Verification of Spent Fuel Assemblies (MTR) in Storage Facilities

Díaz, G.D.; Pardo, L.A., Ferro, J.M.; LLacer, C.D.;
Cristallini, O. and Renha Jr, G.

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VERIFICATION OF SPENT FUEL ASSEMBLIES (MTR) IN STORAGE FACILITIES

Diaz, G.D.[1]; Pardo, L.A.[1], Ferro, J.M.[1]; LLacer, C.D.[1]; Cristallini, O.[2] and Renha Jr, G.[2]

[1]Autoridad Regulatoria Nuclear, Buenos Aires, Argentina - ARN
[2]Brazilian-Argentine Agency for Accounting and Control of Nuclear Materials, Rio de Janeiro, Brazil – ABACC

ABSTRACT

The Central Store for Special Irradiated Fissionable Material (DCMFEI) is an old Argentine facility, designed to store LEU spent fuel assemblies discharged from the research reactors. Spent MTR fuels are normally stored inside concrete wells filled with water and closed with lead plugs on the top. The water is used as shielding and cooling media. Each well can accommodate up to two fuel assemblies.

The facility is under the regulatory control of the Argentine Nuclear Regulatory Authority (ARN). On the other hand, the Brazilian-Argentine Agency for Accounting and Control of Nuclear Material (ABACC) and the International Atomic Energy Agency (IAEA) carry out safeguards inspections to this facility since the beginning of the implementation of the Quadripartite Agreement.

The spent fuel assemblies are maintained under dual containment system by ABACC and IAEA, which requires the verification of fuel assemblies at research reactors and to maintain the continuity of knowledge during the transfers to the storage. The transfer campaign takes one week and it is carried out once per year. In order to reduce the inspection effort is proposed to remove all seals. In this case, the Safeguards Criteria for Storage Facilities request item counting and verification of the spent fuel for gross defect.

Nevertheless, this task present some problems because the spent fuels are not always visible, then item counting is difficult. On the other hand, the introduction of detectors inside the wells is not always possible due to the small space available and the high doses involved when the wells remain opened.

In order to overcame these difficulties ARN and ABACC have designed and tested a method to verify spent fuel assemblies using gamma spectrometry. Spectra were taken with a Cadmium Telluride detector (CZT). An ad hoc modified lead plug was used as detector collimator. The activity of each item was determined trough the main Cs-137 peak. Experience showed that it is possible to distinguish among one, two or no spent fuel assembly. Moreover, the activity measured on each well shows good correlation with the theoretical activity calculated considering burnup, decay time and shielding corrections.

INTRODUCTION

The Central Store for Special Irradiated Fissionable Material (DCMFEI) is an old Argentine facility, designed to store spent fuel assemblies discharged from the research reactors. Spent MTR fuels are normally stored inside concrete wells filled with demineralized water and closed with lead plugs on the top. The water is used as shielding and cooling media. Each well can accommodate up to two fuel assemblies. The storage has 198 wells distributed in 6 rows of 16 wells each, and 6 of 17 wells each.

The wells in each row are interconnected and therefore all the wells in a particular row have the same water level. A pump recirculates the water in each row individually, so water from different rows never mix.

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Nevertheless, this task presents some problems because the spent fuels are not always visible, making item counting quite difficult. On the other hand, the introduction of detectors inside the wells is not always possible due to the small space available and the high doses involved when the wells remain opened. There is also some risk of damaging the fuel assemblies when detectors are introduced into the wells.

In order to overcome these difficulties ARN and ABACC have designed and tested a method to verify spent fuel assemblies using gamma spectrometry. This method should allow item counting and verification for gross defect, ensuring at the same time low dose levels for the inspectors.

The objective of this work is the development of a method for item counting and gross defect verification in this facility, taking into account the limitations previously explained. Consequently, for gross verification it is enough to verify qualitatively the existence of the Cs-137 peak (662 keV) in the well's spectrum and for item counting, it is necessary to distinguish among wells containing none, one or two fuel assemblies.

