

**LIFE II - A COMPUTER ANALYSIS OF FAST REACTOR
FUEL ELEMENT BEHAVIOR AS A FUNCTION
OF REACTOR OPERATING HISTORY**

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The LIFE-II computer code has been developed at Argonne National Laboratory to predict the in-pile thermal, mechanical, and radiation behavior of fast-reactor fuel elements. The code is based on fundamental models of fuel and cladding behavior, and represents an attempt to integrate the detailed results of fuel-element materials studies at Argonne and elsewhere. The framework of the code is an axisymmetric generalized-plane-strain analysis, using three radial sections for the fuel and one section for the cladding, coupled with a one-dimensional thermal analysis. Axial variations in flux and coolant temperature are taken into account by dividing the element into several (ten or less) sections, with appropriate boundary conditions computed for each section. Furthermore, since the properties of most materials are strongly temperature dependent, LIFE-II has been designed to follow any prescribed history of reactor power and coolant temperature variations.

Although the LIFE-II formulation is readily adaptable to other fuel and cladding materials, the specific models discussed in this paper are intended for mixed-oxide fueled, stainless steel clad fast-reactor fuel elements. Materials behavior models in the code describe fuel restructuring, fuel cracking, and hot pressing, migration of fuel constituents, fuel swelling due to solid and gaseous fission products, fission-gas release, fuel-clad interactions, and clad swelling due to void nucleation and growth. The dependence of the various materials properties on temperature, porosity, stress, strain, and radiation, is also accounted for in LIFE-II to the extent of available data. The code conforms to these changes in materials properties when predicting the thermoelastic, creep, and swelling deformations of the fuel element.

Comparison of LIFE-II calculations with the results from actual fuel-element irradiations in the EBR-II reactor, for a wide variety of design conditions, has been largely successful, and has demonstrated the sensitivity of fuel-element performance to reactor operating cycles. The code is being used to perform parametric studies indicating the sensitivity of the predictions to variations in materials properties and design variables, and to focus on the most critical areas in which fuel-element performance data are needed. The code is also providing input to related safety studies by defining the condition of the fuel element at the start of an accident. LIFE-II is thus a realistic and versatile design tool for the development of fast-reactor fuel elements.

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DISCUSSION

M. GUYETTE, Belgium

Q Concerning the boundary condition in radial direction between the fuel and the clad, are you assuming that the radial stress in the clad is equal to the contact pressure or to the sum of the contact and gas pressures ?

R. W. WEEKS, U. S. A.

A When the fuel-clad gap is open, the plenum pressure is assumed to act on the clad; when the gap is closed, the plenum pressure acts only at the boundary of the central void and at the top of the fuel column, and the interface pressure between the fuel and clad is computed based on the creep and swelling analysis of both. This latter interface pressure is almost always much larger than the plenum pressure.

E. ROLSTAD, Norway

Q You mentioned that the fuel thermal conductivity was dependent on temperature and porosity. Don't you consider changes in the conductivity due to irradiation effects ?

R. W. WEEKS, U. S. A.

A The irradiation will influence the porosity of the fuel, which is accounted for, but the effects of stoichiometry changes during burnup are not presently included due to lack of data.

M. GUYETTE, Belgium

Q What is the reason why the program divides the intervals in subintervals ?

R. W. WEEKS, U. S. A.

A The program divides time intervals by linear interpolation if the changes in strain or restructuring exceed specified limits, or if the convergence is too slow. LIFE has been programmed this way to minimize computational errors.

W. P. CHERNOCK, U. S. A.

Q In fuel modeling of fast breeder fuels the accumulation of fission gas bubbles in the region of grain growth in mixed oxides does not appear to be considered. For burnups in excess of 50,000 MWD/MTM this fission gas bubble agglomeration can become an effective thermal barrier and should perturb the conclusions made by use of modeling codes which do not consider this factor. We have irradiated $\text{UO}_2\text{-CaO-ZrO}_2$ and $\text{UO}_2\text{-CaO}_2$ fuels

to burnups in excess of 100,000 MWD/MTU and the best correlation of post-irradiation data was made on the basis of a thermal barrier in the grain growth region after burnups of about 50,000 MWD/MTU. Such gas agglomeration was observed. Although the burnups in water reactors are not high enough to become concerned with this factor, the burnups being proposed for fast breeders certainly must require that this factor be considered in fuel performance modeling codes and in designs. Would you care to comment on this ?

R. W. WEEKS, U. S. A.

A I agree that this may be a problem, but we have work near completion at Argonne that should take care of it. Dr. Roger Poeppel has developed a fuel swelling and gas release subroutine (called GRASS) that considers bubble nucleation, growth, migration, coalescence, and release including resolution and interaction with structural defects in the fuel. This subroutine is now operational and will be included in the LIFE code in the very near future.

H. WALTHER, Italy

Q The question asks for your cracking mechanism. When fuel and cladding are in contact and the fuel breaks the elastic strain energy should be - partially perhaps - transferred to the cladding. Is the corresponding stress variation in the cladding considered in mathematical treatment and observed ?

R. W. WEEKS, U. S. A.

A At present, the elastic strain existing just prior to cracking is assumed converted only to crack volume and plastic strain of the fuel. If the cladding takes up part of this strain conversion, it does so only as a result of the subsequent calculations. I am not aware of any data on this effect.