# POWER DENSITY DISTRIBUTION BY GAMMA SCANNING OF FUEL RODS MEASUREMENT TECHNIQUE IN RA-8 CRITICAL FACILITY

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## ABSTRACT

Power density measurements in the critical facility RA-8 are presented. These measurements were the first systematic use of the reactor. A measurement system was designed, built and proved for this goal. Power profiles are showed and the results are compared with calculated values.

## INTRODUCTION

In 1997 the critical facility RA-8 had the first start-up. This facility was designed for validate the calculation model and codes use in the calculus of the CAREM Reactor and for knowing some neutron characteristics of this reactor. The facility has great versatility for experimental work. It's possible make different arranges or configurations: burnable poisons, control rod simulation, water perturbations, etc.

In this work will be presented the developing and put in function of the technique for power density measurements in the RA-8 facility. That means to solve:

1. Optimise the quantity of point to be measured in order to know the power density
2. Choose a measurement technique. The two most used are a) Activation detectors (foils or wires) b) gamma scanning of the fuel rods.
3. The choose method has to minimise the errors , has to be repetitive, the involved doses has to be in the applicable limits and the irradiation and measurement times has to be adequate to the operation conditions of the reactor

In a detail way is important to take in account:

i) The total number of points to be measured depends of the configuration array, of the number and type of perturbation in the array and the distribution of these perturbations in the array.

ii) It's advisable to begin the measurement serie with the simplest array. That is a cylindrical array with all the fuel rod of the same enrichment. This core configuration allows to obtain radial symmetry and measure only in a radius (about 20 fuel rods)

iii) For axial distribution is necessary to measure in the 80cm. length of the fuel rod. Measuring in 4-cm. space intervals 20 measurements points are required.

iv) 100 to 300 detectors must be putting in the core If activation detectors are used for power density measurement. These detectors introduce flux perturbations and a detailed administrative procedure is necessary in order to assure the measurement quality.

v) Gamma scanning of the fuel rods gives information about the number of fissions during the reactor operation through fission products decay. If activation products can be discriminated, gamma background error can be evaluated, the fuel rods can be reusing, etc., it's possible the implementation of this technique.

## EXPERIMENTAL PROCEDURE

### *Energy Window and Decay Constant*

Gamma scanning of the fuel rods was used. At firs it must be decided if in the gamma measurements it's observed an individual peak coming from individual fission product decay or window energy is selected. The window energy is an energy interval where the decay coming from different fission products. A decay constant has to be associated to this window.

For determine the best option a sample of 90% enrichment was irradiated at the RA-6 reactor and the gamma activation was measured in a HPGe- 20% efficiency detector. The most important peak coming from the fission products corresponds to the $I^{134}$ isotope. For obtain an error below 1% was necessary to measure the sample for about 60 min. after a decay time of 95 min (Table 1). For a power density measurement 100 to 200 points has to be measured, then that times must be improved. Additionally when the time is running after the irradiation (decay time) the background influence become more important. That is the reason for imposing that a total measurement time for a power density must be lower than 24 hours. The conclusion is that is necessary to measure with the lowest decay time and minimise the measurement time. Different energy windows were evaluated and that between 600Kev and 1000Kev was selected. In Table 1 is showed the counts for this area and the measurements made for a 1.8% enrichment sample. In this experiment lower decay and measurement times were used. For 5 min. of measurement in the $I^{134}$ peak the error is about 10% but for the energy window is lower 1%. In the RA-8 the gamma activity is measured with a INa detector, best efficiency but poorer resolution than HPGe, then the comparatives advantages for using energy window are improved.

| Enrichment | Decay Time | Measurement Time | $^{134}I$ | 600 to 1000 KeV |
|---|---|---|---|---|
| **90 %** | 95 min. | 60 min. | 29377 ± 229 | 395000 |
| **1.8 %** | 30 min. | 5 min. | 263 ± 27 | 27000 |

**Table 1 Comparison between $I^{134}$ area peak and energy window 600-1000 Kev for two samples.**

For determining the energy window were analysed the following requirements:

- Spectral region where the main gamma activity coming from fission products
- High contaje with low dead time during the measurement
- Low background and low residual activity by previous irradiation.

For correlate the activity at different times a decay constant was measured for the energy window using 1.8% - enrichment pellets and fuel rods in the system mounted for the measurements. After irradiation the energy window activity were measured at regular intervals. Curves as showed in Figure 1 were obtained. For minimising the error it was decided to obtain the time correction at any time interpolating between the anterior and posterior measured point.

### *Gamma Scanning System*

The gamma scanning system was designed under the following requirements:

- Axial scanning of a fuel rod in a time of about 30 min. optimising the relation measurement time – counts
- Ambient background – fuel rod activity relation that allows measuring at least six hours after the irradiation.
- Fuel rod position incertitude lowers than 1mm.
- Possibilities for making the system automatic controlled by an MCA card.

