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The AUSTRON-Target: The Neutron Flux of Decoupled and Poisoned Moderators

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ABSTRACT

This paper discusses in some detail the time resolution of the thermal neutron flux pulse generated by decoupled, poisoned, ambient temperature water moderators in a flat target configured spallation source. The influence of the reflector material on the time resolution of the neutron pulse is also investigated.

1. Introduction

The AUSTRON spallation source concept[1,2] consists of two different target configurations, namely a cylindrical-split target and a flat-target of rectangular cross-section. In both cases, the target material consists of tungsten with 5% rhenium, the cooling is edge cooling only using alternatively normal or heavy water as coolant. The reflector consists of densely packed cylindrical beryllium rods which are cooled by heavy water. So far only coupled moderators have been investigated.

It was one of the interesting results of the calculations presented in the AUSTRON feasibility study[1] that the flat target develops a rather broad peak of intensive neutron flux which can be utilised to couple favourably a number of moderators to the target. It was possible to show that a coupled wing moderator placed at the position of the flat-target's maximum neutron flux density develops on its surface a thermal neutron flux density which is almost identical to the one of a coupled void-moderator in a split-target configuration.

Therefore, this study concentrates on the flat-target concept and studies the physics of decoupled, poisoned, ambient temperature water moderators. The effect of different reflector materials and compositions on the neutron flux at the beam line entry is also investigated. The calculations were performed with the Monte Carlo simulation computer codes known as HERMES in their KFA-Jülich version. We use the EPR-library[3] for most of the calculations. This library has only one thermal group (0 - 0.414 eV) and therefore does not take care of upscatter processes within the thermal energy region. Such processes could effect the physics of the thermal neutrons and thus change the time resolution of the neutron pulse produced by the

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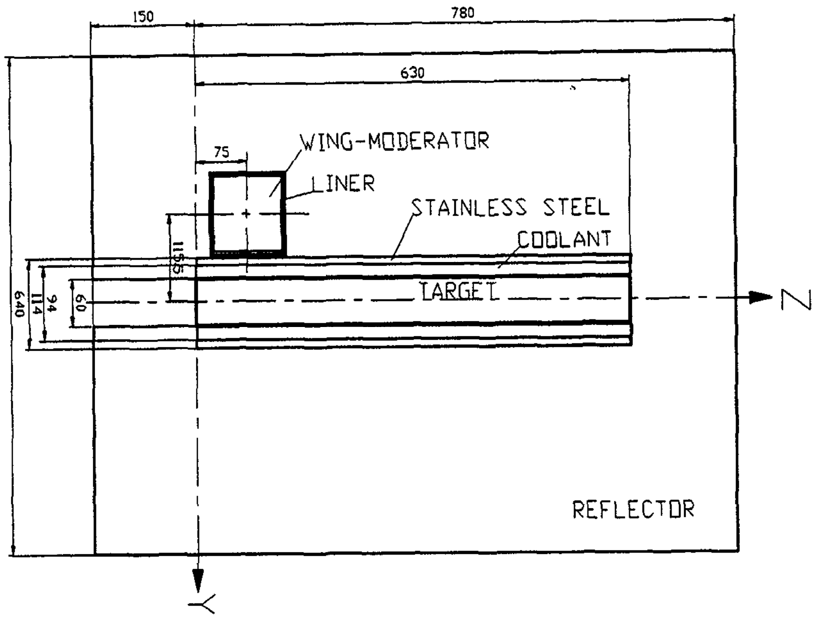


