A "NON-COINCIDENT" NEUTRON COINCIDENCE COLLAR RESPONSE SIMULATION

Paulo de Tarso Dalledone Siqueira, Paulo Rogério Pinto Coelho, Hélio Yoriyaz and Roberto Cabezas

Instituto de Pesquisas Energéticas e Nucleares, IPEN/CNEN-SP
Divisão de Física de Reatores
Caixa Postal 11049
Travessa R-400, Cidade Universitária
05422-970, São Paulo, Brasil
ptsiquei@net.ipen.br, prcoelho@net.ipen.br, hyoriyaz@net.ipen.br

ABSTRACT

This work presents a series of simulations run to evaluate the response of a neutron coincidence collar employed in safe guard experiments of fresh fuel control. Simulations were performed using MCNP code and were restricted to 2 different PWR fuel assemblies, one of then with 6 distinct configurations. A simulation approach was implemented in a way that coincidence counting was circumvented. The obtained results show good qualitative agreement with published experimental data.

1. INTRODUCTION

Neutron coincidence collar has been used as a non-destructive assay equipment to verify the fissile content of fresh fuel assemblies for several years. Neutron Coincidence counting is necessary to avoid an equivocal attribution to fission by the detection of a neutron derived from a single neutron emission nuclear event such as (γ,n) and (α,n) reactions and neutron scattering.

However, calibration of the NCC has still been the main hurdle to overcome since physical standards are usually not available at the plant when the measurements are done. This is the case of the NCC utilised by the Brazilian_Argentine Agency for Accountability and Control of Nuclear Materials (ABACC), for inspection of PWR fuel assemblies at Brazilian nuclear fuel plant.

As an intent to provide information about the response of the collar to physical parameters of the different assemblies assayed, simulations were performed aiming to supply the main features of a characteristic standard fuel element to be built for calibration purposes. These simulations were carried out using the MCNP (Monte Carlo N-Particle) transport code[1].

2. SIMULATION SET UP

Simulations have been performed considering a NCC, a fresh fuel assembly and air as a surrounding universe. Through all simulations, one single assembly was considered each time and it was placed perpendicularly and centered to the NCC ring.

2.1 NCC (NEUTRON COINCIDENCE COLLAR)

The collar has 20 ^{3}He detectors embedded along 3 high-density polyethylene banks. A forth bank contains a source case which holds an AmLi neutron source. These banks are arranged in a way they form the sides of a quadrilateral defining a sample-disposer inner space. Additional specifications about the collar can be found elsewhere [2,3] .

2.2 FUEL ASSEMBLIES

The NCC responses to 2 different assemblies have been evaluated. Although both assemblies are made of a 16 by 16 array, they differ in many design aspects. Table 1 presents the main characteristics of each assembly. Assembly 2 has, however, 6 different configurations. These differences are present due to combinations of ^{235}U enrichments with the presence or absence of burnable fuel rods.

Table 1. Assemblies main characteristics

	Assembly 1	**Assembly 2**
Number of fuel rods	235	236
Number of guide tubes	21	20
Pitch	12.32 mm	14.30 mm
Active height	3657.6 mm	3900.0 mm
Pellet diameter	8.05 mm	9.30 mm
^{235}U Enrichment	3.4 %	1.9% , 2.5% and 3.2 %
Number of Gd_2O_3 rods	0	0 , 8 and 12
Grid composition	Inconel	Zircalloy

3.SIMULATION APPROACH

Tallies were performed for both neutron fluxes and ^{3}He(n,p)^{3}H reaction rates in each detector present in the collar, however results henceforth shown will be concerned to the neutron capture reaction rate by ^{3}He since it is the basic event related to the origin of signal generated by the detectors.

In a regular evaluation of fuel assemblies using a NCC, a two steps procedure is adopted:
1- `passive counting`: performed with no interrogative source, where signals are due to background neutrons and to neutrons from spontaneous fission of ^{238}U;
2- `active counting`: with a interrogative neutron source (AmLi) where signals are regarded to neutrons coming from ^{235}U induced fission and also from (n,xn) reactions besides those forementioned signal sources.

Subtraction of signals intensities allows the inference of ^{235}U content as they are solely due to neutrons from ^{235}U fission and (n,xn) reactions.

