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Validation of CMS/SNF Calculations Against Preliminary CLAB Decay Heat Measurements

Sigurd Børresen¹, Tamer Bahadir², Magnus Kruners³¹Studsvik Scandpower AS, P.O.Box. 15, NO-2027, Kjeller, Norway, sigurd.borresen@studsvik.no²Studsvik Scandpower Inc, 1087 Beacon Str., Suite 301, Newton, MA 02159, USA, tamer@soa.com³Studsvik Scandpower AB, Hantverkargatan 2A, SE-72212 Västerås, Sweden, magnus.kruners@studsvik.se

INTRODUCTION

A comparison of calculated and measured decay heat for 16 BWR fuel assemblies from the CLAB interim fuel storage facility in Sweden is presented. The calculations were carried out by Studsvik Scandpower in cooperation with the Swedish nuclear utilities. The calculations are based on the isotopic summation method using nodal, isotopic concentrations from standard 2-D/3-D CASMO/SIMULATE core-tracking calculations and the new spent fuel module, SNF, of the CMS system [1]. The purpose of the work is to evaluate the capability of this analytical method to predict the decay heat of heterogeneous, BWR spent fuel assemblies. A corresponding evaluation of PWR fuel assemblies will be added later as experimental data becomes available.

The experimental data utilized in this project is provided by Svensk Kärnbränslehantering AB (SKB).

DECAY HEAT MEASUREMENTS

An extensive program of calorimetric decay heat measurements of BWR and PWR spent fuel assemblies from Swedish reactors is presently carried out by SKB in the CLAB intermediate fuel storage facility [2]. The calorimeter has been electrically calibrated and corrections are applied for the fraction of the released gamma heat absorbed outside of the calorimeter. The experimental data used in this benchmark are, according to SKB, still preliminary.

A total of 16 BWR fuel assemblies with burnups from about 20 to 46 GWd/t and well characterized irradiation histories were selected for this benchmark. The assembly designs include 8x8 and 9x9 lattices, as well as the more heterogeneous SVEA-64 and SVEA-100 lattices. The cooling times were in the range from 10 to 15 years.

METHOD OF CALCULATION

The SNF calculation method is based on utilizing the 2-D lattice physics code CASMO-4 [3], alternatively HELIOS [4], for performing the isotopic depletion/build-up calculations and 3-D nodal depletion/power density histories from 3-D core follow calculations using SIMULATE-3 [5], or equivalent. The required 2-D/3-D

calculations are done as part of normal in-core fuel management (ICFM). In this case, the CASMO-4 calculations were performed with the latest version of the JEF-2.2 library in order to generate isotopic concentrations for all isotopes included in the SNF model. The 3-D nodal power histories were supplied by the various Swedish utilities whose fuel is part of this benchmark. The SNF program evaluates the EOL, nodal isotopic concentrations by integrating the isotopic chains over the 3-D nodal power histories, usually consisting of several hundred time-steps. The final decay heat is obtained by solving the isotopic decay chains and applying energy release data from the ENDF/B-VI Decay Data file.

RESULTS

A plot of the calculated decay heat of each of the 16 BWR assemblies vs. the corresponding measured values is shown in Fig.1. As may be seen, the agreement between calculation and measurement is good, although a slight, systematic underprediction may be noticed.

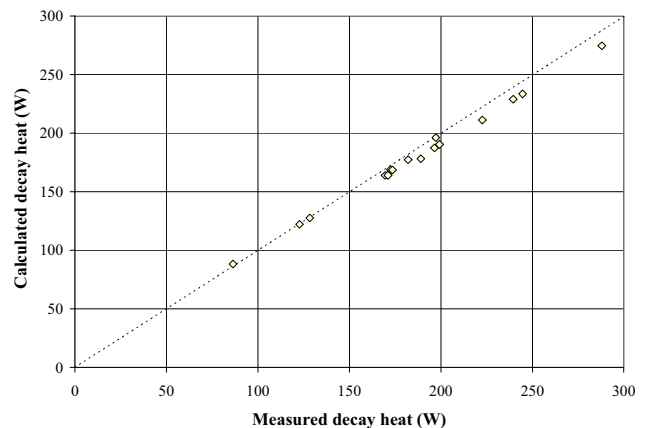


Fig. 1. Calculated decay heat vs. measured decay heat of 16 BWR spent fuel assemblies.

The average calculation-to-experiment ratios (C/E) for each of the four fuel assembly designs of this benchmark and for the total are shown in Table I. The average C/E ratio is 0.970 ± 0.022 and there is no clear trend among the different assembly types, except for the slightly lower than average value for the 9x9 lattices. It may be noticed that the SVEA water-cross lattices are

computed with the same accuracy as the less heterogeneous lattices.

TABLE I. Average burnup and C/E-ratio per fuel assembly type and total.

Assembly type (# assemblies)	Aver. Burnup (MWd/t)	C/E aver. And std. deviation
8x8 w/1 or 2 waterholes (5)	28,826	0.982 ± 0.033
9x9 w/5 waterholes (3)	35,587	0.953 ± 0.004
SVEA64 w/ watercross (4)	35,883	0.963 ± 0.009
SVEA100 w/ watercross (4)	35,188	0.976 ± 0.016
Total (16)	33,448	0.970 ± 0.022

The slight, systematic underprediction of the decay heat of this benchmark may be due to either a bias in the measurements, keeping in mind that the experimental results are preliminary, or to calculation uncertainties. Due to the quite long cooling times of the stored assemblies the relative decay heat of the actinides (e.g. ^{238}Pu , ^{241}Am and ^{244}Cm) is significant and of the order of 20-30%. The calculated concentrations of these isotopes, especially that of ^{244}Cm , depend strongly on the given fuel assembly burnups. Burnup uncertainties thus contribute to uncertainties in the calculated heat. Also, some under-prediction of ^{244}Cm and maybe also ^{238}Pu , seem to be a common problem in isotopic measurement comparisons with several codes and nuclear data libraries [1], [6]. This may be the case in these calculations also.

However, consistent, good results were obtained for the different lattice designs and operating histories and it is concluded that the CMS/SNF approach is well suited for calculation of the decay heat of heterogeneous BWR fuel assemblies that have been stored for 10-15 years.

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