HEDL-SA-2299

CONF-810606--29

FUEL PIN LIFE EVALUATION

FOR THE MULTIDUCT TEST ASSEMBLY IN FFTF

Edward L. Tang

December 1980

American Nuclear Society
Annual Meeting

June 7 - 12, 1981

Miami Beach, Florida

HANFORD ENGINEERING DEVELOPMENT LABORATORY
Operated by Westinghouse Hanford Company, a subsidiary of Westinghouse Electric Corporation, under the Department of Energy Contract No. DE-AC14-76FF02170
P.O. Box 1970, Richland, Washington 99352

COPYRIGHT LICENSE NOTICE
By acceptance of this article, the Publisher and/or recipient acknowledges the U.S. Government's right to retain a nonexclusive, royalty-free license in and to any copyright covering this paper.

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

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.

FUEL PIN LIFE EVALUATION FOR THE MULTIDUCT TEST ASSEMBLY IN FFTF

E. L. Tang

A multiduct fuel pin test assembly (MFTA) has been developed for the breeder reactor fuel development programs in the Fast Flux Test Facility (FFTF) at HEDL. The MFTA, designed as a test vehicle consists essentially of two fuel pin regions, the inner test pin region and the outer driver pin region separated by the inner and the intermediate ducts. The objective of this report is to analyze and to determine to what extent the driver pins in the outer region of MFTA can be operated beyond the three reactor operating cycles (300 EFPD) set for the standard FFTF driver pins, so that the MFTA as a test vehicle can be reused for further irradiation tests. The analysis is to demonstrate that the driver pin cladding structural integrity can be maintained during an intended life by taking into account all possible operating conditions, namely, the normal steady-state and the most severe expected transient events.

The criterion for the present analysis is based on the cumulative stress rupture damage fraction. The cumulative damage fraction will reflect the combined effects of both the thermal and neutronic envinronmental and mechanical histories of the driver pin throughout its possible lifetime. Analytically, it can be stated that cladding integrity can be assured over the operating lifetime so long as:[1]

$$\int_0^{\tau_o} \frac{dt}{t_r[\sigma(t), T_c(t)]} + \sum_{i,j} \kappa_{ij} \int_0^{\tau_i} \frac{dt}{tr_{ij}[\sigma(t), T_c(t)]} < 1 \qquad (1)$$

where the factor κ_{ij} is the number of i-th occurrence for the j-th type of transient. The tr_{ij} describes the stress rupture time function for the j-th event at the i-th occurence at time t. The first term in Equation 1 represents the accumulated stress rupture damage fraction for a normal steady-state operation of time period of τ_o EFPD. The second term describes the sum of all rupture damage fractions for all possible occurences and/or repetitions of transient events during the life τ_o.

For the MFTA analysis in which we have established the FFTF driver pin at the center of the reactor core as the benchmark for comparison with the driver pin in MFTA at Row 3, Equation (1) can be rewritten as:

$$\left[\int_0^{\tau_o} \frac{dt}{t_r[\sigma(t), T_c(t)]} + \sum_{i,j} \kappa_{ij} \int_0^{\tau_i} \frac{dt}{tr_{ij}[\sigma(t), T_c(t)]}\right]_{MFTA} \leq$$

$$\left[\int_0^{\tau_{300}} \frac{dt}{t_r[\sigma(t), T_c(t)]} + \sum_{i,j} \kappa_{ij} \int_0^{\tau_i} \frac{dt}{tr_{ij}[\sigma(t), T_c(t)]}\right]_{FFTF} \quad (2)$$

Equation (2) simply implies that if the total accumulated rupture damage fraction for the driver pin in MFTA at Row 3 is less than or equal to that of the FFTF driver pin at the core center for 300 EFPD, the cladding integrity of the driver pin in MFTA can be maintained.

The steady-state pin lifetime analyses for the driver pins in MFTA at Row 3 and the FFTF driver pin at the core center are performed by using the SIFAIL computer code.[2] It calculates the thermal and mechanical properties of a mixed uranium-plutonium oxide fuel pins in a fast neutron environment and provides the temperature distributions in fuel pin and cladding, the fuel restructuring characteristics, the fission gas generation and release, the cladding mechanical deformations due to swelling and creep, and the stress rupture damage fraction for the cladding. As an example, Figure 1 displays the cladding OD temperatures along the active pin axial positions for comparison between the FFTF driver pin at Row 1 and the hot pin in MFTA at Row 3 for steady-state operations of 3 to 5 cycles.

