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A Hybrid Be/D_2O Reflector for ISIS

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We examine how the replacement of the inner portion of the beryllium reflector near the cryogenic moderators at ISIS by heavy water affects the performance of the neutron source.

In order to give a new reflectometer at ISIS a full view of the hydrogen moderator, it became apparent that the portion of the beryllium reflector surrounding the liquid hydrogen moderator would have to be reshaped. Unfortunately, because of the very high radiation field, it is virtually impossible to retrieve the reflector to have it machined. The fabrication of a new Be reflector is an equally unattractive solution in view of the rather high costs of Be and Be machining. A possible alternative is to abandon the idea of using Be around the cryogenic moderators, and replace Be with some other reflecting medium. Although heavy water is not as good a material for neutron reflection as beryllium, the calculations presented below show that it is a very acceptable substitute. In practice, one would build a stainless steel container shaped like the piece of Be reflector to be replaced, and fill it with heavy water. Computer simulations based on the LAHET Code System show that the neutronic penalties associated with this operation are acceptable.

The model used for the Monte-Carlo simulations does not have many of the engineering realities of the actual target system. Some of the most drastic simplifying assumptions are

- The target is a solid cylinder; the plates and their cladding were not mocked-up,
- A D_2O jacket surrounding the target cylinder to take into account the presence of coolant,
- Details of the steel pressure vessel surrounding the target were ignored,
- Details of the moderators and the canisters surrounding them were left out,
- The moderators have not been rotated,
- The openings cut in the reflector in front of the moderators have zero angular opening.

(The model is not unlike the computer models used in the initial design of ISIS [1], with perhaps a slightly greater degree of details.) Of course, some (if not most) of the details that

	All Be refl.	Be/D_2O refl.	All D_2O refl.
H_2O (fore)	1	1	0.71
H_2O (aft)	1	1.1	1.2
CH_4	1	0.93	0.81
H_2	1	0.86	0.70

Table 1: Calculated (relative) intensities for a Be/D_2O and a pure D_2O reflector at ISIS. Neutrons with energy E < 100 meV define the "useful" signal.

	All Be refl.	Be/D_2O refl.	All D_2O refl.
H_2O (fore)	14 ± 0.7	13 ± 0.7	10 ± 1
H_2O (aft)	32 ± 2	26 ± 2	24 ± 2
CH_4	35 ± 2	33 ± 2	30 ± 2
H_2	52 ± 3	58 ± 3	58 ± 2

Table 2: Second moment of the time distribution (~ pulse width) for a Be/D_2O and a pure D_2O reflector at ISIS. Neutrons with energy E < 100 meV define the "useful" signal.

were omitted are important for an absolute determination of the neutron source performance. However, this need not concern us here, and the model is probably adequate for our purpose. The results will thus be quoted in terms of performance *relative* to, say, a pure Be reflector. We studied not only the effect of a partial replacement of the Be reflector by D_2O (as described above), but also the effect of replacing the entire reflector by D_2O. This latter situation, besides its intrinsic interest, might become relevant one day if more moderator replacements are required or requested by the users.

Our reference case is an all Be reflector - a situation similar to the present ISIS target station. We then replaced the inner part of the reflector surrounding the cryogenic moderators by a heavy water tank (Fig.1), and determined the penalty paid in terms of neutron current at each moderator (relative to what the current was for an all-Be reflector). In the next computer simulation, we turned the entire reflector into heavy water. In both cases, we also calculated the second moment of the time distribution averaged over all neutrons with energy E < 100 meV:

$$\sigma = \frac{1}{100\text{meV}} \int_0^{100\text{meV}} (\overline{t^2} - \bar{t}^2)^{1/2} dE,$$

where $\bar{t}$ is the mean-emission time for neutrons leaking from the moderator for a neutron with energy E. In all cases it was assumed that the proton pulse is a delta function at $t = 0$. The quantity σ is a measure of the pulse width. The results are summarized in Tables 1 and 2.

