shield	Gain
1	CH_2	37.5s	-	-	1
2	CH_2	50 s	-	-	1.06
3	CH_2	10s+60f	-	-	1.83
4	CH_2	22.5s+60f	-	-	1.91
5	CH_2	22.5s+60f	-	Pb	3.31
6	CH_2	"	CH_2	Pb	3.21
7	CH_2	"	Be	Pb	5.43
8	H_2O	30s	Be	Pb	4.42
9	H_2O	45s	Be	Pb	4.25
10	H_2O	55s	Be	Pb	4.22
11	H_2O	15s + 60f	Be	Pb	5.66
12	H_2O	7.5s+90f	Be	Pb	5.72
13	H_2O	22.5s+90f	Be	Pb	5.50

Table 1 Relative thermal neutron leakage from the moderator surface for various configurations with fins and with and without reflector and shielding

* G.S. Bauer, F. Gompf, W. Mannhart, W. Reichardt, R. Scherm and H. Spitzer "Thermal Neutron Leakage from hydrogeneous Moderators for a Spallation Neutron Source"

** G.S. Bauer, J.P. Delahaye, H. Spitzer, A.D. Taylor and K. Werner: "Relative Intensities and Time Structure of Thermal Neutron Leakage from Various Moderator-Decoupler Systems for a Spallation Neutron Source" report under preparation.