Spent Fuel Attribute Tester Realisation and Application

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Abstract. Presently 19-element natural uranium fuel bundles are used in 220 MW(e) Indian PHWRs. The core average design discharge burn-up for these bundles is 7000 $MW\cdot d\cdot Te^{-1}U$ and maximum burn-up for assembly goes upto of 15000 $MW\cdot d\cdot Te^{-1}U$. Use of fuel materials like MOX, Thorium, slightly enriched uranium etc in place of natural uranium in 19-element fuel bundles, in 220 MW(e) PHWRs is being investigated to achieve higher burn-ups. The maximum burn-up investigated with these bundles is 30000 $MW\cdot d\cdot Te^{-1}U$. In PHWR fuel elements no plenum space is available and the cladding is of collapsible type. Studies have been carried out for different fuel element target burn-ups with different alternative concepts. Modification in pellet shape and pellet parameters are considered. These studies for the PHWR fuel elements/assemblies have been elaborated in this paper.

1. INTRODUCTION

The most widespread method for verifying the presence of the fissile material is the viewing of Cherenkov light. However it cannot be applied if the water is not clean enough and it doesn't identify the source of radiation. A more sophisticated method of verification is the SFAT where a medium resolution gamma detector identifies the source of radiation through a collimator tube. Such a device was designed and built in our Institute and it was tested in a series of verification problems.

2. SETTING UP THE DEVICE

Our apparatus consists of a detector house, which provides place for a 500 mm^3 CZT detector and a lead collimator shielding the detector from side directions and a set of closed end (watertight) steel collimator tubes of 1 m length and 50 mm diameter, containing air (Fig. 2.1). The collimation itself is provided by the surrounding water.

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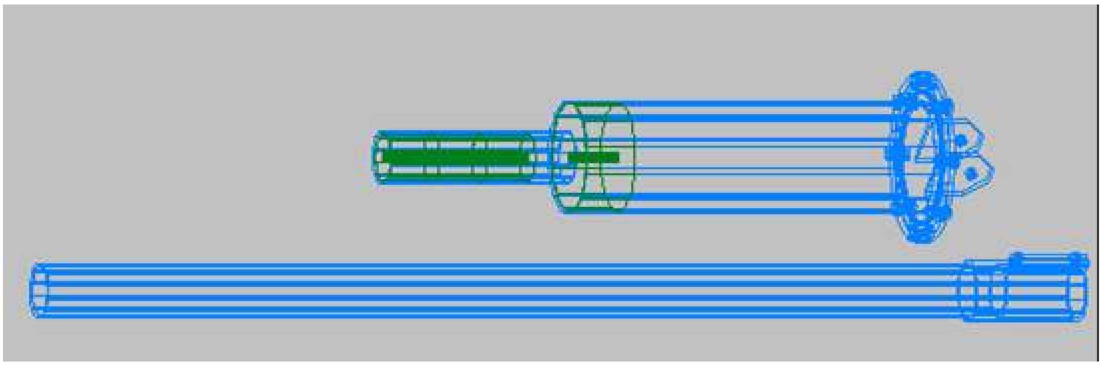

FIG. 2.1. Detector house and collimator tubes. The thick green line shows the volume inside the lead collimator.