Simulations have also been done in two steps:
1- `total`: all neutrons in the system are treated with no distinction, so the ^{3}He(n,p)^{3}H reactions in the detectors are due to neutrons from the source, ^{235}U fission and (n,xn) reaction;
2- `no fission`: all induced fission reactions and (n,xn) reactions are treated as a neutron capture reaction, therefore the only neutrons in the system are those from the source.

Subtraction of simulation results of the later step from the first one results in detectors reactions rate induced by neutrons from ^{235}U fission and (n,xn) reactions as is the case of the experimental procedure (Figure 1).

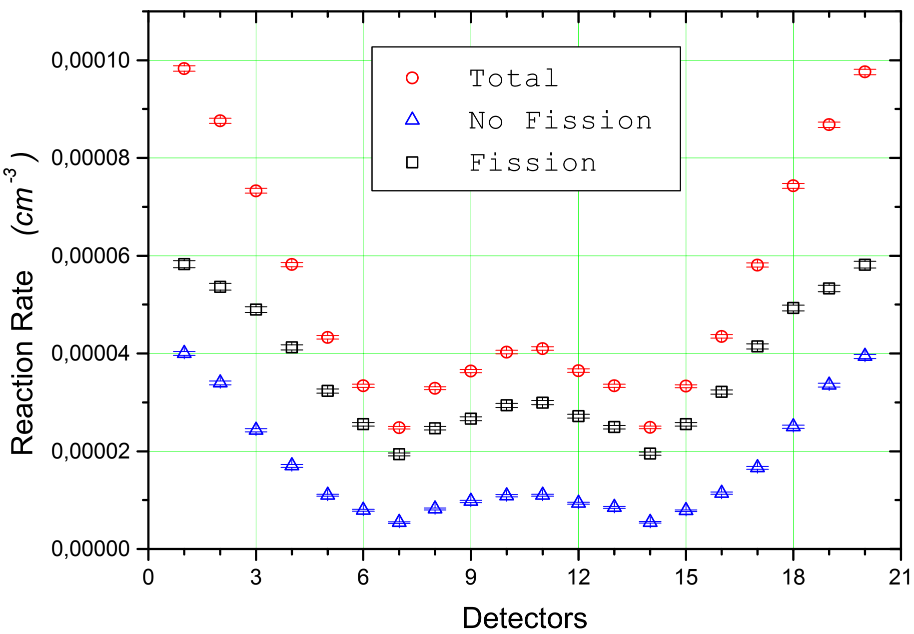

Figure 1. Reaction rate values for each one of the 20 detectors in the collar. The two steps simulated results are shown in circles (Total) and triangles (No Fission). The assumed net reaction rate is shown in squares (Fission).

An average reaction rate value was taken as an intent to obtain a characteristic value for each system configuration simulated, however, as the geometric efficiency of each detector is rather different a normalisation was done taking advantage of a reference configuration (**Figure 2**).

