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An International Intercomparison of Results for the Reactivity Effect of Steam Ingress into the Core of a Gas-Cooled Fast Reactor

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Abstract

Steam ingress into a GCFR core may lead to reactivity effects which are undesirable from the point of view of reactor safety. The amount of reactivity increase caused by a certain steam concentration is usually subject to some uncertainty as has become evident by occasional comparisons between different laboratories for specific examples. The aim of the present intercomparison is to determine and compare on an international basis the influence of different nuclear data sets and various calculational methods on the predicted steam ingress reactivity by means of simple fundamental mode neutronic calculations, thus avoiding any ambiguity and complexity with respect to the geometric modelling of a given experimental or design arrangement. The material compositions chosen as some kind of benchmarks differ in: plutonium isotopic composition, fission product concentration, absorber material concentration, fuel temperature and size of the core. From previous experience these parameters are expected to have a significant influence on the calculated steam density reactivity coefficient. Other probably less important design parameters have not been varied in the present study.

The analysis of the results obtained from laboratories in France (Cadarache), Germany (KfK), Japan (JAERI), Switzerland (EIR Würenlingen), and USA (ANL) shows that there still exist considerable deviations in the predicted steam ingress reactivity effect essentially caused by differences in the nuclear data basis used. A detailed evaluation of the results of corresponding perturbation calculations reveals that the observed discrepancies may be considered as not too surprising because there is a large cancellation of positive and negative contributions to the degradation - or moderation - term coming from different energy regions. Since this term is usually the dominating individual term, especially at low steam densities, it is obvious that small changes of partial components may lead to large relative changes for the total value.

In order to explain in a quantitative way the most important discrepancies observed between the results of the various laboratories participating in the present study, a closer examination of the nuclear data sets involved in this intercomparison would be necessary probably supplemented by a careful evaluation or reevaluation of the nuclear data forming the basis of the data sets involved. A somewhat restricted sensitivity study concerning the influence of nuclear data changes is presented in an appendix to the present report. A more refined treatment of that kind would give a better insight as to which nuclear data in which energy range are most significant for the steam ingress reactivity effect and which accuracy and reliability can be expected for or probably attributed to the prediction of this quantity if one assumes reasonable values for the presently existing nuclear data uncertainties. Furthermore an intercomparison activity like the present one could be repeated or continued with the emphasis of using more modern nuclear data, e.g. based on ENDF/B-V or KEDAK-4. If sufficient agreement has eventually been obtained for this kind of simple benchmarks, an extension to more complicated examples

including heterogeneity- and streaming-effects would be desirable. Finally it may be concluded from the present study that, due to existing uncertainties in predicting steam ingress reactivity, it may be adequate to measure this quantity in several critical assemblies if they are characterized by major differences in their material composition and/or geometric arrangement of their components. This may apply to GCFR criticals as well as to LMFBR criticals because the reactivity effect of an entry of lubricating oil into a LMFBR core is similar to that of a steam ingress into a GCFR core.