The cladding integrity and pin life for the transient-over-power (TOP) and the loss-of-flow (LOF) events are investigated by using the LAFM computer code.[3] LAFM predicts the time and the location of fuel pin failure as well as the state of the fuel inside the pin at the time of failure. The failure criterion adopted by LAFM is a linear life fraction rule, based on the stress-rupture lifetime. The anticipated events analyzed for the TOP are the rod drop with primary scram, and reactivity insertions of 0.5¢/sec, 3.4¢/sec and 25¢/sec with primary scrams and secondary scrams. For LOF, the accidents due to total loss of electric power, one primary pump mechanical failure, and the continuous flow reduction are analyzed. A special reactivity insertion accident of 3$/sec is also investigated. All the transient events were initiated with reactor operating at full power of 400 MW with a coolant inlet temperature of 695°F. The life fraction profile along the axial positions of the driver pin for 3$/sec transient is shown in Figure 2. The profile represents the quasi-steady-state life fraction for the pins, after a rapid transient period.

The driver pin lifes of MFTA are evaluated by assuming that all the transient events discussed above occur once in its lifetime. The total cumulative damage fraction throughout the pin lifetime are summarized in Table 1 for comparison between the driver pin of FFTF after 300 EFPD and the driver pins of MFTA after 300, 400, and 500 EFPD operations. The result shows that all the TCDF values for the driver pin in MFTA at Row 3 are less than that at Row 1 for FFTF, and the cladding integrity is expected to be maintained after 500 EFPD operation.

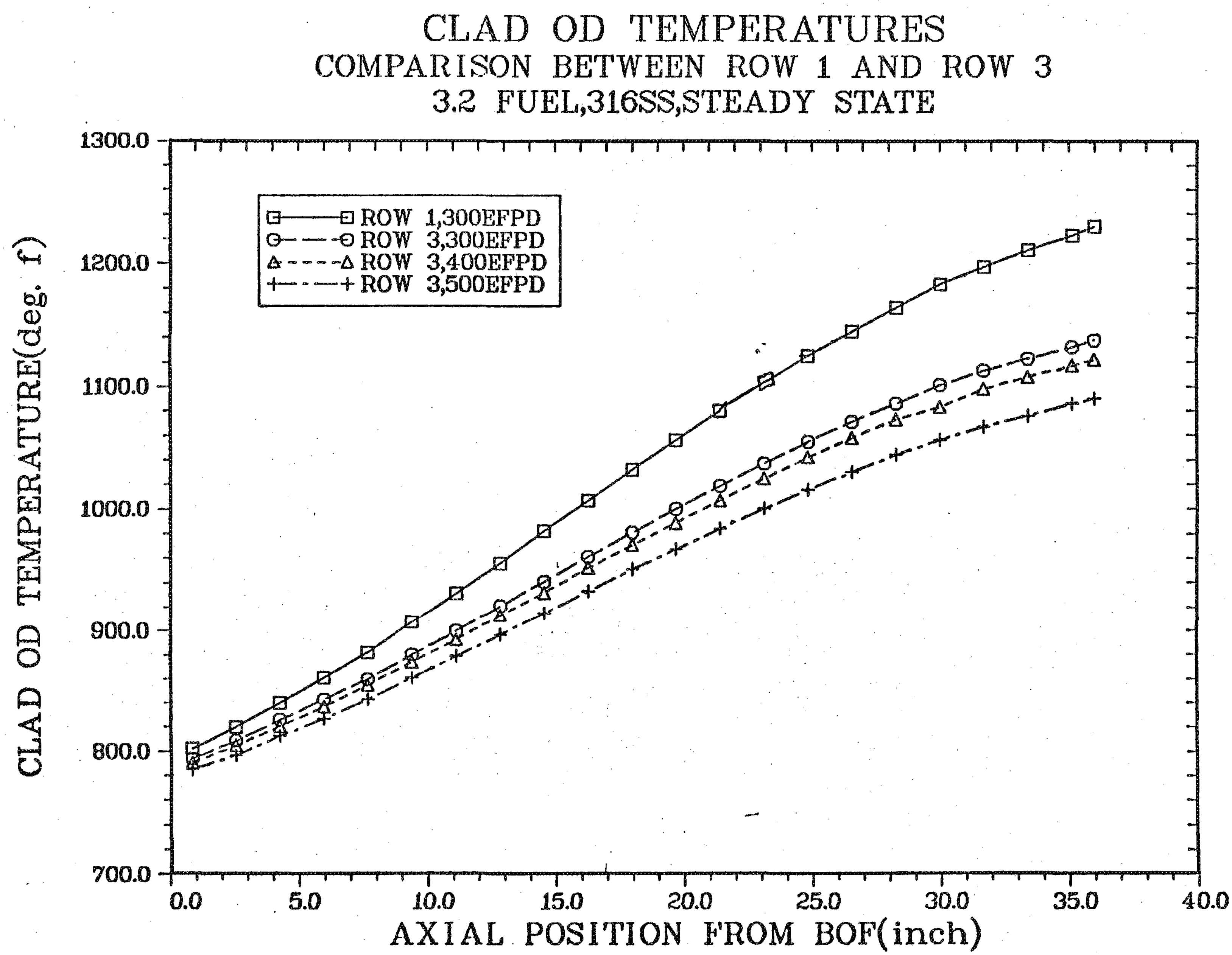
A detailed discussion of the method of analyses will be presented at the meeting.

