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THE INFLUENCE OF TARGET AND REFLECTOR COOLANT ON THE THERMAL NEUTRON LEAKAGE FLUX FROM AN SNQ-TYPE MODERATOR

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Summary

Light and heavy water as a cooling fluid have been compared experimentally for both the target and the reflector in the SNQ mock-up with respect to their effect on thermal neutron leakage from the SNQ-moderator. The cumulative gain (i.e. both target and reflector cooled with heavy water) in thermal neutron leakage flux was found to be less than 12 %. This figure does not appear to justify the effort of using heavy water as a cooling medium for the SNQ target station.

Introductory Remarks

Fluids are ubiquitous in the target-moderator-reflector assemblies of spallation neutron sources. Since we are dealing with very high radiation fields atomic or light molecular fluids with low absorption cross section are to be preferred. Light water seems to be a good choice in this respect, especially since it is easy to handle and cheap. On the other hand, its outstanding moderation properties might make it undesirable to have water in the target to avoid premature neutron moderation and resulting increased absorption of the neutrons. The situation is particularly critical, if a thermal neutron decoupler is used around the moderator, whence it was concludet that the SNS-target should have D_2O cooling. D_2O is less strongly moderating and shows virtually no neutron absorption. Were it not for the increased cost of a D_2O cooling system (tritium handling etc.), this would certainly be the best choice. In order to obtain a quantitative basis for this decision, we performed measurements with both H_2O and D_2O as target and reflector coolant of the SNQ target station mock-up at Saclay, France. Although no decoupler will be used around the SNQ-moderator, the interest in these measurements was triggered by an indirect conclusion drawn from earlier measurements that polyethylene, used to simulate the reflector coolant seemed to have a negative effect on the thermal neutron leakage from the moderator.

Experimental Details

The experimental set-up is shown in a series of sectional views in figure 1. The targets were contained in a 30 ton lead shielding part of which could be rolled back for access. A 60x60x40 cm^3 graphite block under the target was used to simulate a large moderator (D_2O-tank) and the moderator-reflector assembly under investigation was placed on top of the target. The targets used were the sandwich-type lead slab targets of our former investigations[1] and, for the first time, a realistic simulation of the proposed SNQ rod-type lead slab target. In contrast to the sandwich-type target, where the coolant was simulated by polyethylene sheets resulting in an average "dilution" to 90 % by volume for the heavy metal (including aluminum sheets simulating the heavy metal canning), the rod-type target shown in figure 2 had the same composition as the SNQ target wheel (76 % heavy metal, 16 % coolant, 8 % canning aluminium). The integrated moderator-reflector assembly shown in figure 3 contained separating walls between the moderator volume and the reflector part in order to be able to employ H_2O as moderating fluid and D_2O as reflector coolant independently.

The applied proton currents were of the order of 1nA and 1.1 GeV kinetic energy. The proton beam cross section, monitored by several wire chambers in front of the target, was of approximately circular shape of about 3 cm half height diameter. The absolute proton calibration and the therefrom deduced absolute neutron leakage fluxes have been obtained as described in a previous paper.[2]