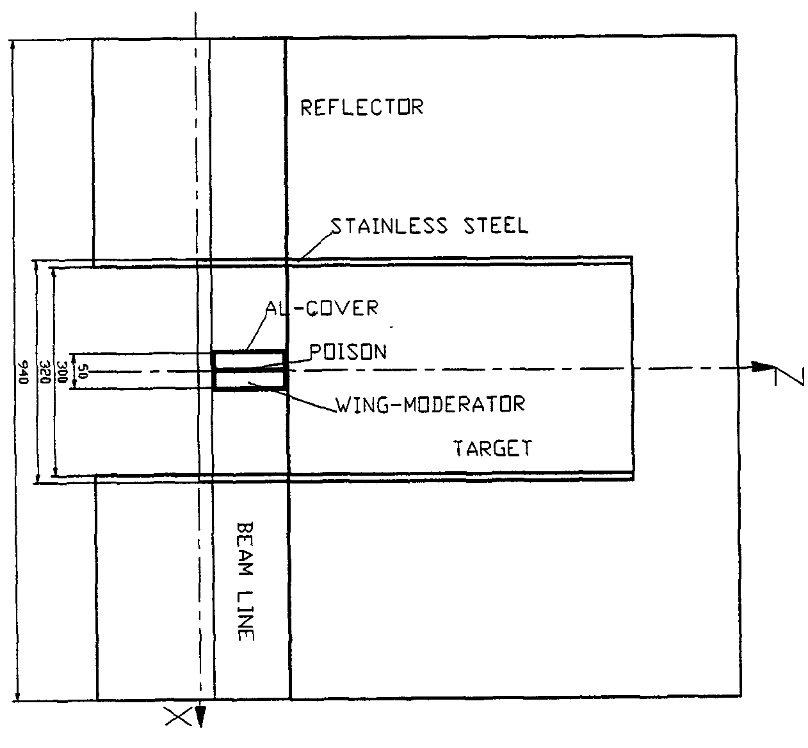


Figure 1. The AUSTRON flat-target configuration. Dimensions are in centimetres.

moderator. This cross-section library has the further disadvantage that it contains only cross-sections for normal and heavy water at 800 K. Our calculations have therefore been supplemented by a number of calculations using a 53 group cross-section library (named Spallation-library) with 16 thermal groups. This library was supplied to us by courtesy of KFA-Jülich. This library has the advantage that the normal and heavy water cross-sections are given for 300 K but so are the cross-sections for all the other materials. This means that we have the wrong temperature especially for the target material.

Thus the results discussed here are meant to give a qualitative picture of the physics involved and can only be used with caution for quantitative statements.

2. Configuration

The configuration of the target complex is shown in Fig. 1. The target itself consists of a tungsten 5% rhenium rod of rectangular cross-section of the dimensions 30x6x63 cm^3 in the (x,y,z)-directions. The top and bottom (x,z)-face of this rod is edge cooled adding about 1.7 cm of a heavy water - target material admixture (75% heavy water, 25% target material) to the structure. Another 1 cm is added by a stainless steel casing. The side (y,z)-faces are not cooled. This complex is symmetrically surrounded by a reflector body of the dimensions 940x640x930 cm^3 in the (x,y,z)-directions. The reflector consists of 90% beryllium, or a combination of beryllium with an outer nickel shell, or graphite and 10% heavy water which is used as coolant.

The target is hit by a proton beam of 1.6 GeV with a pulse frequency of 25 Hz and an average beam current of 128 μA. The (x,y)-cross-section of the proton beam is assumed to be of ellipsoidal shape and the intensity distribution is assumed to be of Gaussian type with a σ_x^2 of 20 and a σ_y^2 of 1.2 cm^2.

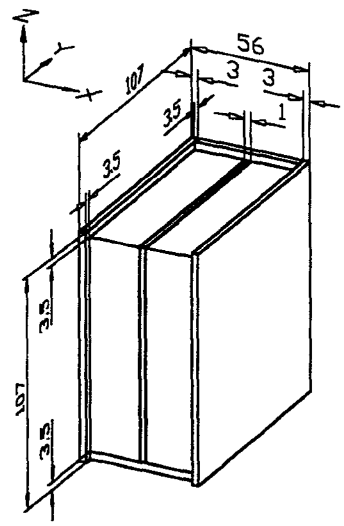


Figure 2. The moderator with the top-(x,y)-face and the front-(x,z)-face removed. All dimensions are in millimetre.