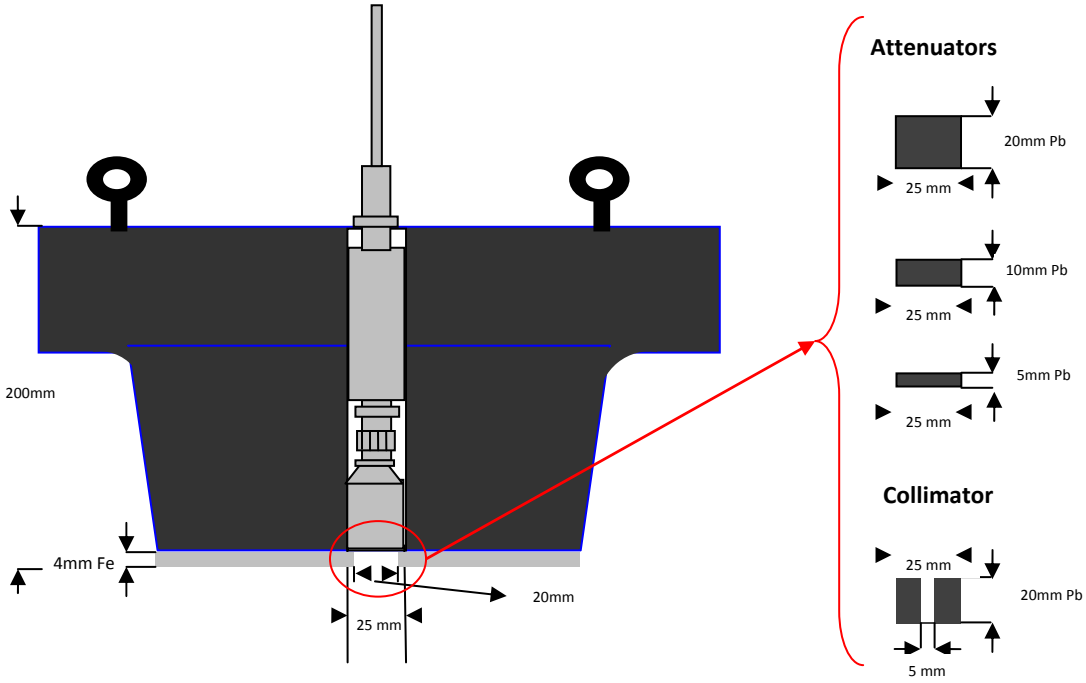
COLLIMATOR DESIGN

There had been several attempts to obtain the gamma spectra of the wells. The gamma spectra obtained with Sodium Iodide (NaI) and CZT detectors for closed wells show very few counts and do not give enough information to evaluate how many fuel assemblies are inside. In addition, when the measurement is carried out on a closed well it is not possible to ensure that the spectrum obtained is due only to the well. On the other hand, working with open wells involves high doses, especially when the well contains two fuel assemblies, because of the small thickness of water shielding. Even though a lead plate was used as a shielding over the opened well, the resulting dose values remained high and the obtained spectrum presented contributions from the neighbor wells. Besides these high doses, the introduction of a detector inside the well is not convenient due to the small space available and the risk of damage to the fuel assembly.

In order to overcome these difficulties ARN and ABACC designed a collimator. For this purpose a lead plug was modified as shown in Figure 1. As it was one of the plugs of the facility it fits perfectly into the top of the well. The lead plug has a 4mm Fe cover at its bottom. Two eyebolts were added to enable the crane to lift the plug. A hole of 25 mm in diameter was made in the center of the lead zone. This hole is large enough to contain the Cadmium Telluride detector inside. In the Fe plate the diameter of the hole

is reduced to 20 mm. Thus, the detector placed inside the collimator can not fall. The detector has a total diameter of 24 mm, but the crystal only occupies an area of 10x10 mm in the center, so the plate of Fe does not contribute to attenuation. This design ensures that the spectrum obtained is due only to the well that is being measured, without introducing a detector in it.

Discs of 25 mm in diameter and different thickness were used as attenuators in different preliminary measurements. A lead collimator with a diameter of 5 mm was used in some measurements.