REFERENCES

1. D. C. Jacobs, "The Development and Application of a Cumulative Mechanical Damage Function for Fuel Pin Failure Analysis in LMFBR Systems," WARD AT145-17-2171-43, February 1974.

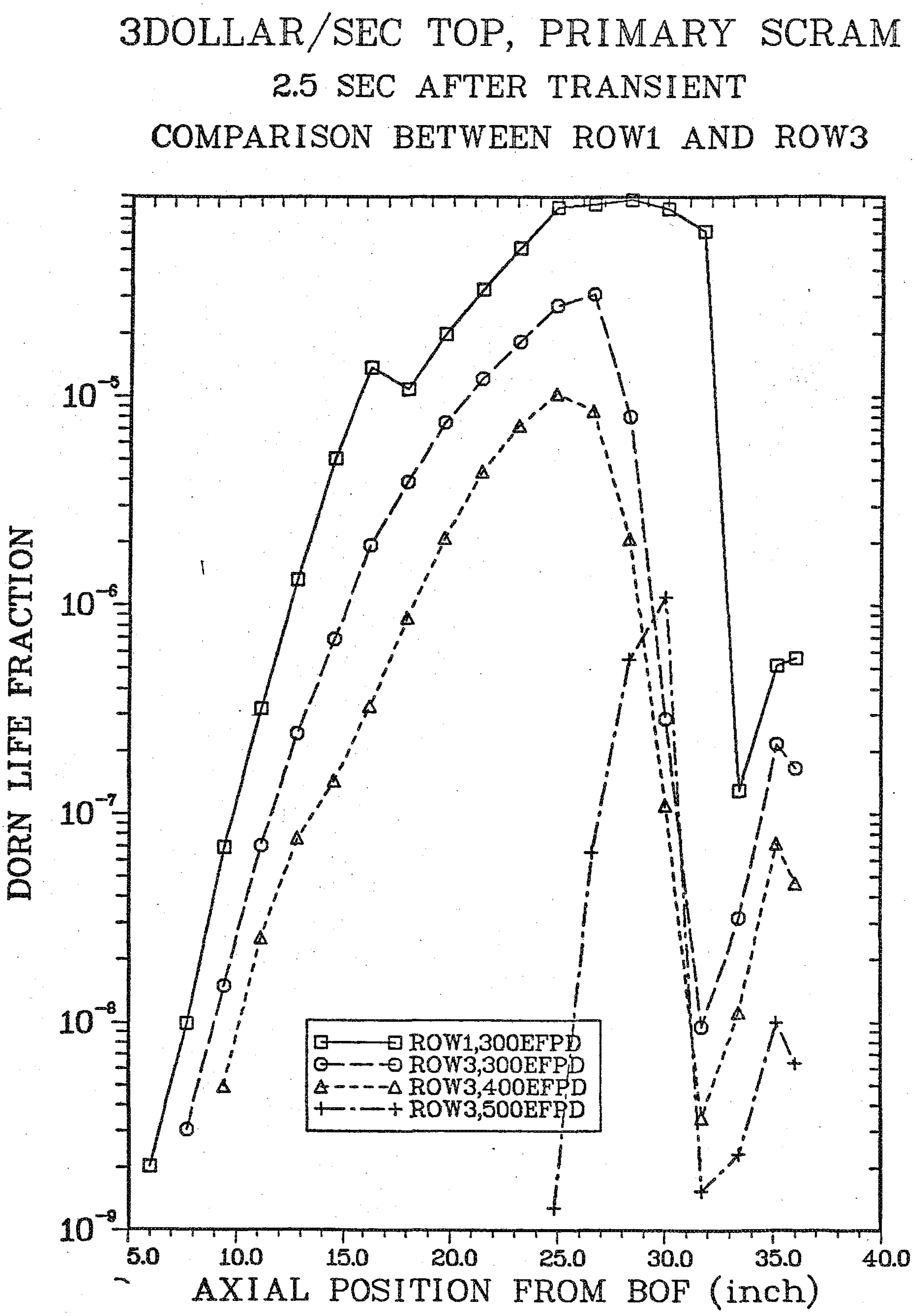
2. D. R. Wilson and D. S. Dutt, "SIFAIL: A Subprogram to Calculate Cladding Information and Damage for Fast Reactor Fuel Pins," HEDL-TME 79-34, May 1979.