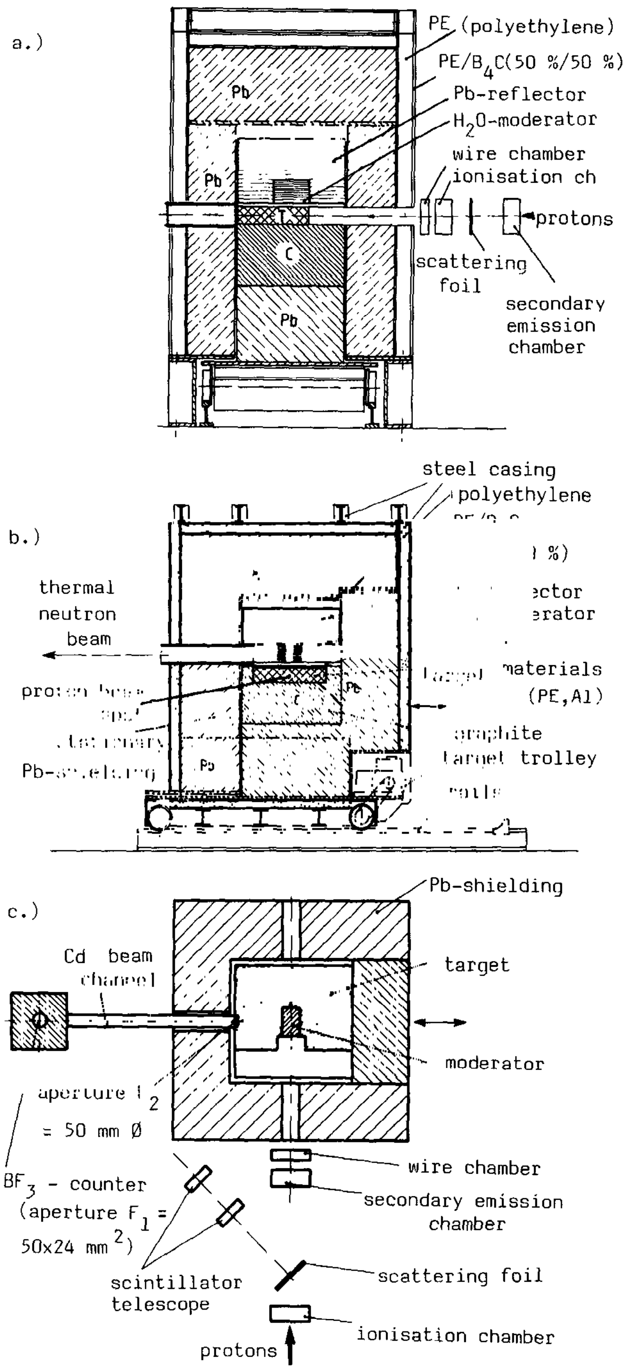

Figure 1. The SNQ target station mock-up
a.) vertical section parallel to proton beam
b.) vertical section perpendicular to proton beam
c.) schematic horizontal section

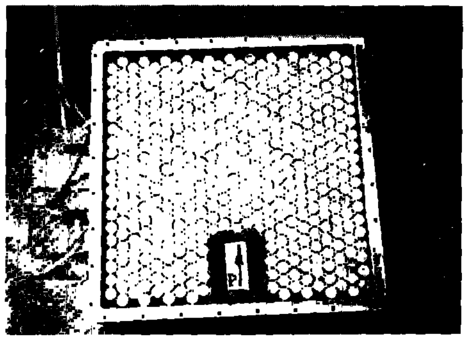

Figure 2. SNQ rod-type model target
rod diameter: 23 mm, rod height: 100 mm
separation between rod centers: 25 mm,
aluminium canning simulated by 5 mm diameter rods in each triangular space between rods.

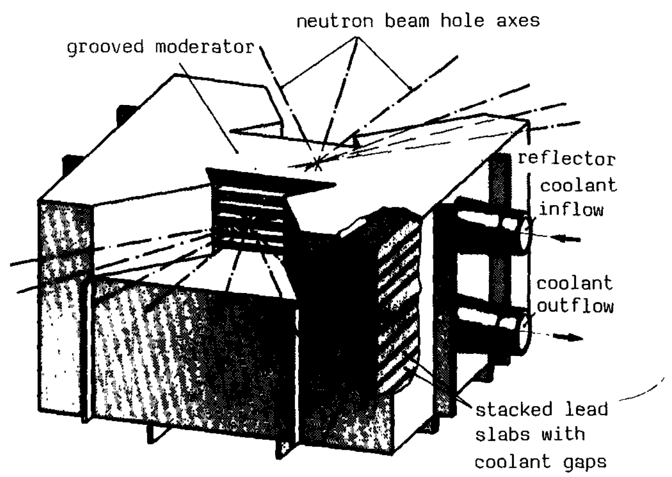

Figure 3. SNQ moderator-reflector arrangement

Results and Discussion

All together 12 combinations of targets, target-coolants and reflector-coolants have been measured including for comparison air in the coolant gaps of both target and reflector. Also including again the sandwich-type target extensively employed in earlier investigations should both confirm the reproducibility of our results and serve as a direct comparison of the two targets. The results of all measurements are compiled in Table 1.