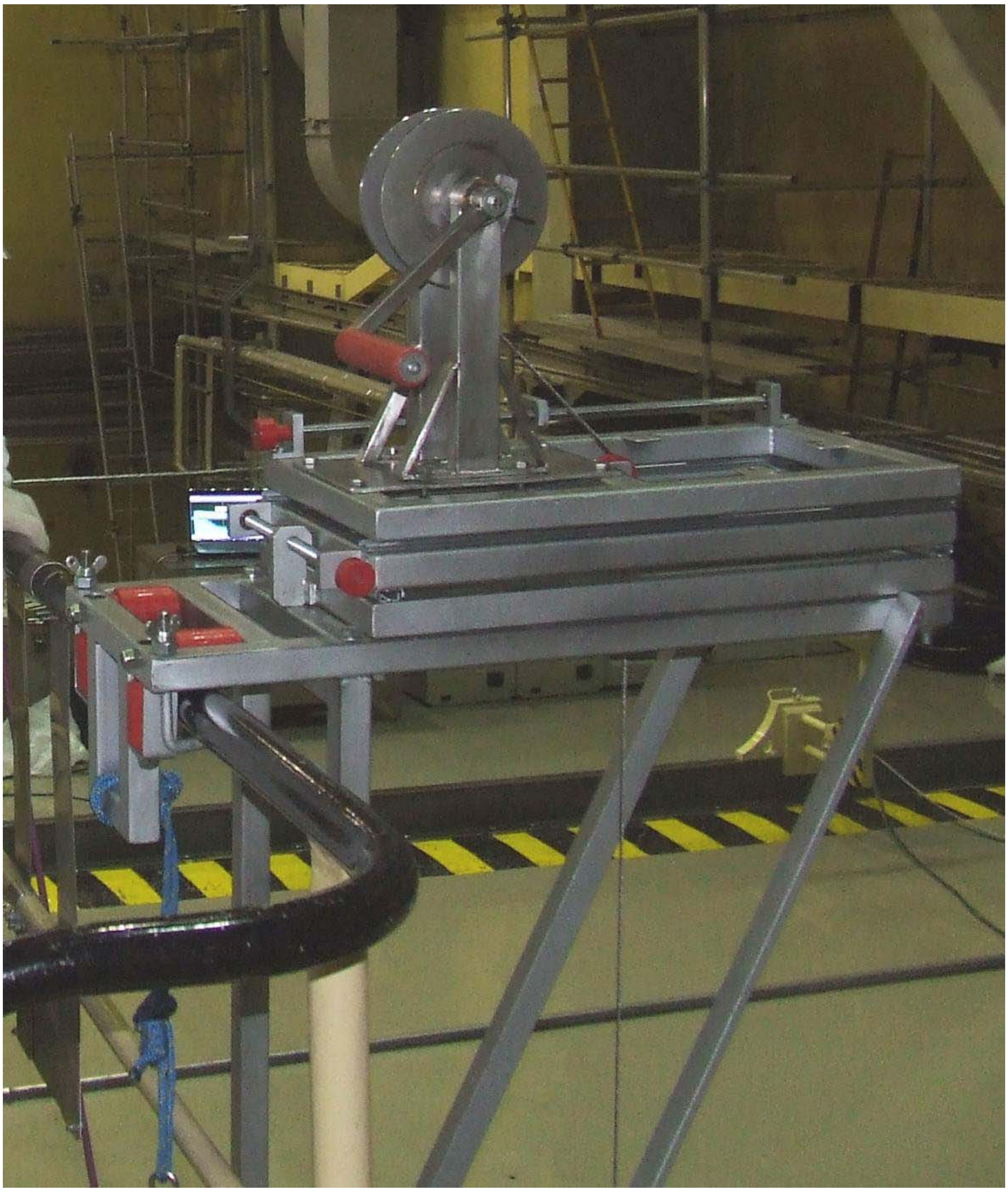

FIG. 2.2. The stand with the winch.

The number of the tubes applied depends on the task. The maximum number of 6–8 tubes can be applied when the assemblies are stored in two levels and the assemblies in the lower level have to be verified. In most cases use of 2–4 collimator tubes is suitable while for assemblies cooled for a long time, use of 1 or 2 tubes provides good results. A part of the system is a stand for holding and positioning the detector and collimator tube system, which can be installed on the railings of the refuelling machine, or on a service bridge (Fig. 2.2). By the aid of the stand the mounted system can be moved above the assembly to be examined and sunk under water by the winch. A rough positioning can be done by moving the refuelling machine or substituting bridge, and by shifting the stand perpendicularly to the railing by the aid of rollers. Fine positioning goes by screws on the stand in two directions. The system can be mounted up to 4 collimator tubes laid just on the platform in advance and can be let down as a whole to the pond, while in the case of a longer collimator the individual tubes can be joined step by step and let the mounted part moving down. Detector house is connected at last.

For performing verification, the lower end of the collimator tube enters into the headpiece of an assembly until it neither impacts on the upper grid nor leans against the interior of assembly head, ensuring that the spent fuel and the detector are in line of sight through the collimator tube (Fig. 2.3). Positioning is supported by a TV camera and monitor as a surveying system. A camera mounted to the detector house may promote a more compact design.