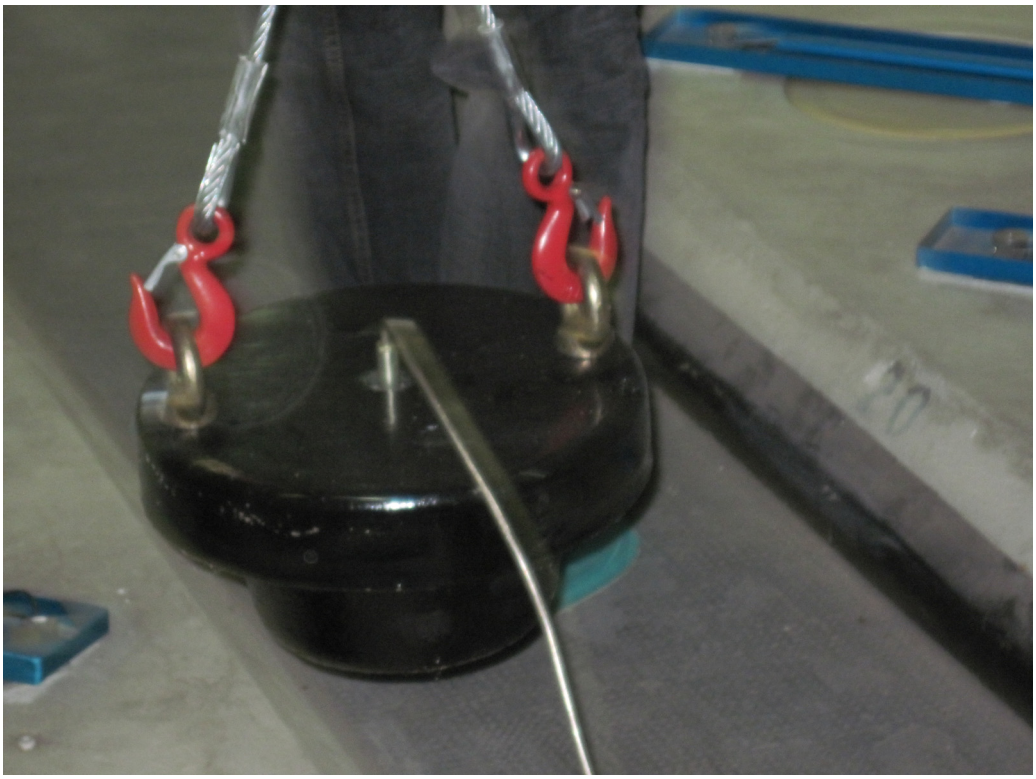


Figure 1: Collimator

FIELD MEASUREMENTS

One of the problems in the facility is the high doses involved when wells remain open. The method developed by ARN and ABACC for acquiring the spectra helps to avoid unnecessary exposure to high doses for inspectors.

The measurement points were selected considering two criteria. Firstly, a dosemetric evaluation of the facility was made using handheld radiation detectors in order to characterize the radiation field for selecting the measurements points: wells with high, medium and low background. And secondly, the U mass declared: wells with regular fuel assemblies (~1350 grams) and control fuel assemblies (~975 grams).