3. P. K. Mast, "The Los Alamos Failure Model (LAFM): A Code for the Prediction of LMFBR Fuel Pin Failure," LA-7161-MS, NRC-7, Los Alamos Scientific Laboratory, March 1978.



CLAD OD TEMPERATURES
COMPARISON BETWEEN ROW 1 AND ROW 3
3.2 FUEL,316SS,STEADY STATE
ROW 1,300EFPD
ROW 3,300EFPD
ROW 3,400EFPD
ROW 3,500EFPD
CLAD OD TEMPERATURE(deg. f)
AXIAL POSITION FROM BOF(inch)
1300.0
1200.0
1100.0
1000.0
900.0
800.0
700.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0

FIGURE 1



3DOLLAR/SEC TOP, PRIMARY SCRAM
2.5 SEC AFTER TRANSIENT
COMPARISON BETWEEN ROW1 AND ROW3
DORN LIFE FRACTION
AXIAL POSITION FROM BOF (inch)
ROW1,300EFPD
ROW3,300EFPD
ROW3,400EFPD
ROW3,500EFPD

FIGURE 2

TABLE 1

TOTAL CUMULATIVE DAMAGE FRACTION
FOR COMPARISON BETWEEN ROW 1 AND ROW 3

CDF Events / Fuel Pin	FFTF ROW 1 300 EFPD	MFTA Row 3 300 EFPD	MFTA Row 3 400 EFPD	MFTA Row 3 500 EFPD
Steady-State	$3.0X10^{-3}$	$2.86x10^{-4}$	$4.77x10^{-4}$	$6.72x10^{-4}$
0.5¢/sec, PS(a)	$1.65x10^{-4}$	$1.55x10^{-5}$	$4.84x10^{-6}$	$1.36x10^{-6}$
0.5¢/sec, SS(b)	$3.20x10^{-3}$	$3.3x10^{-4}$	$9.3x10^{-5}$	$2.67x10^{-5}$
3.4¢/sec, PS	$1.24x10^{-4}$	$1.57x10^{-5}$	$4.7x10^{-6}$	$1.09x10^{-6}$
3.4¢/sec, SS	$1.28x10^{-3}$	$1.51x10^{-4}$	$4.17x10^{-5}$	$1.01x10^{-5}$
25¢/sec, PS	$9.21x10^{-7}$	$8.4x10^{-8}$	$3.02x10^{-8}$	$3.67x10^{-9}$
25¢/sec, SS	$3.56x10^{-6}$	$3.8x10^{-7}$	$1.25x10^{-7}$	$1.82x10^{-8}$
3$/sec, PS	$8.64x10^{-5}$	$3.06x10^{-5}$	$1.03x10^{-5}$	$1.07x10^{-6}$
Rod Drop	$3.86x10^{-4}$	$6.8x10^{-5}$	$3.06x10^{-5}$	$4.05x10^{-6}$
Flow Reduction	$5.51x10^{-3}$	$1.18x10^{-3}$	$5.29x10^{-4}$	$7.12x10^{-5}$
Loss of Elec- tricity	$7.95x10^{-5}$	$1.27x10^{-5}$	$5.91x10^{-6}$	$8.02x10^{-7}$
One Pump Failure	$9.79x10^{-5}$	$1.56x10^{-5}$	$7.21x10^{-6}$	$9.78x10^{-7}$
TCDF(c)	$1.39x10^{-2}$	$2.11x10^{-3}$	$1.21x10^{-3}$	$7.9x10^{-4}$

(a)PS=Primary scram
(b)SS=Secondary scram
(c)TCDF=Total cumulative damage fraction through pin lifetime