FIG. 2.3. End of the collimator tube above the fuel assembly.

Although it was developed for verifying VVER-440 assemblies, and also the positioning stand was designed to the refuelling machine established in the Paks NPP, the system can be used, with a minor change and transformation of the stand, in other plants as well.

The signal from the detector comes to the mini MCA analyser through a watertight insulated cable controlled by a laptop computer.

3. APPLICATIONS

Assemblies and other objects stored in the spent fuel pond were examined by the SFAT. The spent fuel assemblies produce a 662 keV peak from the fission product Cs-137 as well as 1173 keV and 1332 keV peaks from Co-60, an activation product originating from the headpiece of the assemblies. If the cooling time of the assembly is less then 6 years, the 794 keV peak of the Cs-134 (2 y half life) can be observed as well. However, for very fresh assemblies (CT<1 y) the Compton-tail of the peaks of Zr-95 (half-life 64 d) and other short-lived activation products can cover the Cs peaks (Fig. 2.4).

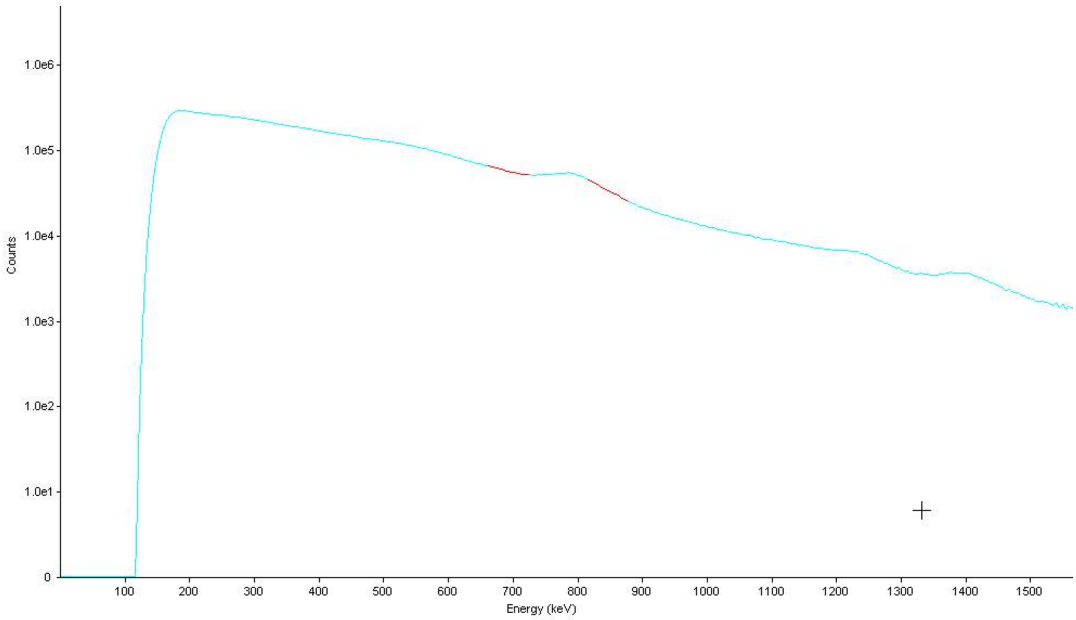

FIG.2.4. Spectrum from the spent fuel assembly with CT=8 months.

With medium cooling times both Cs-134 and Cs-137 (Figs 2.5–2.6) peaks can be clearly observed. As the intensity of the Cs-134 peaks is proportional to the square of the burn-up, so the burn-up can be assessed from the extrapolated initial value of the intensity.