The replacement of the central portion of the Be reflector by D_2O does not affect adversely the performance of the water moderators in a significant manner. The effect is more pronounced for the cryogenic moderators. Interestingly, the intensity from the aft light water

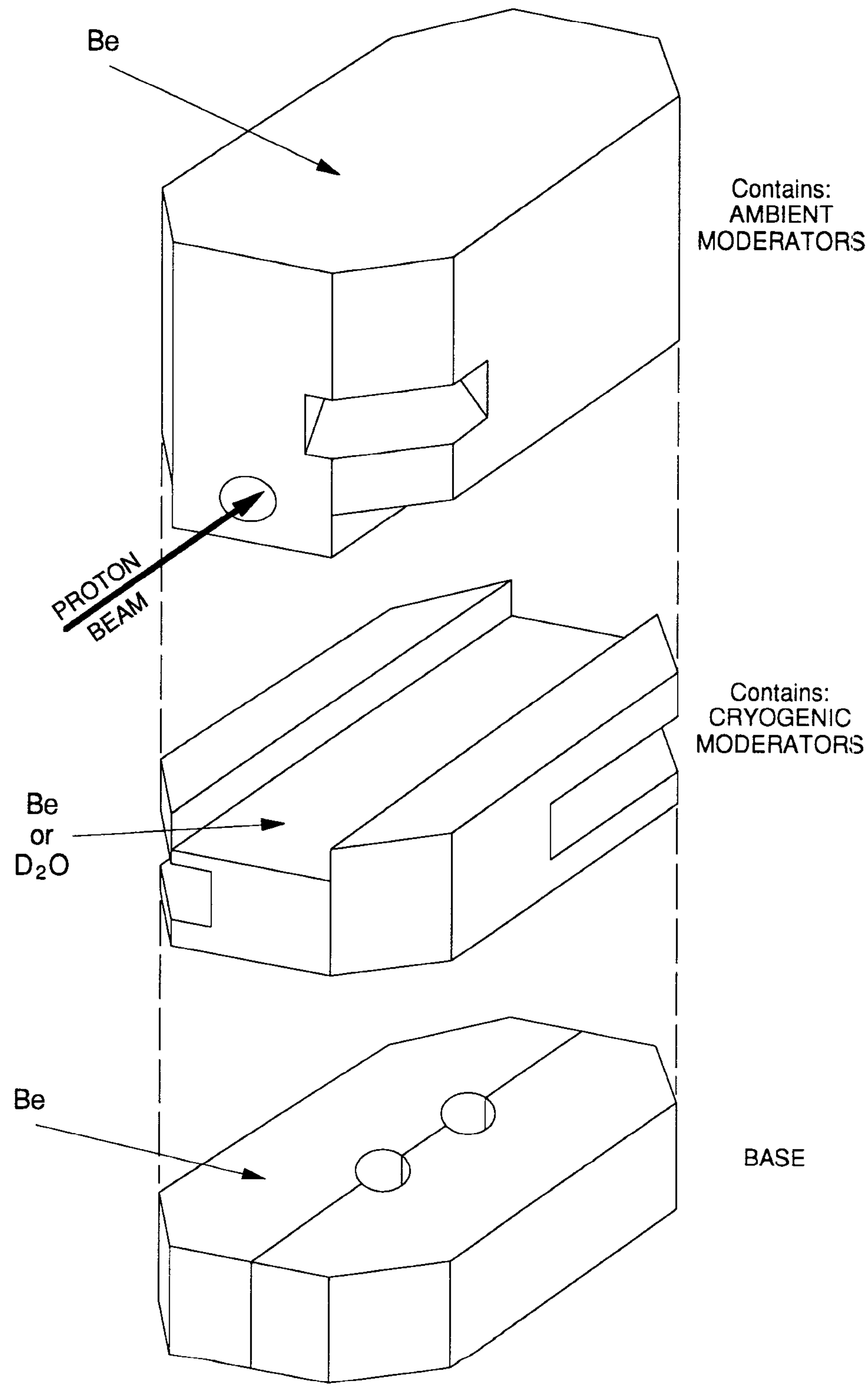

Figure 1: Geometry of the neutron reflector at ISIS

moderator *increases*. A possible explanation is that the average mean free path in D_2O of the (fast) neutrons produced in the target is larger than in Be. This seems to suggest that more neutrons are now able to leak through the D_2O reflector and find their way to the aft light water moderator than before (when the all-Be reflector was in place). Notice that the light water moderator is still surrounded by Be in its immediate vicinity. The situation is somewhat different for the hydrogen moderator which, following the same reasoning, should also see more neutrons, but is incapable of making efficient use of these extra neutrons because it is now entirely surrounded by D_2O, a much less efficient reflector than Be. An all-D_2O reflector leads to more drastic reductions in intensity - between 20% to 30% - except at the aft water moderator whose intensity *increases* further. In both cases (Be/D_2O or all D_2O) the pulse width is not significantly affected. The neutron pulses from the water moderators are somewhat sharper; the pulse width of neutron pulses from the liquid hydrogen moderator are somewhat broader, but altogether the resolution of the various moderators should not be dramatically affected.

References

[1] F. Atchison, "A theoretical study of a target reflector and moderator assembly for SNS", Rutherford-Appleton Laboratories Internal Report, RL-81-006, (1981).