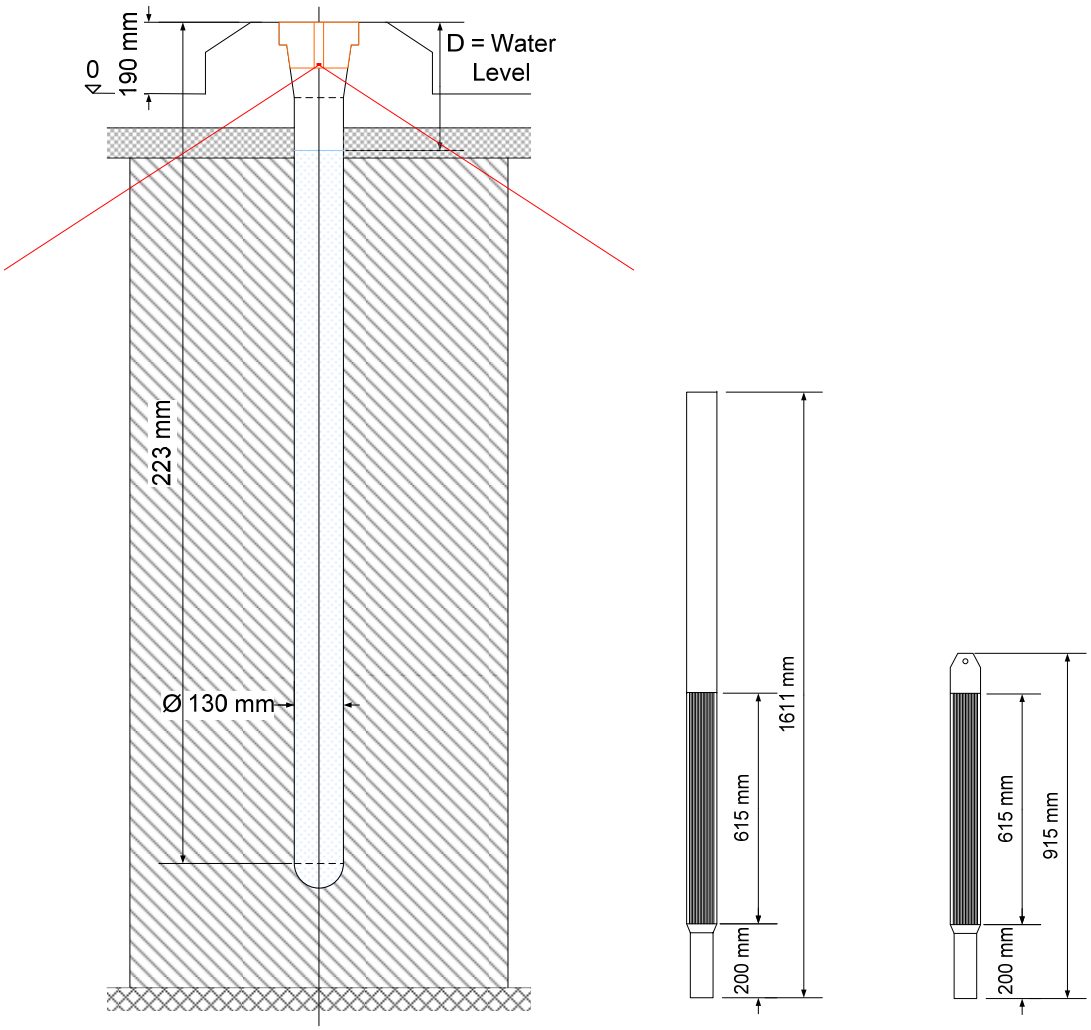


Figure 2: well profile, control and regular fuel assemblies schemes.