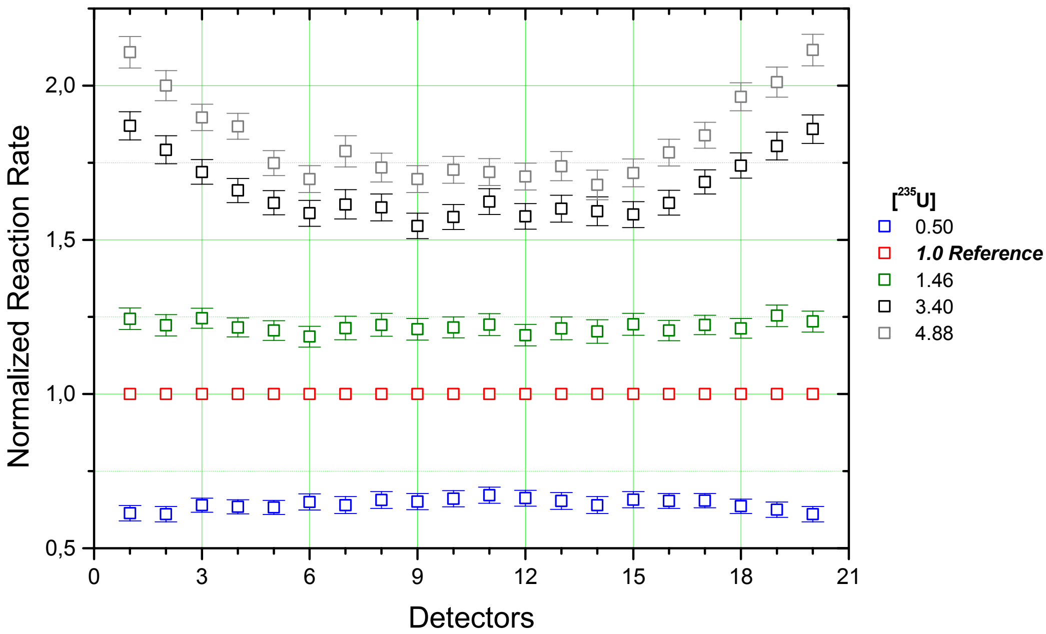

Figure 2. Normalised Reaction rate values for each one of the 20 detectors in the collar. Normalisation is done detector by detector and the ^{235}U enrichment configuration of 1 percent is taken as reference (red squares).

4. STUDIED PARAMETERS

The main parameters of the assemblies influencing the NCC response studied in this work were:

- height;
- ^{235}U enrichment;
- burnable poison presence and
- grid composition.

These last 2 parameters were evaluated by fuel assembly scanning. Both assemblies had all these parameters evaluated, however the illustrative results henceforth shown will be restricted to only one of them whenever no significative differences are present.

4.1 ASSEMBLY HEIGHT

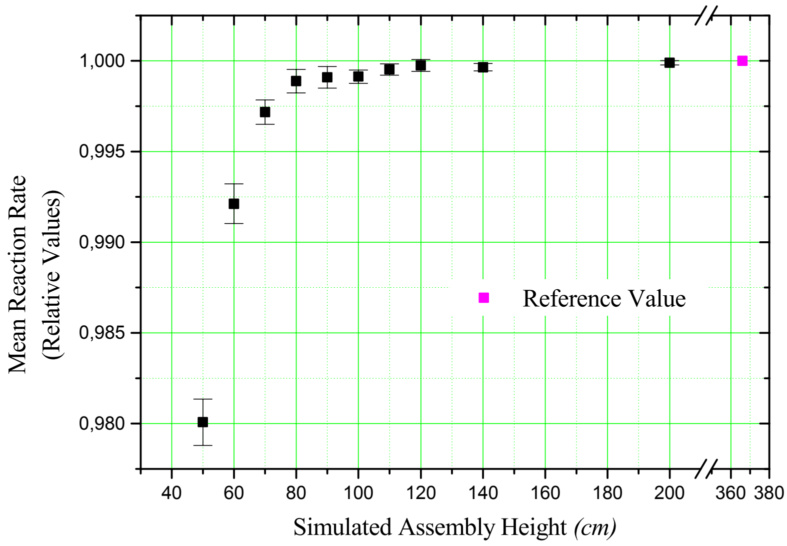

Figure 3. Influence of the assembly height on the NCC response. The real height (3657.6 mm for Assembly 1) is used as a reference value (pink square).

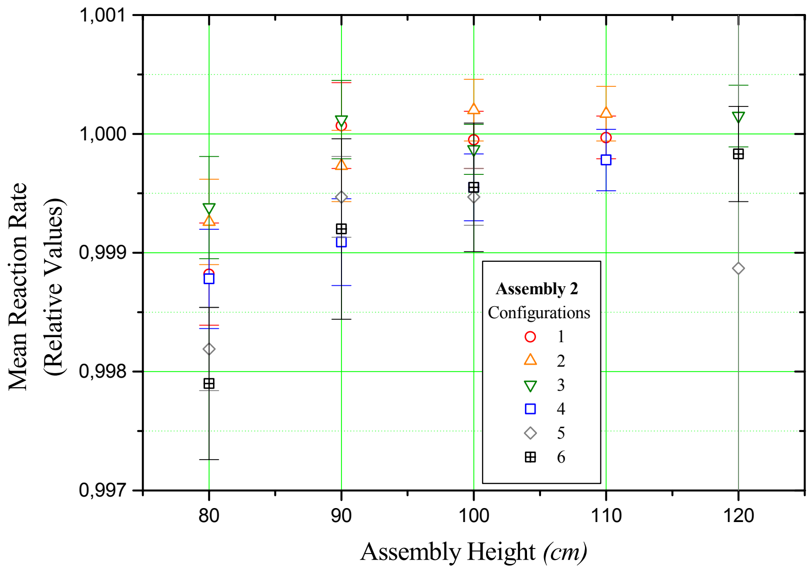

Figure 4. Influence of the assembly height on the NCC response. Values shown are related to Assembly 2 and its real height (3900 mm) is used as a reference value (not shown).

