DTIC Rosen

Westinghouse Electric Corporation

TID-25756

RECEIVED BY DTIC JUL 19 1971

There is no objection from the patent point of view to the publication or dissemination of this document:

Assistant General Counsel
for Patents

MAST

Mr. R. A. Anderson
Asst. Gen. Counsel for Patents
U. S. Atomic Energy Commission
Germantown, Maryland

By

7/16/71

In Re: Patent Clearance Request

I. Form: Original X Supplement Contract AT(30-1)-4210

II. re Report Technical Paper Classification Unclassified

Title Sensitivity of Fuel Pin Behavior to Void Swelling and
Irradiation Creep of Stainless Steel

Author(s) A. Boltax, T. P. Soffa, and A. Biancheria

III. Determination of Patent Status: Complete X Incomplete

(a) It is deemed that no significant adverse patent effect will result from:

(1) Immediate publication in entirety X

(2) Immediate publication with deletions

(b) Publication withheld pending patent action as follows:

(c) Release in confidence - Release now is limited to transmittal of document copies in confidence to those authorized by USAEC as recipients in advance of patent clearance with express notice impressed upon each copy restricting use solely to performance of USAEC contracts and prohibiting publication

IV. Follow-up

(a) Deleted matter cleared for publication
(b) Release in confidence notice cancelled } see reverse side for basis and notification

Items of patent interest noted

If none, so state

(X) None (pp.)

() (pp.)

All status included above X See reverse side

Perry W. Davison

(W) PATENT REPRESENTATIVE
P. W. Davison

7/7/71
DATE

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

Sensitivity of Fuel Pin Behavior to
Void Swelling and Irradiation Creep of Stainless Steel*

A. Boltax, T. P. Soffa, and A. Biancheria

Westinghouse Advanced Reactor Division

Analytical studies of the behavior of stainless-steel-clad, mixed-oxide fuel pins with the OLYMPUS and CYGRO-F computer codes^{1,2} have revealed the significance of void swelling and irradiation creep of stainless steels on the burnup capability of this LMFBR fuel system. These studies revealed the major effects of fuel pellet and/or fuel smear density, fluence-to-burnup ratio, and cladding temperature on the dimensional behavior of fuel pins. Additional studies performed with these codes will be reported involving detailed analysis of the sensitivity of fuel pin behavior to void swelling and irradiation creep of solution treated and cold-worked Type 316 stainless steel.

In the OLYMPUS and CYGRO-F computer codes, cladding strain is reported as the sum of four principal strain components:

1. Start-of-life (SOL) strain. This is the plastic strain of the cladding due to fuel/clad mechanical interaction which occurs on start-up for fuel pins with small SOL fuel/clad gaps.
2. Stress-free void swelling of stainless steel.

*Work partially funded under Contract AT(30-1)-4210.

3. Irradiation creep of stainless steel including a low temperature component which decreases with increasing temperature and a high temperature component which attains maximum values in the temperature range 550 to 700°C. The high temperature irradiation creep is believed to give rise to enhanced swelling and is also referred to as stress-induced void growth (SIVG).³
4. Total plastic strain of stainless steel including plastic strain and secondary creep strain. These strain components include effects of irradiation hardening. The total plastic strain is used to determine the failure limiting strain of stainless steel.

Sensitivity studies were performed on the components of cladding strain for fuel pins subjected to typical test reactor (EBR-II) and LMFBR operating conditions. The studies were performed using the current FFTF design equations for void swelling and irradiation creep of stainless steel (as given in reference 2) as the reference case. The effects of variations of low and high temperature irradiation creep and stainless steel swelling (particularly the fluence dependence and the occurrence of swelling saturation) on cladding thermal strain were studied.

Figures 1 and 2 illustrate some of the analytical results at cladding mid-wall temperatures of 480 to 590°C, respectively. The variables include pellet density, low temperature irradiation creep, and high temperature irradiation creep (SIVG). The results obtained in Figures 1 and 2 reveal the major effect of fuel pellet density on total plastic strain of the cladding. The benefits obtained from lowering the fuel pellet density are reduced significantly at cladding temperatures where thermal creep becomes important ($T > 550^{\circ}\text{C}$).

Additional studies were performed which show the sensitivity of the total plastic strain to various levels of saturation of cladding swelling (10-15%) and fuel swelling (20-35%). These results highlight the need for additional reactor data at high fluence and burnup to determine the burnup capability of mixed oxide fuel pins.

References

1. A. Boltax, P. Murray, and A. Biancheria, Fast Reactor Fuel Performance Model Development, Nuc. Appl. and Tech., 9, 1970. p. 326.
2. A. Boltax, A. Biancheria, B. L. Harbourne, and T. P. Soffa, "Mixed Oxide Fuel Pin Performance Analysis Using the OLYMPUS Code", To be published in the proceedings of the ANS Conference on "Fast Reactor Fuel Element Technology", April, 1971.
3. F. Garner, W. G. Wolfer, A. Biancheria, and A. Boltax, "The Effect of Stress on Radiation-Induced Void Growth", To be published in the proceedings of the Conference on "Radiation-Induced Voids in Metals", June, 1971.

Figure 1

Prediction of the burnup dependence of the total plastic strain of mixed oxide fuel pins at a cladding temperature of 480°C

Figure 2

Prediction of the burnup dependence of the total plastic strain of mixed oxide fuel pins at a cladding temperature of 590°C