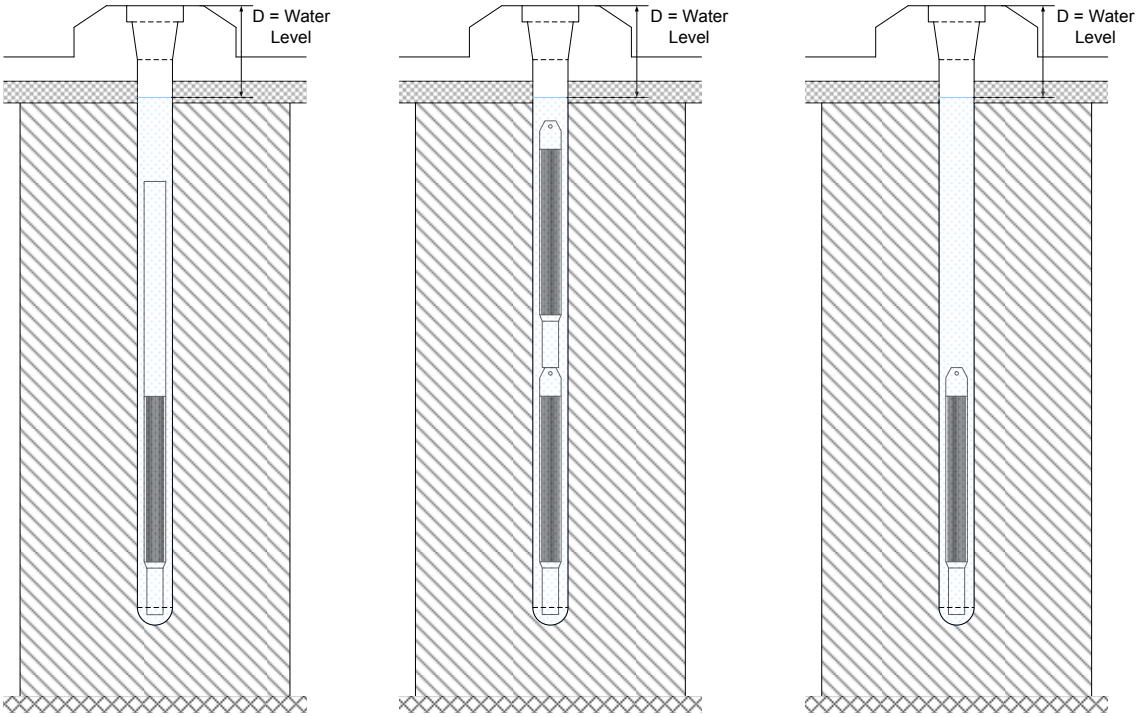


Figure 3: schematic for the nuclear material distribution inside the wells

The procedure to take the spectra is the following. Before opening the well, the detector was placed inside the collimator. Then, the crane operator removed the plug from the well and replaced it with the collimator containing the CZT detector. During this operation, all staff was required to move behind a lead wall by the radiation protection procedure. Once the collimator plug was properly seated, the personnel were allowed to leave the positions behind the lead shielding.

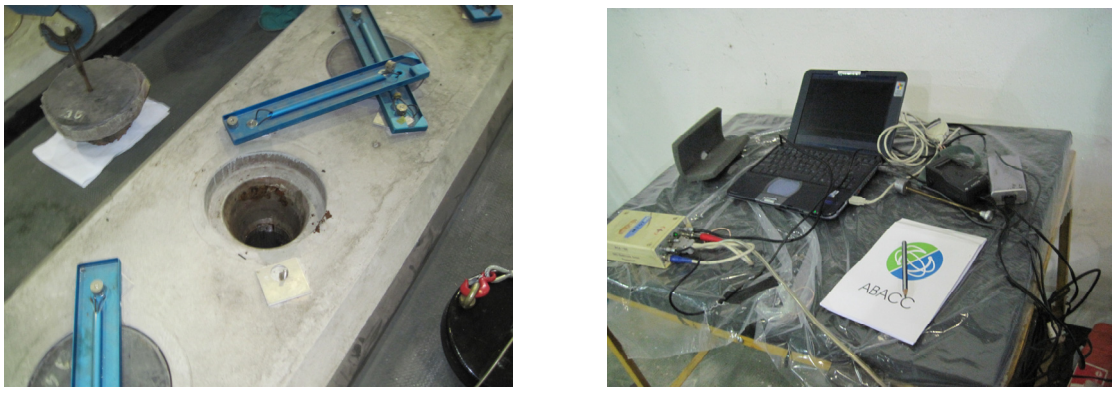


Figure 4: (a) Open well. (b) Equipment used for Gamma Spectra Acquisition.

The CZT detector was connected to the mini multichannel analyzer (MMCA) GBS MCA-166 by a 20 meters long cable. The MMCA and the notebook were located in a safe place, away from the well. The detector used was a Ritec Cadmium Zink Telluride CZT500(S) with a crystal of 10×10×5 mm and a guaranteed resolution (FWHM) of less

than 18KeV at 662 keV. The gamma spectrum was acquired using the program WinSpec v1.03.0001, with 512 channels configuration. A region of interest of 33 channels (85.2 keV) around the 662.7 keV peak of Cs-137 was considered. After the acquisition, the collimator was removed and replaced by the original plug. At this moment the staff accomplished with the radiation protection procedures. During the replacement of the plugs, the dose was measured at the personnel location, behind the lead wall. No significant variation from dose background was observed.