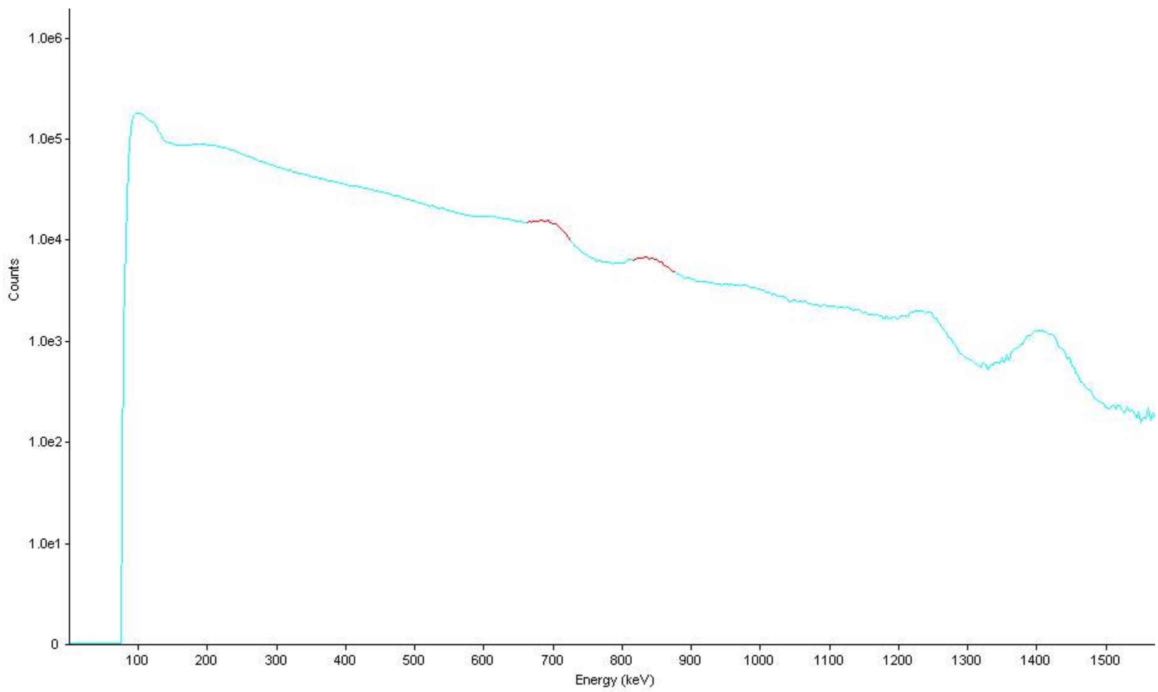

FIG. 2.5. Spectrum from the spent fuel assembly with CT=2.7 y, BU=22.6 GW·d·t^{-1}U.

