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Title: Test-Fuel Power-Coupling Dependence on TREAT Control-Rod Positions

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MASTER

Abstract: Test-Fuel Power-Coupling Dependence on TREAT Control Rod Positions

The Transient Reactor Test (TREAT) is a graphite moderated, UO_2 fueled test reactor located at the Idaho National Engineering Laboratory and operated by Argonne National Laboratory. Test fuel is placed in containment vessels in the center of the reactor and subjected to computer-controlled transient irradiations which can result in experimental fuel melting or even vaporizing. The reactor was designed to have a strong negative temperature coefficient and to operate adiabatically. Consequently large reactivity insertions, up to 6.2% $\Delta k/k$, may be required during a transient as the core temperature increases as much as 570^{o}C. This reactivity insertion is accomplished typically over 10 to 20 seconds by hydraulically actuated transient control rods.

Evaluation of empirical data has indicated that control-rod-position changes cause power-coupling changes during a transient and usually are the primary factor in determining the ratio of the transient-averaged to steady-state test-fuel power coupling. To a good approximation, the power-coupling effects of rods can be expressed as the product of separable exponential functions with rod height as the independent variable. The maximum effect of the transient rod pair closest to the test is a 25% change in power coupling as the rods move from their fully inserted to their fully withdrawn position. Similarly, the transient rod pair farthest away causes a 16% change.

The precise behavior of power coupling during transient operation is extremely complicated. Flux tilts due to rod motion and core temperature changes occur simultaneously and have interacting effects. Furthermore, the core loading and position of other control rods affect the relative

importance of the position of a particular rod pair. The approach taken in this evaluation was to make assumptions of effect separability and simple functional dependence and to test these assumptions against empirical data.

The power-coupling equation was assumed to have the following form:

$$PC_{TR} = (PC_R)(PC_T)(PC_{SS}) \tag{1}$$

where PC_{TR} = instantaneous value of power coupling during the transient

PC_R = power-coupling dependence on rod position

PC_T = power-coupling dependence on temperature

PC_{SS} = steady-state value of power coupling

and:

$$PC_R = e^{a\Delta h_1} e^{b\Delta h_2} e^{c\Delta h_B} \tag{2}$$

where: Δh_1 = instantaneous position of rod pair T-1 relative to its steady-state position

Δh_2 = instantaneous position of rod pair T-2 relative to its steady-state position

Δh_B = the outer rod-bank transient position relative to its steady-state position.

Since available data is limited to the ratio of transient-averaged power coupling to the measured steady-state value (TCF), an approximate expression for TCF was derived in order to determine the optimum values of a, b, and c that best fit experiment. Thus, from equations (1) and (2), we obtain:

$$TCF \simeq e^{a\overline{\Delta h_1}} e^{b\overline{\Delta h_2}} e^{c\overline{\Delta h_3}} \overline{PC_T} \tag{3}$$

where $\overline{\Delta h}$ equals the energy-averaged deviation of the transient position of the rod from its steady-state value.

Using equation (3) and experimental values of TCF, the constants a, b, and c were selected to fit the available experimental data within the assumed mathematical expression. The constants a, b, and c were determined to be:

a = 0.005618/in.

b = 0.003654/in.

c = -0.002634/in.

Table 1 presents a comparison of calculated-vs-experimental values of TCFs together with other germane data. The temperature effect was obtained from one-dimensional transport calculations and is discussed in a separate paper at this symposium. Note that the temperature effect is large only in the F3,4 experiment. In all other cases, the effects of rod position are far more significant in determining the TCF. Table 1 also contains information on which transient rod pair initiated the transient, the total transient energy, and peak temperature in order to illustrate that equation (3) with the values of a, b, and c given above seems to predict TCF irrespective of these differences.

Thus, it appears that rod-position changes during transient operation causes power-coupling changes during the course of a transient and generally is the primary factor in determining the value of the TCF. The wide range of experimental values of TCFs is due to large differences in energy-averaged values or rod heights relative to their steady-state value. In addition, it appears that the power-coupling effects of rods can be treated as separable and exponential in behavior with rod height as the independent variable.

TABLE 1

Calculated Transient Correction Factors (TCFs) Compared to Experiment

Experiment	Transient	Rod Moved First	Energy(MJ)	Peak Temp(°C)	CALCULATED VALUES Temp Effect	Rod Effect	TCF	Exp. TCF	Ratio (Calc. TCF / Exp. TCF)
F3/4	2099/2100	T-1	2034	466	0.925	0.872	0.807	0.80	1.008
J1	2151	T-1	1260	327	1.037	0.864	0.896	0.92	0.974
J1	2156	T-2	1115	340	1.037	0.856	0.888	0.95	0.935
L03	2257	T-2	2203	467	1.009	0.916	0.924	0.94	0.983
L03	2258	T-1	2270	500	1.009	0.911	0.920	9.91	1.011
L03	2260	T-1	507	157	1.011	0.786	0.795	0.77	1.032
C04	2280/2281	T-2	2005	423	1.012	0.894	0.905	0.87	1.040
L03	2301	T-1	508	169	1.011	0.784	0.792	0.80	0.990
L03	2302	T-1	2082	485	1.010	0.903	0.912	0.90	1.014
L03	2303	T-2	416	180	1.012	1.055	1.068	1.06	1.007
L03	2304	T-1	922	264	1.016	0.806	0.819	0.83	0.986
L03	2305	T-1	1519	381	1.017	0.848	0.862	0.87	0.991
C06	2349	T-1	608	227	1.021	0.892	0.910	0.89	1.023
RFT	2351	T-2	505	177	1.014	1.000*	1.000*	1.000*	1.000
RFT	2356	T-2	789	221	1.015	1.042*	1.043*	1.047*	0.996
RFT	2359	T-2	1778	438	1.013	1.154*	1.153*	1.144*	1.008

*These are not actual transient correction factor (TCF) values, but are shown to indicate changes relative to transient 2351.

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