For the measurements was used a manual system and then was designed and build the automatic system. The scheme of the system is showed in Figure 2. The fuel rod is moving trough a rail system. The measurement zone is positioned over a colimator made of Pb. A Pb cover surround this zone for minimise the background.
A NaI-3” detector was used with the standard electronic associated and MCA card allowed make a program for the acquisition and will command the automatic system.

### *Power Density in cylindrical homogeneous core configuration*

Four irradiations were made in a cylindrical core configuration with 1300 fuel rods, 1.8% enrichment. In Figure 3 is showed the grid. It has in total, 3500 positions for fuel rods. The estimated reactor power was 1Watt and the irradiation time 20 minutes. The operation mode was in all cases by moderator height, in order to avoid control plates perturbation. The time from the shutdown to the beginning the gamma scanning was about 5 minutes. The total gamma scanning measurements for about 110 points take approximately 5 hours. As usual procedure one point of a fuel rod was used as monitor for assure the right utilisation of the decay curve. This point was measured in 45 minutes intervals and acceptable coincidence was found. Before each irradiation background was measured in each control rod.

Power density measured values were compared against calculated data and experimental values obtained by gold foil activation as it’s showed in Figure 4 by radial profile. The measurement was made in a radius and in each fuel rod three points were measured. For three fuel rods axial profile was obtained measuring in 2cm intervals.
The used codes for calculation were CONDOR[1] and CITVAP[2].

### *Power Density in heterogeneous cylindrical core configuration*

The measurement technique was used for a regular perturbed core configuration. A regular water hole was simulated extracting equispaced fuel rods as is showed in Figure 5. The measurement zone is indicated too. Radial profiles results can be observe in Figure 6, where are compared against calculated values. Fuel rods along a perturbed radius were measured and fuel rods surrounding the perturbation. In Figure 6 are showed the two values with different colours.

### *Radial Buckling and Radial Reflector Saving*

Radial values for buckling and reflector saving are presented in Table 2 . These values were obtained adjusting the experimental data to the theoretical expressions (Bessel Functions)

| Core Configuration | Experimento | Radial Buckling ($cm^{-2}$) | Reflector Saving(cm) |
|---|---|---|---|
| Homogeneous Core | Measurement 1 | 0.00549 ±0.00017 | 6.34 ±0.45 |
| | Measurement 2 | 0.00492 ±0.00008 | 8.17 ±0.25 |
| | Measurement 3 | 0.00521 ±0.00007 | 7.18 ±0.28 |
| | Measurement 4 | 0.00489 ±0.00009 | 8.27 ±0.29 |
| Heterogeneous Core | | 0.00482 ±0.00011 | 8.11 ±0.36 |

**Table 2: Radial Bucking and reflector saving**

### *Conclusions*

The power density measurement system by gamma scanning is in operation in the RA-8. That means:

- Design and construction of the measurement system
- Characterisation of the system colimator – detector
- Evaluation of the decay constant for the energy window
- Irradiation and wait time optimisation
- Comparison between experimental and calculated data

It's recommended by power density determination to use the parameters used in the above irradiation (Irradiation time, wait time, reactor period start up, power level) in order to minimise the errors.

It's useful to utilise fuel rods as "experimental fuel rods" so that these are only for power density measurements. The residual activity after 48 h. may be neglected. However it's recommended to measure residual activity in each fuel rod.

Some measurements axial profiles showed spatial distortion compared with the expected value. It's proposed an experiment with a dismountable fuel rod so each pellet can be measured separately. This experiment lets observe if the distortion coming from the zone of the fuel rod that is out of the measurement zone and make corrections to the system.

These experiments are the first systematic use of the critical facility RA-8. That means that organisation aspects were implemented for co-ordinate experimental and operation groups. The operation group gain experience in assembled and disassembled core configurations and in the operation in mode moderator – height.

***Acknowledgement***

Operation Group of RA-6 and RA-8 reactors
Maintenance Group of RA-6 – RA-8 reactors