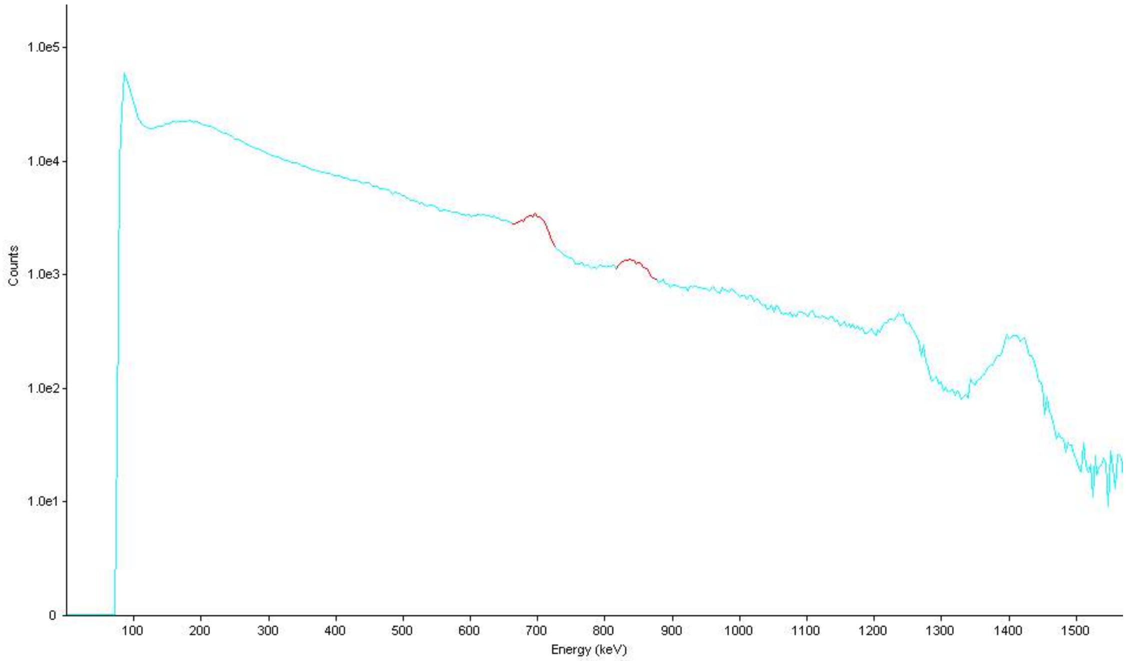

FIG. 2.6. Spectrum from the spent fuel assembly with CT=3.7 y, BU=41 GW·d·t^{-1}U.

Due to the 30 y half-life of Cs-137, the 662 keV peak can even be revealed after an extreme long ((>14 y) cooling time (Fig. 2.7) or very low burn-up (order of a few GW·d·t^{-1}U) up to 6–7 y cooling time, when the Cherenkov viewing device (ICVD) is not suitable for verification. The measuring time needed for a relyable spectrum lies between 300–1200 s.

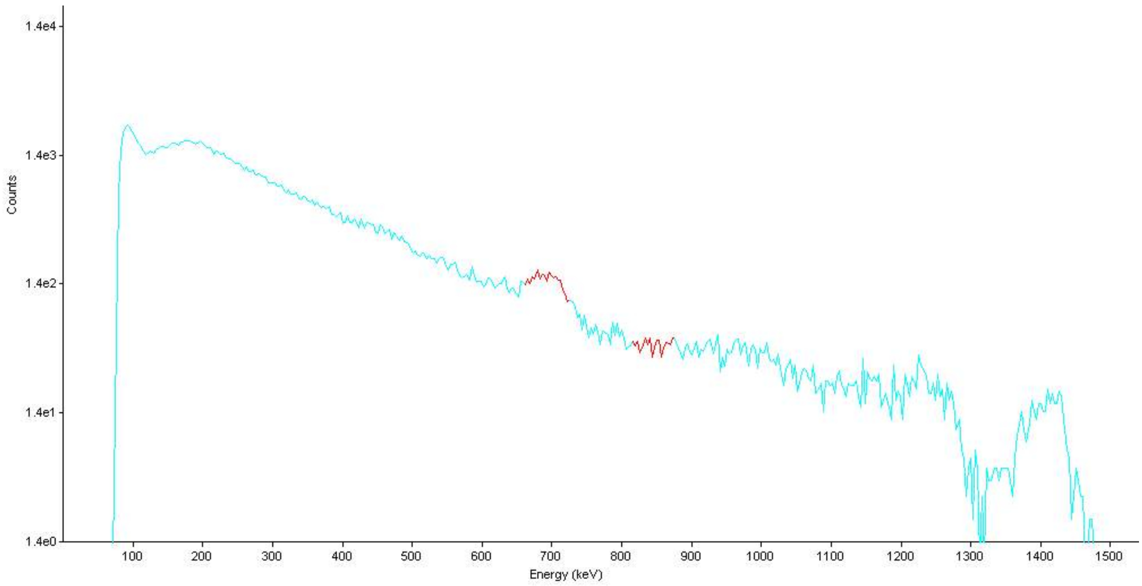

FIG. 2.7. Spectrum from the spent fuel assembly with CT >14 y.

With the same method, we verified the fissile material content of those canisters which contained damaged spent fuel originating from the 2004 incident, and demonstrated the absence of the fissile material in canisters containing only the head and foot parts of the assemblies. In addition we demonstrated the absence of fissile material in the containers of irradiated Co-60 sources.

4. SUMMARY

SFAT is useful, whereas acknowledging its limits, for verifying fissile material in fuel assemblies, containers and other objects. Detection of undeclared irradiation is also possible, even in the presence of Co-60. Necessary measurement time is 300–1200 s pro assembly/object, depending on its parameters.

Even if it cannot be a rival of ICVD in comfortable employment and easy evaluation, in cases where the water in the pond is of too high level or bad quality, burn-up is very low or cooling time is too long, as well as if the task is to verify an assembly in the lower rack, it may be a good alternative for substituting ICVD.

REFERENCES

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