The moderator (see Fig. 2) is placed on top of the steel case (y = 5.5 cm) and is centred around the z-position (= 7.5 cm off the target's front face, Fig. 1) of the maximum in the neutron flux density. The moderating liquid, normal water of ambient temperature, is contained in an aluminium can of 5x10x10 cm^3 volume in the (x,y,z)-directions. The aluminium wall is 3 mm thick and a 0.5 mm thick sheet of ^{10}BC is used as decoupler on the (x,y)- and (x,z)-faces of the can. An additional strip of ^{10}BC is used as poison. This strip is smeared out to a thickness of 1 mm and 50% ^{10}BC for better numerics. The neutron flux leaving the (y,z)-face of the moderator in direction of the positive x-axis is called the *forward-scatter* flux while the one leaving in direction of the negative x-axis is called *back-scatter* flux.

The moderator is connected to a beam line opening in the reflector which is of a 11x11 cm^2 cross-section. This beam-line is built of an aluminium tube of 3 mm wall thickness and a liner of 0.5 mm thickness consisting of ^{10}BC can be added. (For an easier set-up of the geometry data used in the calculations the ^{10}BC was smeared out over the wall, now 3.5 mm thick.) The neutron flux at the end of this beam line (on the outer surface of the reflector) is also monitored throughout our calculations.

3. Results

The calculations concentrated mainly on the time resolution of the thermal neutron flux pulse as it appears on the moderator surface facing the beam line and on the time resolution of the thermal neutron pulse as it appears at the end of the beam line. Fig. 3 compares the time resolution of the average thermal neutron flux density for a moderator which is centred around the *z*-axis. We compare a coupled, a decoupled, a decoupled and poisoned, and, finally, a decoupled, poisoned moderator with a liner in the beam line. The results show, firstly a moderate decrease in the peak flux density for each modification applied to the moderator. With each additional feature added to the moderator the pulse also becomes shorter. The pulse is most efficiently shortened by decoupling the moderator, adding poison and the liner results in an additional reduction of the pulse length. It is also interesting to note that the liner is very effective in reducing the final tail of the pulse while it has almost no influence on the starting ramp. The pulse half-width varies between about 30 μs for the coupled moderator and about 10 μs for the decoupled, poisoned moderator with a liner in the beam-line.

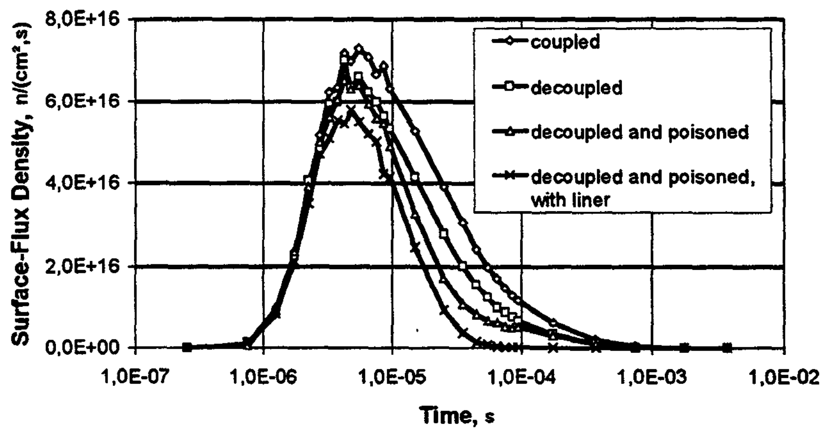
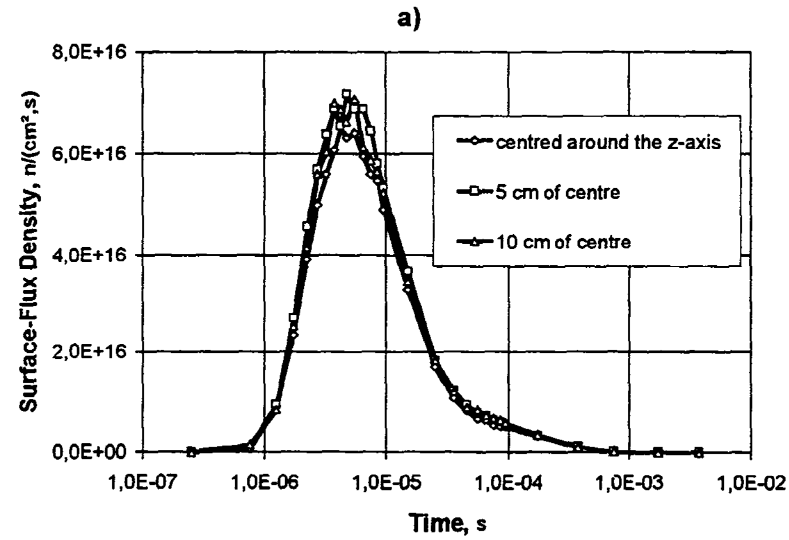


