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Transfer functions may be used to calculate component feedbacks or temperature increments by convolution of the transfer function with the appropriate fractional change in system-quantity. Power-change transfer functions have been reported (1). The corresponding flow transfer functions for this case, and comparison with the power transfer functions, are reported here. Results of feedback simulation of ramped flow transients using flow transfer functions are also described.

Power-change transfer functions were calculated (1) for the Experimental Breeder Reactor II (EBR-II) Reactor by imposing a step-change in power (with constant flow) of -10 percent upon a twenty-four channel model of the EBR-II reactor using a modification of the EROS (2) kinetics code. (In this version of the code, the feedback reactivity calculation is disconnected from the basic power/reactivity iteration.) It was seen that the transfer function could not be modeled as a single term but had to be modeled by a series of terms. The corresponding power-change transfer functions have now been calculated for a step-change in power of +10 percent using the same methods. Table 1 shows the axial dependence of the EBR-II row 2 fuel transfer function for both the step-up and step-down power changes. (For simplicity, only the first expansion term is presented.) It is seen that they are essentially identical. This is to be expected since the steady-state and transient temperature solutions (1) are linearly dependent on power.

The same methods have been used to calculate transfer functions for a -10 percent and +10 percent step-change in system flow rate. (The total system reactivity that is input into this modification of the EROS code was zero since a constant value of power is required to calculate flow-only transfer functions.) The axially-dependent transfer function results for the fuel in core row 2 are also shown in Table 1. (As with the power-change transfer

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functions discussed earlier, only the first term in the series expansion of the transfer function is shown.) It is seen that the results are different for a step-up or a step-down in flow rate. This might be expected since the steady-state temperature solution is inversely proportional to the system flow rate. The ratio of the step-up coefficient to the step-down coefficient varies axially in the fuel from 0.8 - 0.95. (A simplified estimate of this ratio using steady-state quantities is 0.8.) The time constants for the step-up transfer functions are shorter than the step-down transfer functions because, with a higher flow rate, the coolant is cooler, and hence, the heat can escape faster from the fuel pin (i.e., a shorter time constant).

In the current analysis of feedback simulation using flow transfer functions, the relative flow shape (at a constant power of 60 MW(th) and an initial flow rate of 464 kg/s at the pumps) assumed was composed of four segments: (a) a linear relative flow increase from 1.0 at 0.0 s to 1.1 at 2.0 s, (b) constant flow from 2.0 to 5.0 s, (c) a linear drop in relative flow from 1.1 at 5.0 s to 0.9 at 9.0 s, and (d) constant flow from 9.0 s to the end of the calculate interval (20 s). This flow history was input, along with a zero system reactivity, into the modified EROS code. Shown in Fig. 1 is the comparison between the EROS generated feedback reactivity for the two-radial midplane fuel nodes of the stereotypical rod 2 driver channel (initial sodium coolant velocity 6.7 m/s) and the analytically calculated feedbacks when 1 or 4 terms are used in the feedback reactivity transfer function. (In these calculations the step-up transfer functions were used when the total flow change was positive whereas the step-down transfer functions were used when the total flow change was negative.) It is seen from the figure that the more terms that are used in the definition of the transfer function, the better the fit to the numerically calculated results.

These results together with the previously reported results (3), indicate that reasonable estimates of reactivity (or temperature) effects due to various types of power or flow initiating transients can be made using models that would not necessitate iteration-type computer codes.

References:

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Table 1. Axial Dependence of Power and Flow Transfer Functions in EBR-II Mk-II Driver Fuel (row 2)

Core Axial Node	Power Transfer Function				Flow Transfer Function			
	-10% Power		+10% Power		-10% Flow		+10% Flow	
	$h_1(0)$[a]	τ_1[b]	$h_1(0)$	τ_1	$h_1(0)$	τ_1	$h_1(0)$	τ_1
1 (bottom)	-8.54^{-4}[c]	0.104	-8.35^{-4}	0.105	1.08^{-4}	0.111	1.01^{-4}	0.104
4	-1.39^{-3}	0.135	-1.38^{-3}	0.135	5.84^{-4}	0.131	5.10^{-4}	0.123
6	-1.74^{-3}	0.149	-1.72^{-3}	0.149	9.42^{-4}	0.142	8.32^{-4}	0.131
8	-1.49^{-3}	0.169	-1.48^{-3}	0.170	9.96^{-4}	0.159	8.95^{-4}	0.144
10 (top)	-1.44^{-3}	0.175	-1.43^{-3}	0.176	1.03^{-3}	0.167	8.47^{-4}	0.153

[a]The units of the transfer function coefficient are \$/s.

[b]The units of the transfer function time constant are s.

[c]Read -8.54^{-4} as -8.54×10^{-4}.

Fig. 1. Stereotypical row 2 channel (3 subassemblies) midplane nodal (node height = 3.45 cm) fuel feedback reactivity versus time for a ramped flow shape calculated using either the EROS code or various expansion terms in the feedback reactivity transfer function.