Figures 3 and 4 show the dependence of the NCC response with respect to the assemblies height. Estimated responses for shortened assemblies differ by less then 1 % for height values above 60 cm. Above 90 cm the NCC response is statiscally equal to any larger value.

4.2 ASSEMBLY SCANNING

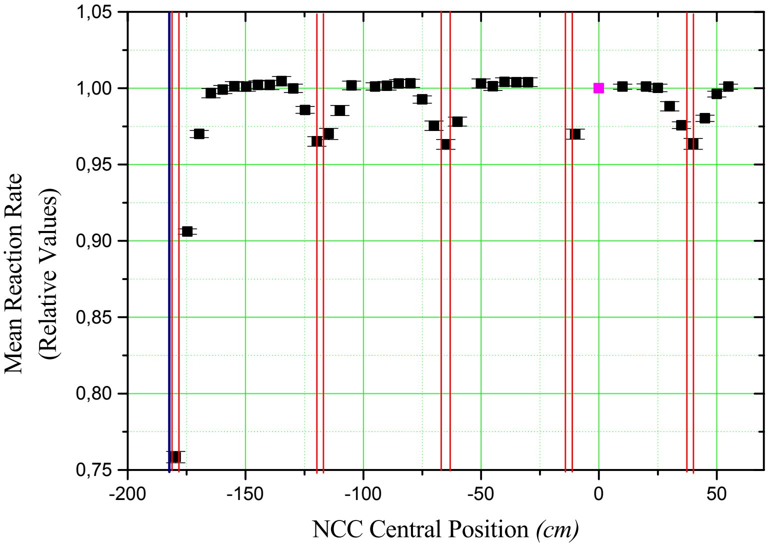

Figure 5. Assembly 1 scanning. Its central position is used as a reference value (pink square). Red lines indicate Inconel grids; dark blue line indicates the bottom limit of the active length.

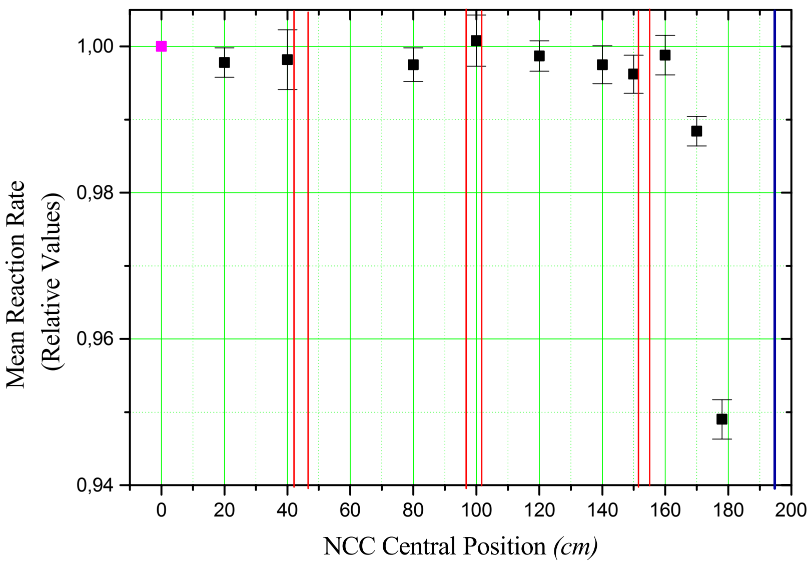

Figure 6. Assembly 2 scanning with no burnuble poison rods. Its central position is used as a reference value (pink square). Red lines indicate Zircalloy grids; dark blue line indicates the upper limit of its active length.