Figure 3. Time resolution of the average thermal neutron flux density on the moderator surface facing the beam-line for various moderator configurations. The moderator is centred around the *z*-axis which results in almost identical results for the forward- as well as the back-scatter mode.

Figs. 4a,b compare the forward- and back-scatter mode of a decoupled and poisoned moderator (with no liner in the beam line) which is moved off its centre position around the z-axis. While the thermal neutron flux barely changes in back-scatter mode, we experience a significant decrease of this flux in forward-scatter mode. Thus if the moderators are to operated in an off-centre configuration the back-scatter mode is to be preferred.



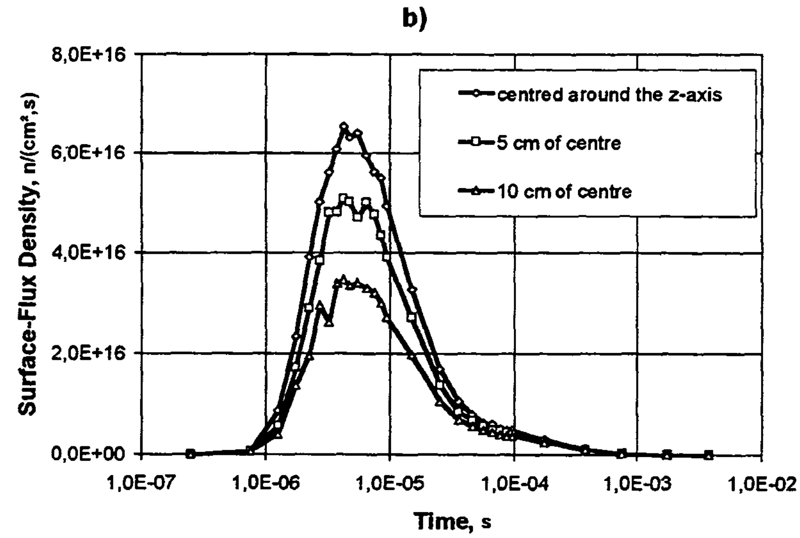


Figure 4: Time resolution of the average thermal neutron flux density on the surface of a decoupled and poisoned, ambient temperature water moderator for various x-positions of the moderator. There is no liner in the beamline. a) Back-scatter mode, b) forward-scatter mode.

Monitoring the neutron pulse at the end of the beam line on the outer surface of the reflector revealed virtually no change at all for the pure beryllium or pure graphite reflectors. A very interesting result can be reported for the beryllium reflector with an outer nickel shell the thickness of which has been varied between 0 and 10 cm. The corresponding results are presented in Fig. 5. They show that an outer nickel shell up to a thickness of about 7.5 cm has almost no influence on the maximum neutron flux density. This maximum density starts to decrease for nickel shells thicker that 7.5 cm. On the other hand, adding the outer nickel shell results in important improvements in the time structure of the neutron pulse: a 10 cm thick outer nickel shell decreases the initial ramp of the neutron pulse by at least two orders of magnitude and decreases substantially the final tail of the neutron pulse. Thus an outer nickel shell is very favourable for the production of neutron pulses with a clearly defined initial ramp.

