VERIFICATION OF CORE FUEL IRRADIATION HISTORIES IN A LIGHT WATER REACTOR

E.Gryntakis, W.Alston, B.Torres Barrios, Y.Kulikov, G.Tributsch
International Atomic Energy Agency - IAEA

H. Menlove, T.D. Reilly , R. Siebelist
Los Alamos National Laboratory- LA

G. Almeida, L. Rovere, O. Calzetta Larrieu
Brazilian-Argentine Agency for Accounting
and Control of Nuclear Material- ABACC

I. Abstract

To date no technique has been available to the Agency to perform measurements to confirm the irradiation history of individual core fuel elements in order to resolve anomalies resulting from, for example, surveillance failure. At a series of measurements using the fork detector in an LWR in one member state, it was possible for the Agency, with the cooperation of the member state and the US Support Programme, to satisfactorily confirm the irradiation histories of the reactor core fuel from different core loadings. The paper describes the techniques used and the results obtained in the measurements of fuel with different irradiation histories.

II. Introduction

In LWR inconclusive containment results or surveillance failures during reactor opening results in anomalies, the resolution of which require re-verification of both spent and core fuel assemblies. One diversion scenario is, for example, the replacement of irradiated fuel by fresh fuel with falsified ID numbers. For such an also be measured through the ionization of helium gas in the tubes. The fission chambers also measure (apart from the fission fragments) the gamma rays (energies up to a few MeV) and the alpha particles (energies up to about 5 MeV). Theoretically, by adjusting the low level discriminator in the pre-amplifier to about 6-10 MeV, it should be possible to separate the neutron spectrum from the gamma and alpha spectra.

In practice, in the measurements of fuel assemblies with short cooling time, the pile-up of gamma rays results in the overlap of the spectra so that gamma rays will be counted as neutrons. This is probably the reason why recent tests performed in one member state (the low level discriminator had an adjustment of about 6-10 MeV) gave a much higher than expected neutron yield. The expected gamma and neutron rates in spent fuel assemblies were calculated at Los Alamos by the burnup code ORIGIN-2. For short cooling time (less than about two months) there is no difference in the gamma yield for fuel with 1, 2, 3 or 4 cycles of irradiation because the gamma yield is dominated by the rays of the short half-life isotopes (Ru-103, Ba-140, Zr-95 ,Nb-95 with T1/2 39.4 d, 12.8 d, 64 d, 35 d, respectively) produced during the last few months of irradiation in the core. After several years cooling time Cs-137 (T1/2= 30.2 years) is the dominant gamma isotope and the burnup is almost directly proportional to the gamma count rate.

In PWR fuel assemblies with 30 days cooling time, the dominant neutron emitter is the Cm-242(T1/2=163d) and the neutron ratio 2nd-cycle/1st-cycle is about 15, 3rd-cycle/1st-cycle about 66 and 3rd-cycle/2nd cycle about 4. After 3 years cooling time the neutron yield is dominated by Cm-244 (T1/2 = 18.1y) not be counted. This is partly compensated through the increase in the efficiency of the detector. For increasing the efficiency, all cadmium absorbers used during the normal operation of the fork detector were removed. This increased the neutron count rate by a factor of about 4.

The ratio of the neutron count rate (A/B) for the two sets of fission chambers should always stay constant, so that if a difference was found in the measurements of fuel with very short cooling time, it would be an indication that the gamma rays have had an influence on the neutron counts. In this case, because corrections are difficult, the best approach would be to repeat, if possible, the measurements a few weeks later.

The tests performed can be summarized as follows:

(a) Assembly of the fork detector in the original configuration of the fission chambers (connection of the two fission chamber tubes inside the polyethylene holes in one set and the two others outside polyethylene in the other set) and connection of the two ion chamber tubes (one set, one possible connection).

(b) Test in the air of the fission chambers with a Cf-252 source and of the ion chambers with a Am-241 source.

(c) Removal of all Cd-absorbers and comparison of the new measured neutron rate with the previous one (increase by a factor of about 4).

(d) Change the configuration of the fission chambers sets (two similar sets with connection of the one fission chamber tube inside the polyethylene hole with the opposite fission chamber tube outside the polyethylene).

with very low burnup (556 and 5885 Mwd/t U, respectively) were also measured for comparison.

The main part of the measúrements included 17 recently discharged fuel assemblies of three different cycle strata:

Stratum D : 2 assemblies with 4 irradiation cycles, burnup about 31 MWd/t U and enrichment in U-235 2.61%

Stratum E : 9 assemblies with 3 irradiation cycles, burnup about 23 MWd/t U and enrichment in U-235 2.1%

Stratum F : 6 assemblies with 2 irradiation cycles, burnup about 17 MWd/t U and enrichment in U-235 3.41 %

The older fuel assemblies gave the same A/B neutron ratio of 2.0 within experimental uncertainties. The A/B ratio for hot fuel assemblies was found to be about 2.4. This difference is thought not to be due to the gamma pileup but probably to a gain reduction because of the high ionization current in the fission chambers. To correct this effect the measured A+B neutron rate was increasedd by 20%. The corrected neutron rate for the hot fuel is therefore 1.2x(A+B).

The results of the measurements are summarized in Table I. Channels A and B were added together to correct geometrical differences and to improve the counting statistics.

Fig. 1 shows the (A+B) neutrons rate versus the gamma rate . From these figure the different irradiation histories in the strata D, E and F can be readily distinguished.

VII References

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Fig.1 Neutron Rate VS Gamma Rate