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Calculation of the normalized gain for a neutron detector in various void conditions in a BWR subchannel.

by

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Abstract

Calculations were done using the S_n code ANISN in order to estimate the response of a fission detector in a BWR subchannel assembly under various void and temperature conditions. Spatial effects, like oscillations of the fuel and detector assemblies, were also estimated.

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Introduction

In studying the properties of BWR reactors by noise analysis Bergman(1985) has used a small fission chamber inside a BWR core. In the evaluation of the measurements two specific questions arise:

1) What is the relative stat response of the detector when the mean-void changes in the box- and the bypass-coclant flow?

2) What is the detector response when the detector assembly or the fuel oscillates? In other words, how large is the gradient of the neutron flux when the geometry changes.

To answer these questions some calculations have been done on a simplified geometry, where the void fraction, coolant temperature and detector position could be varied.

Calculations

The calculations were done with the ANISN code, which has been used earlier for calculations at our institute. Since a one-dimensional geometry is necessary in ANISN, an infinite cylindrical arrangement was assumed as shown in Fig. 1.

The detector was a fission chamber, containing 90% uranium 235 and having a wall of stainless steel 0.1 cm thick.

Calculations were first done for various void content α_1, α_2 and α_3. At the same time the thickness of the water film (Δx_1) was varied (calculations A1 - D3).

Then α_3 was kept fixed at 0.2 and $\alpha_1 = \alpha_2 = 0$ and the width of the bypass channel (D_{spalt}), the flow channel (FLC) and the water film (Δx_1) varied (calculations E1 - G4).

The density of the moderator was varied in calculations H1 - H4 in order to estimate the effects of variations in the temperature of the coolant.

Finally, the void content α_2 was varied from 0.00 to 1.00 in the calculations I1 - I10.

The conditions for each calculation are given in Table 1. The quantity of interest in all cases is the detector response, which also is listed in Table 1.

The ANISN code is based on the S_n method in a multigroup formulation. For further details the reader is referred to Bell and Glasstone(1970) or Kaffehr(1983). In principle the S_n method can give very accurate results as pointed out by Sjöstrand(1980). However, in practice several approximations must be done. In addition to the modelling of the geometry mentioned above the following should be mentioned:

1) 16 groups of neutrons were used.

2) Isotropic scattering was assumed for all nuclides except hydrogen, where anisotropy to first order was taken into account.

3) The angular distribution of the neutron flux was considered in 4 directions only (S_4 approximation).

4) The source in the calculations was assumed to be a fission source, distributed evenly in all parts containing U-235.

5) Reflection condition was used on both the left and right boundary.

6) The calculations were made for a cylinder with 10 cm radius containing 59 spatial points. The same calculation was also done using 114 points within a 4 cm radius in order to study the effect of different mesh sizes on the neutron flux. The total flux was weighted groupwise with the U-235 fission cross section. The results obtained were normalized at the maximum value. Fig. 2 shows the curves for the two different spatial meshes. The differences are negligible in all parts not containing fuel.

Discussion

To assess correctly the uncertainty in the calculated detector response it would have been necessary with more detailed calculations using e.g. more neutron groups. However, the aim of the present work was to to estimate the variation of the detector response in relation to a change in the individual parameters. Thus, we can presume that the relative values are accurate in the cases where we do not have variations in the radial direction. The cases where any part of the assembly oscillates can not be described correctly with a one dimensional model,so the results given for these cases may have considerable uncertainty.

For a discussion of the relevance of these calculations to the interpretation of the noise measurements the reader is referred to Bergman(1985).

References

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Kaffehr E., Design Calculations for a shield around a ^{252}Cf neutron source., CTH-RF-45, (1983)

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case	α_1	α_2	α_3	Δx_1	D_{spalt}	FLC	Relative Fission rate
	%	%	%	cm	cm	cm	
A1	0.20	0.00	0.00	0.10	0.20	0.40	1.000
B1	0.50	0.00	0.00	0.05	0.20	0.45	0.935
B2	0.50	0.00	0.05	0.05	0.20	0.45	0.928
C1	0.70	0.00	0.00	0.02	0.20	0.48	0.894
C2	0.70	0.05	0.00	0.02	0.20	0.48	0.889
C3	0.70	0.05	0.10	0.02	0.20	0.48	0.876
D1	0.85	0.10	0.00	0.01	0.01	0.49	0.860
D2	0.80	0.10	0.05	0.01	0.01	0.49	0.861
D3	0.80	0.20	0.10	0.01	0.01	0.49	0.853
E1	0.20	0.00	0.00	0.10	0.15	0.40	0.976
E2	0.20	0.00	0.00	0.10	0.10	0.40	0.939
E3	0.20	0.00	0.00	0.10	0.05	0.40	0.930
E4	0.20	0.00	0.00	0.10	0.00	0.40	0.935
E5	0.20	0.00	0.00	0.10	0.25	0.40	1.025
E6	0.20	0.00	0.00	0.10	0.30	0.40	1.051
F1	0.20	0.00	0.00	0.10	0.20	0.45	1.019
F2	0.20	0.00	0.00	0.10	0.20	0.40	1.000
F3	0.20	0.00	0.00	0.10	0.20	0.35	0.981
F4	0.20	0.00	0.00	0.10	0.20	0.30	0.963
G1	0.20	0.00	0.00	0.05	0.20	0.40	0.995
G2	0.20	0.00	0.00	0.00	0.20	0.40	0.990
G3	0.20	0.00	0.00	0.15	0.20	0.40	1.005
G4	0.20	0.00	0.00	0.20	0.20	0.40	1.011
H1 1)	0.20	0.00	0.00	0.10	0.20	0.40	1.017
H2 2)	0.20	0.00	0.00	0.10	0.20	0.40	1.014
H3 3)	0.20	0.00	0.00	0.10	0.20	0.40	1.010
H4 4)	0.20	0.00	0.00	0.10	0.20	0.40	1.009
I1	0.20	0.10	0.00	0.10	0.20	0.40	0.989
I2	0.20	0.20	0.00	0.10	0.20	0.40	0.980
I3	0.20	0.30	0.00	0.10	0.20	0.40	0.970
I4	0.20	0.40	0.00	0.10	0.20	0.40	0.961
I5	0.20	0.50	0.00	0.10	0.20	0.40	0.952
I6	0.20	0.60	0.00	0.10	0.20	0.40	0.943
I7	0.20	0.70	0.00	0.10	0.20	0.40	0.934
I8	0.20	0.80	0.00	0.10	0.20	0.40	0.926
I9	0.20	0.90	0.00	0.10	0.20	0.40	0.917
I10	0.20	1.00	0.00	0.10	0.20	0.40	0.909