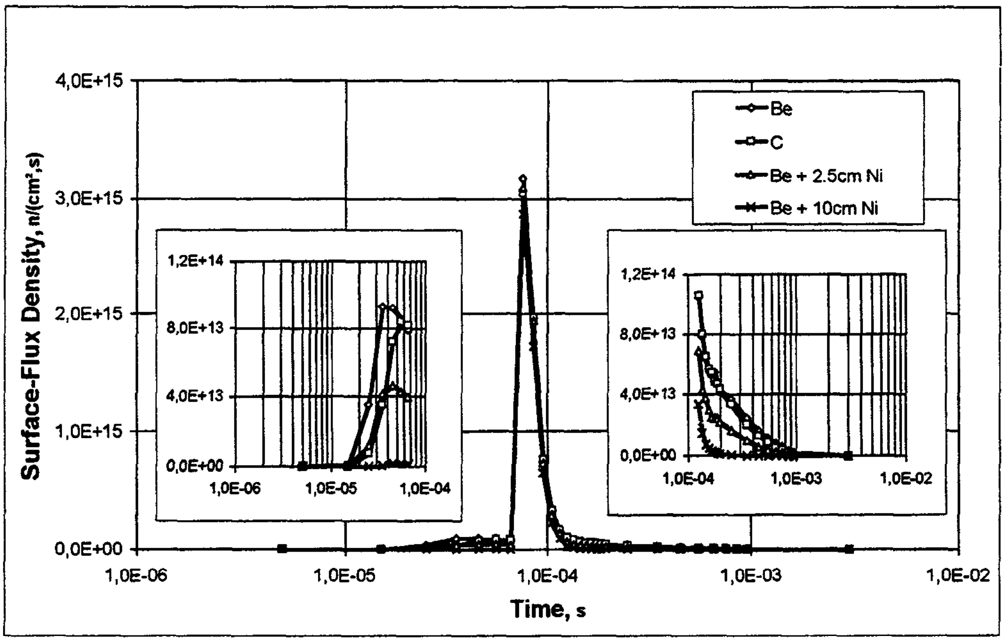


Figure 5: Time resolution of the average thermal neutron flux at the end of the beam line (outer surface of the reflector. The two inserts show the initial ramp of the neutron flux pulse and its final tail, respectively.

All the above results were found using the EPR cross-section library. Additional calculations using the Spallation-library with 16 thermal groups tried to establish the influence of upscatter processes within the thermal energy region on the time resolution of the neutron pulse, for the price of having the wrong temperature for the target material. The results are inconclusive: they do show a slight broadening of the neutron pulse at the moderator surface and also a moderate decrease in the peak value for the flux density. But this could also be due to the wrong temperatures in all the other materials. More calculations are certainly necessary if one wants to clearly separate the temperature effects from the effects caused by upscattering processes within the thermal energy region. Nevertheless, the general trends outlined so far stay unchanged.

4. Conclusions

We studied, using numerical simulation, the time resolution of the neutron pulse produced by decoupled and poisoned, ambient temperature water moderators in a flat-target configuration. We found that decoupling and adding a liner to the beam line through the reflector had the most influence on the time structure of the neutron pulse. Both reduce the half-width of the pulse and the liner reduces in addition quite substantially the final tail of the pulse. Poisoning results in an additional shortening of the neutron pulse.

Changing the reflector material from beryllium to graphite was found to have no effect on the time resolution of the neutron pulse. Replacing some of the reflector material by an outer nickel shell resulted in a remarkable improvement of the time structure of the pulse by suppressing the initial ramp of the pulse. It also results in an improved tail of the pulse and thus supplements the effect of the liner.

Arranging several moderators which are operated in back-scatter mode around the maximum neutron flux density on the surface of the target-coolant-casing block of our flat-target configuration will result in an over all better performance than a split-target configuration with one void and several wing moderators. Keeping the costs in mind, a graphite reflector seems to be preferable over a beryllium reflector and an outer nickel shell will result in a greatly improved time structure of the thermal neutron pulse.

5. Acknowledgements

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6. Literature

[1] G. Kahr et al., in *AUSTRON Feasibility Study,* ed. P. Bryant, M. Regler, and M. Schuster (AUSTRON Planungsbüro, Vienna, 1994).

[2] M. Schuster et al., *Physica B* **213&214** (1995) 851.

[3] EPR Neutron Cross-Section Library, DLC-37, *RSIC Data Library Collection* (RSIC Center, Oak Ridge, 1978).