meas. #	target	target coolant	reflector (vol.%)	reflector coolant	thermal neutron leakage flux ϕ_{th} [10^{14}n cm^{-2} s^{-1}]
1	Pb (sandw.)	polyeth.	-	-	4.42
2	"	"	Pb (90%)	air (10%)	5.48
3	"	"	"	H_2O "	5.35
4	"	"	"	D_2O "	5.75
5	Pb (rods)	air	-	-	3.49
6	Pb (rods)	D_2O	-	-	4.24
7	"	"	Pb (90%)	air (10%)	5.18
8	"	"	"	H_2O "	5.10
9	Pb (rods)	H_2O	-	-	4.02
10	"	"	Pb (90%)	air (10%)	4.80
11	"	"	"	H_2O "	4.91
12	Pb (rods)	H_2O (void)	Pb (90%)	H_2O (10%)	5.15

Table 1: Comparison of measured thermal neutron leakage fluxes for various target, reflector and coolant combinations. The flux values are scaled to 5 mA proton current. Measurement # 12 differs from # 11 with respect to displaced coolant water ("void") at the entrance (front gap of the rod assembly of Fig. 2) of the beam.

Effect of reflector coolant

For both targets we started with (using a polyethylene moderator of the same shape as the H_2O moderator) measurements with a void at the reflector position inside the shielding. The increase in neutron leakage flux measured with the reflector filling the void, once again demonstrates the advantage of a tight target-moderator-reflector-shielding arrangement. Using light water instead of air as a coolant does not significantly alter the measured fluxes, as can be seen by comparing the results of measurement # 2 and # 3, # 7 and # 8 as well as # 10 and # 11 of Table 1. From this consistent set of results an important gain in thermal leakage flux using D_2O as reflector coolant could no longer be expected. As a matter of fact the measurement # 4 (D_2O reflector coolant) exhibited only a 7.5 % flux increase as compared to H_2O coolant (# 3).

Effect of target coolant

The SNQ target wheel will contain about 16 % (by volume) of coolant in the reaction zone. Especially for the case of protons on lead when the range is rather long, this will lower the absolute neutron flux due to stronger heavy metal dilution. Apart from this one would expect that using D_2O as coolant results in a flux gain by at least the same factor as obtained for the reflector cooled with D_2O. The reason for this expectation is the particular geometry of the SNQ-target-moderator configuration: Absorption of neutrons thermalized in the large D_2O-moderator (simulated in this experiment by a graphite block, compare fig. 1) will be much stronger in a H_2O-cooled target thus preventing them from reaching the H_2O-moderator on the other face of the target, where they could contribute to the measured leakage flux. Somewhat surprisingly, the measured flux gain amounted to only about 4 % (meas. # 8 and # 11), which might as well be within the experimental uncertainty. These results indicate that, for the particular geometry of the SNQ target-moderator geometry, moderation in the target plays no significant role and also cross talk between both moderators is not very important, not even for the low absorption material lead-D_2O. The fact that the extra dilution in going from the sandwich type target (90 % heavy metal) to the rod target (76 % heavy metal) results in only 4 % flux reduction (measurements # 3 and # 12) might be due to spallation processes in the oxygen of the coolant.

Conclusion

Gain factors of 1.08 for a D_2O-cooled reflector and 1.04 for a D_2O-cooled (rod-type) target, which might combine to a total gain factor of 1.12 certainly do not justify the complications implied by using D_2O as target and reflector coolants for the SNQ-project. At the same time we were able to show that a hexagonal packing of targets rods, necessarily resulting in a stronger dilution of the target than the sandwich target we used for earlier experiments, does virtually not lower the thermal neutron leakage flux. The measurements thus have essentially confirmed the H_2O-cooled concept selected for the SNQ target station DIANE.

References

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