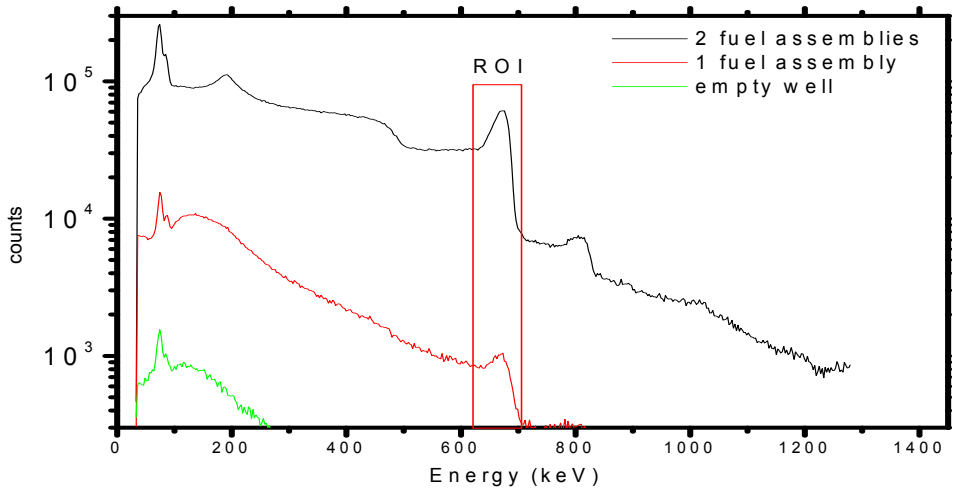


Figure 5: Spectra from a well containing 2 fuel assemblies, a well containing one fuel assembly, and an empty well.

One of the problems observed was the contribution to the background of water contaminated with fission products, particularly Cs-137 in some rows. There is also some remaining contamination on the walls of the well. This contamination takes place when a damaged fuel assembly is stored in a well. All the wells in a particular row are interconnected and the water is periodically recirculated and passed through ion exchange resins. The water contamination in a particular row is uniform, so the background is the same for all well in that row. The water of the different rows does not mix. Taking into account that the level of contamination depends on the fission products concentration and the level of water, the background of each row differs from each others. The last well of each row has no fuel assemblies and is considered as a "control well". The control well is used to test the quality of water and to determine the background spectrum of the row. The gamma spectrum of the control well was acquired and applied as background for the corresponding row. The water level in the control well was also measured for shielding correction calculations.

DATA EVALUATION AND METHOD PROPOSAL

The method proposed is the following. Acquire the spectrum from the selected well and determine the numbers of counts in the region of interest around the Cs-137 peak (W). In order to obtain a background acquire the control well spectrum and determine the counts number in the ROI (B). Then, calculate A=W-B. Finally, compare A with the Table 1 to determine if the well contains one, two or none fuel assemblies. Figure 6 shows a flowchart of the method.