*FIGURES*

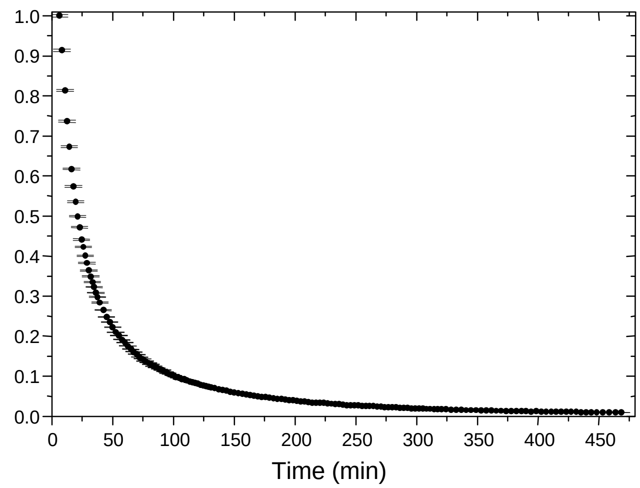


**Figure 1 Decay Curve corresponding to the 600-1000 Kev energy window**

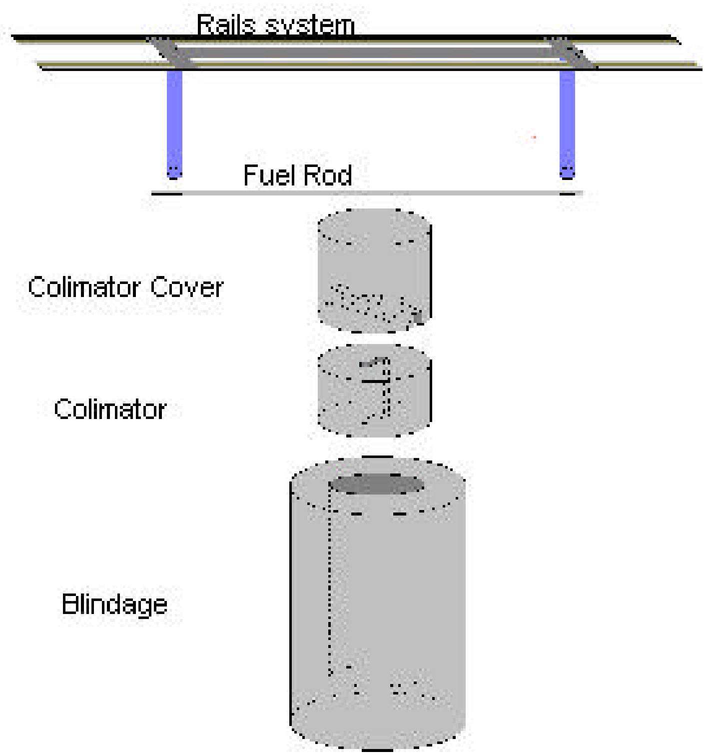


**Figure 2: Scheme of the measurement system**

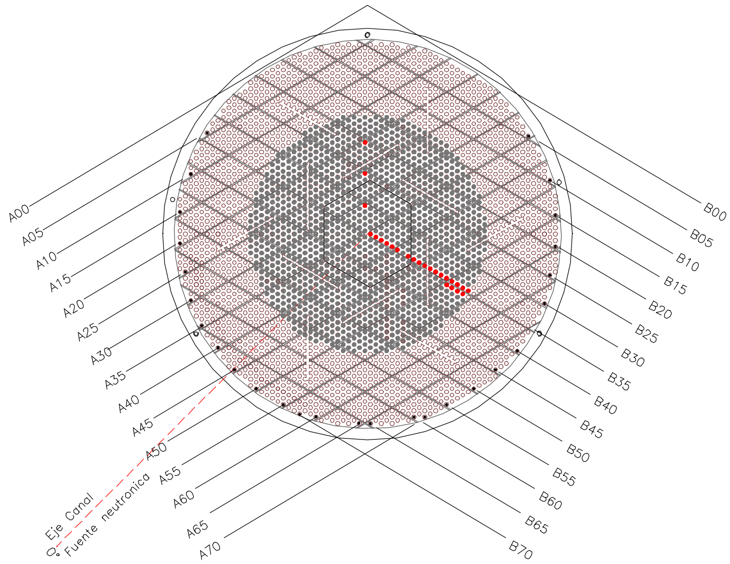


**Figure 3 Core grid and core configuration with 1300 fuel rods. Red points indicates the measured fuel rods.**

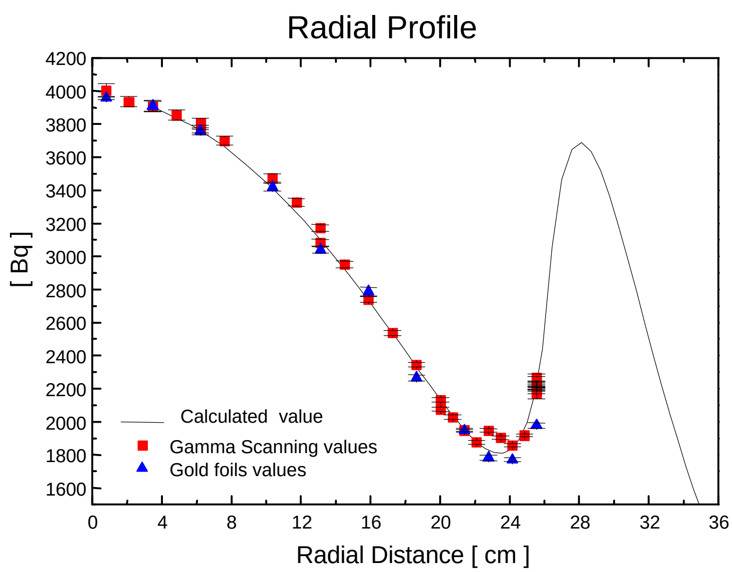


**Figure 4**: **Radial profile for homogeneous core configuration.**

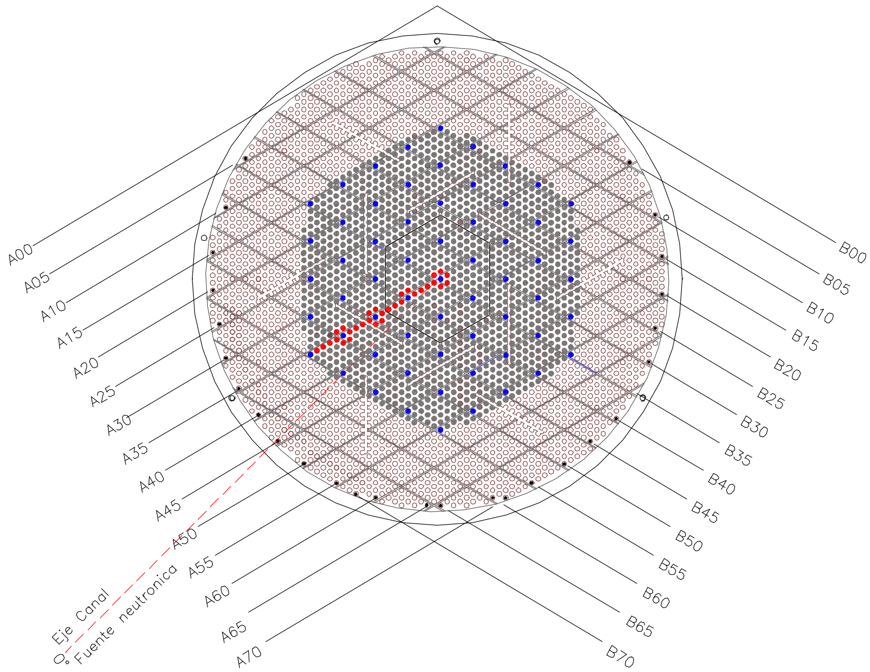