Table 1. Summary of initial data and results

All results are related to calculation A1. The void contents are denoted α_i, the water film in the flow channel is denoted Δx_1, and the flow channel is FLC.

1) Water density adjusted to T = 270 °C
2) Water density adjusted to T = 273 °C
3) Water density adjusted to T = 276 °C
4) Water density adjusted to T = 279 °C

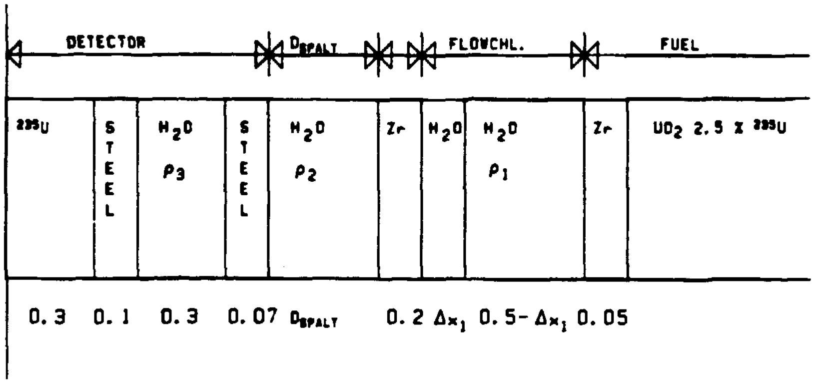

Fig. 1

Layout of the detector assembly and its environment in the calculations. The fuel is approximated by about 10 cm of fuel with reflective boundary condition on the outer surface. Measures in cm.

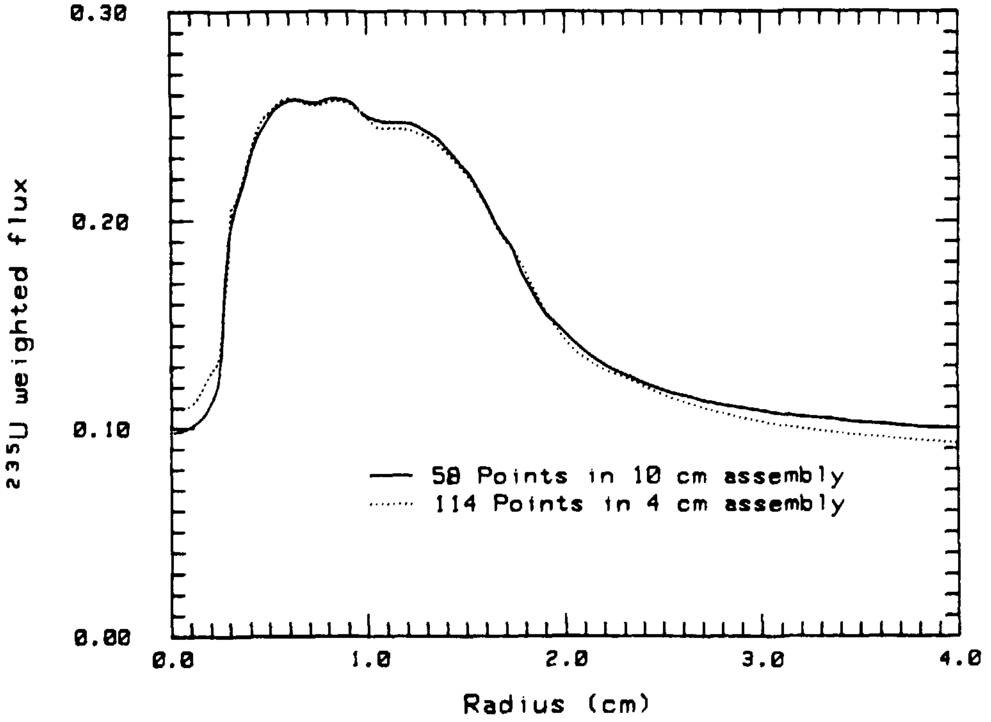

Fig. 2

Effect of the mesh in the calculations. The figure above shows the flux shape with an 10 cm assembly subdivided into 58 intervals and a 4 cm assembly subdivided into 114 intervals. In practice the second mesh is about four times finer than the first one. Results are normalized at the highest flux level. Note that the flux is approximately equal in the two cases for all parts not containing fuel.