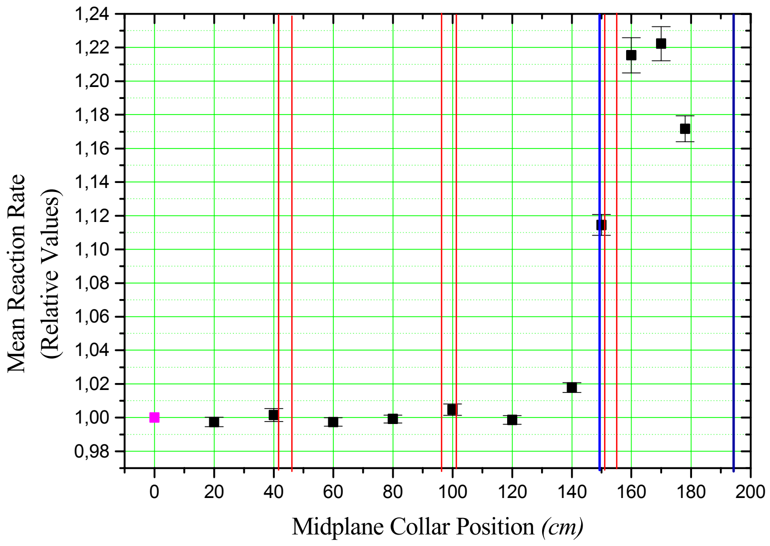

Figure 7. Assembly 2 (configuration with 12 burnuble poison rods) scanning Its central position is used as a reference value (pink square). Red lines indicate Zircalloy grids; light blue line indicates poison upper limit; dark blue line indicates its active length upper limit.

Figures 5 – 7 show the NCC response to scanning "experiments" performed with different assemblies. It turns clear in figure 5 the NCC response reduction influenced by Inconel grids. It is also observed when the NCC is positioned in the vicinities of the active volume, which is also observed in figures 6 –7. These figures also evidence the influence of burnuble poison.

4.3 ^{235}U ENRICHMENT

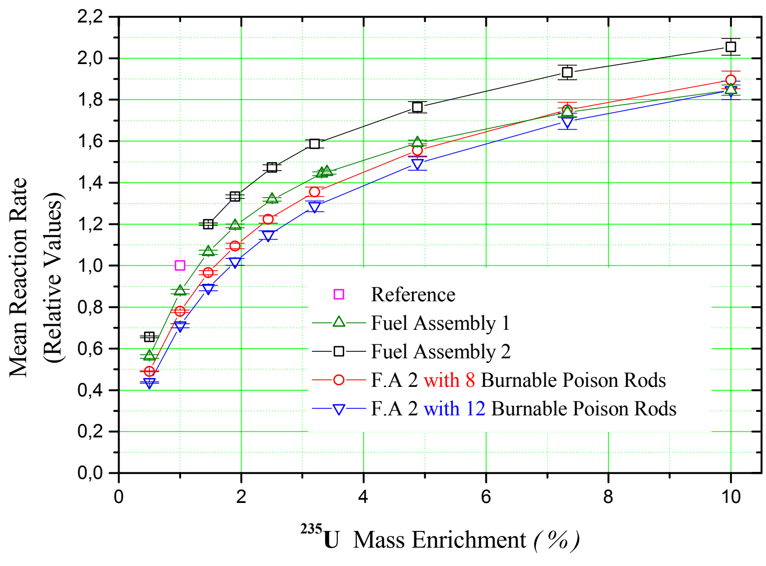

Figure 8. Calibration curves for the different fresh fuel assemblies.

Figure 8 shows the influence of ^{235}U enrichment on NCC response. Assembly 2 with ^{235}U enrichment of 1 % in its configurations with no burnable poison rods has been used as a reference value. It allows a intercomparation between all assemblies.

CONCLUSIONS

This work presents a methodology to simulate the physical response of NCC in fresh fuel evaluation by passing one of its fundamental working principles which is the coincidence counting and, although electronic response has not been taken into account, the results obtained are in qualitatively accordance with experimental results[2,3]

Besides the calibration curves for each type of fuel assembly many other parameters were evaluated as:

- fuel assembly scanning;
- height sensitivity;
- presence of burnable poison and
- ^{235}U gradient

ACKNOWLEDGEMENTS

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