**Figure 5 Fuel rod configuration for the Heterogeneous. Blue circles indicates the water hole**

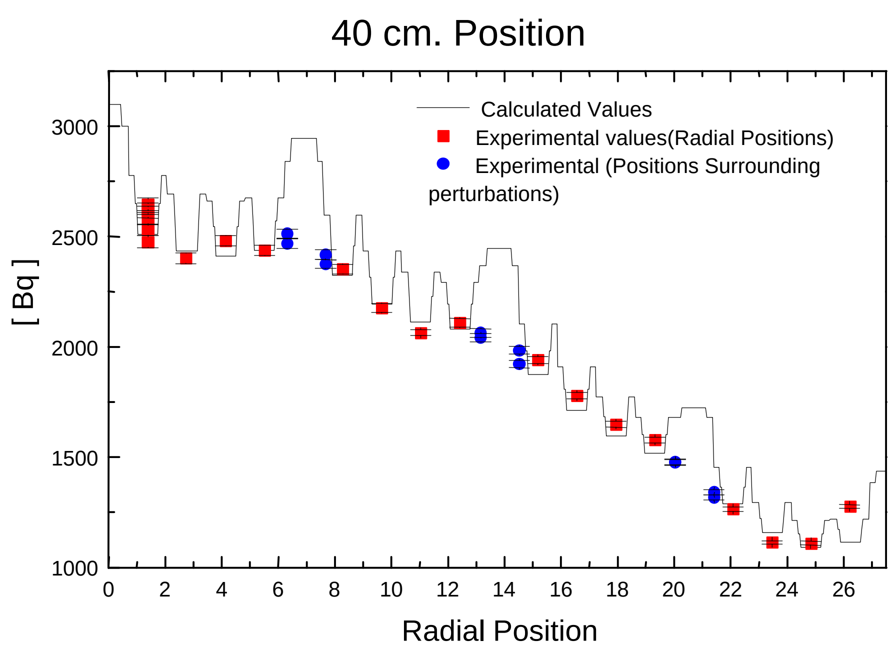


**Figure 6: Radial Profile in water hole perturbed core - Red Points indicate the radial measured points along the perturbation. Blue Points are the measured points surrounding the perturbation**

***REFERENCES***

1 – CONDOR 1.3. Manual del usuario, 1995
2 – Sistema RCP 1.0. Manual del usuario del Código CITVAP 3.1