TABLE III

Percentage Perturbation in Power for Small Perturbations in Reactivity or Inlet Temperature (Constant Power-to-Flow Ratio)

LMR Type	10¢ Change in External Reactivity (%)	10 K Change in Inlet Temperature (%)
Oxide-fueled	5.88	2.35
Metal-fueled	66.67	20.00

perturbation in the oxide-fueled core, the power perturbations become very large in the metal-fueled LMR.

To summarize, the oxide-fueled core appears to have a desirable highly damped response to small perturbations during normal operation, whereas the metal-fueled core is much more sensitive to such perturbations. Note that this difference in response to perturbations is prominent only for large cores. In small test fast reactors like Experimental Breeder Reactor II (metal) and RAPSODIE (oxide), the Doppler contribution is small and the dominating coefficient is ρ_{pf}, which makes the responses of the differently fueled cores to small perturbations similar.

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July 20, 1988

REFERENCE

1. K. O. OTT, *Nucl. Sci. Eng.*, **99**, 13 (1988).

Response to "Comparison of the Response to Small Perturbations in Metal- and Oxide-Fueled Liquid-Metal-Cooled Reactors"

The letter by Lee[1] addresses the response to small perturbations in inlet temperature (T_i) and externally applied reactivity (ρ_x) in metal- and oxide-fueled liquid-metal-cooled reactors (LMRs). As his analysis makes use of the steady-state reactivity formula of Ref. 2 ($\rho = 0$), his results have to be considered the asymptotic response to small perturbations. The two types of perturbations are discussed separately in Secs. I and II.

I. INLET TEMPERATURE PERTURBATIONS

Lee's Eq. (3) follows directly from Eq. (22) or (23) of Ref. 2, i.e.,

$$\delta T_i = \frac{\rho_{pf} + \rho_p}{a_i}\,\delta p = \begin{cases} -525\text{ K}\;\delta p\text{ (oxide)} \\ -150\text{ K}\;\delta p\text{ (metal)} \end{cases} , \quad (1)$$

using the coefficient values of Ref. 2. In Eq. (1), δp and δT_i are both unknown. If Eq. (1) is applied to an unprotected loss-of-heat-sink (ULOHS) incident, the required second equation comes from the asymptotic equality of power (p_{as}) and heat rejection rate p_{ras}. As p_{ras} is much smaller than $p_0 = 1$, δp_{as} is close to -100% (i.e., $\delta p_{as} \approx -1$).

Equation (1) is then solved in Ref. 2 for the remaining unknown, δT_{ias}:

$$\delta T_{ias} = 525\text{ K (oxide)}$$

and

$$\delta T_{ias} = 150\text{ K (metal)} . \quad (2)$$

Thus,

$$\delta T_{ias)metal}/\delta T_{ias)oxide} = 1/3.50 , \quad (3)$$

with the inference that in a ULOHS incident metal cores have a considerably smaller and thus more desirable temperature response than oxide cores.

Lee treats δT_i in Eq. (1) as a given input and finds the δp response by inversely applying Eq. (1), giving

$$\delta p)_{metal}/\delta p)_{oxide} = 3.50 , \quad (4)$$

with the inference that metal-fueled cores are much more sensitive to small perturbations than oxide-fueled cores, which have a highly desirable damped response.

While the numerical value on the right side of Eq. (4) is correct, we believe that Lee's conclusion with respect to desirability is mistaken. In discussing this question, it is important to consider the power level at which a perturbation is applied.

At nominal power T_i changes are more likely on the up side resulting from a deterioration of the heat rejection capability, leading to a *decrease* in power, that is, a factor of 3.5 stronger for metal than for oxide. The maximum T_i decrease that can be experienced at nominal power (either by a sudden increase in power demand or by accident) is quite limited. The consideration of the corresponding power increase is subject of the safety design.

Below nominal power, T_i changes may be effected in both directions, bringing into play the strong sensitivity of the power response. This opens up the intriguing possibility of controlling the reactor with the balance of plant (BOP) as discussed in some detail in Ref. 3. Of course, changing the inlet temperature in an LMR pool design is a very slow process as one needs to effect a temperature change in several thousand tons of metal. This novel control approach would hardly be possible if the core response to a T_i change would be "highly damped."

II. REACTIVITY PERTURBATIONS

Reactivity perturbations and the overpower transients (TOP) are not discussed in Ref. 2. A companion paper to Ref. 2 on TOP has been prepared for submittal to *Nuclear Science and Engineering*. Therefore only some general comments are presented here:

1. In case of a longer term, or asymptotic response, the power is determined by the heat rejection capability of the BOP and not by Lee's Eq. (2). The input reactivity is fully compensated by feedback resulting from a temperature change in the system.

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2. For short-term transients, the reactivity formula, Lee's Eq. (1), as taken from Ref. 2, is inapplicable. A more detailed kinetics and feedback reactivity description is required for determining the short-term response.

3. As reactivity insertions come from control rod extraction, it is important to note that the metal core has a much smaller control rod worth requirement than the oxide core (primarily because of higher internal breeding), suggesting that smaller reactivity perturbations should be considered for metal than for oxide.

III. SUMMARY

The power response to a change in *inlet temperature* is indeed much stronger for metal- than for oxide-fueled cores as pointed out by Lee. But this is largely an advantageous feature of the metal-fueled cores and not a disadvantage as implied in Lee's letter.

The evaluation of the response to a *reactivity change* requires either a more detailed kinetics and reactivity description (for short-term transients) or a consideration of the BOP (asymptotic response). The results presented by Lee are not a valid quantification of the power response in either case.

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September 7, 1988

REFERENCES

1. S. M. LEE, *Nucl. Sci. Eng.*, **101**, 94 (1988).

2. K. O. OTT, *Nucl. Sci. Eng.*, **99**, 13 (1988).

3. H. P. PLANCHON, J. I. SACKETT, G. H. GOLDEN, and R. H. SEVY, *Nucl. Eng. Design*, **101**, 75 (1987).