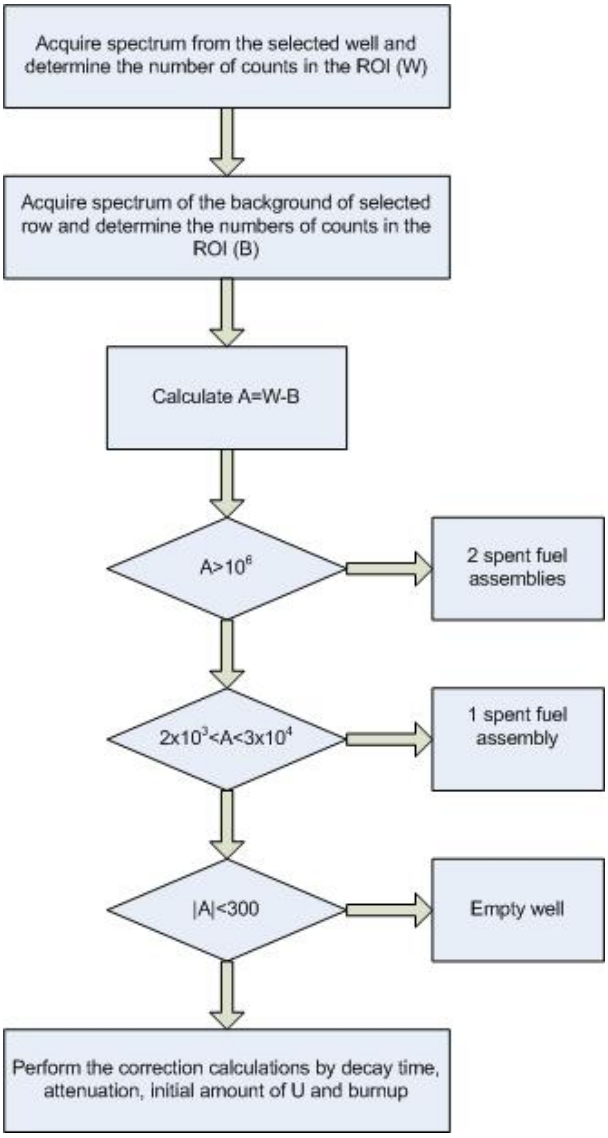


Figure 6: Flowchart of the proposed method.

Although the acquiring spectrum procedure allows avoiding unnecessary exposure to high doses, and ensures that the spectrum belongs only to the contents of the measured well, the spectra taken from different rows are not comparable, because each row has a different background and water level and, therefore, different radiation attenuation. A simple comparison of spectra of different rows would not distinguish between a well with a very decayed fuel assembly and an empty well with a very high background.

To properly evaluate the contents of a well it is necessary to make corrections to the measured activity. Corrections to be considered are the attenuation due to water and lead, the decay time and the mass of Cs-137, which is proportional to the burnup and the initial amount of uranium [2]. When the same detector is used for all measurements it is not necessary to make any correction for detector efficiency, while using always the same collimator permits to ignore the attenuation due to lead thickness. The solid angle correction might even be neglected by assuming that the fuel assemblies are always in the same position, but the other corrections cannot be neglected. For attenuation correction it is only necessary to measure the water level, but the corrections for decay

time and burnup require data that are only available in the reactor records and not in the storage facility. To avoid these inconveniences it is proposed to subtract the background from each spectrum. This requires taking a spectrum of an empty well in the same row and subtracting it from the selected well measurement. The background on each row with an acquisition time of 300 seconds, varies from 10^2 to 2.5 x 10^3. Consequently, we consider the number of counts in the ROI in the well's gamma spectrum and subtract the background in the same ROI from this value.

To standardize the method we fixed the acquisition time in 300 seconds. Typical values obtained are shown in the Table 1.

Material Distribution	**Measured (counts)**	**Measured minus background in the control well (counts)**
2 fuel assemblies	$1.2x10^6$	$1.2x10^6$
regular fuel assembly, control fuel assembly	$3x10^3$ to $3x10^4$	2 $x10^3$ to 2.9 $x10^4$
Empty well	Up to $2.5x10^3$	-300 to 300

Table 1. Typical values obtained and the correction subtracting the background.

The method allows us to discriminate even between a well with a very decayed fuel assembly and an empty well with high background. In case of an abnormal result, the corrections mentioned above can always be performed.

CONCLUSIONS

This experience showed that it is possible to distinguish among wells containing one, two or no spent fuel assembly. To achieve this goal it is necessary to acquire the spectra of the selected well and the reference empty well of the same row (for background) and determinate the number of counts in the region of interest in each case. After this, we should subtract the background to obtain the absolute activity. Then, by using Table 1 it is possible to conclude if there are two, one or none fuel assemblies in the well.

The different Cs-137 activities observed in some wells, even when they do not compromise the resolution required for this test, can be explained by the attenuation due to the water, the decay time and the particular amount of Cs-137 in the contained fuel assemblies.

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