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**TITLE:** Doppler and Sodium Void Worth Effect on the Progression of an LOF Event in CRBRP Heterogeneous Core

**AUTHORS:** D. M. Switick  
S. K. Rhow  
J. L. McElroy

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ADVANCED REACTOR SYSTEMS DEPARTMENT • GENERAL ELECTRIC COMPANY  
SUNNYVALE, CALIFORNIA 94086

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DOPPLER AND SODIUM VOID WORTH EFFECT  
ON THE PROGRESSION OF AN HCDA LOF EVENT  
IN CRBRP HETEROGENEOUS CORE

D. M. Switick, S. K. Rhow and J. L. McElroy  
Advanced Reactor Systems Department  
General Electric Company  
Sunnyvale, California 94086

The CRBRP has adopted a heterogeneous core design<sup>1</sup> where some blanket assemblies (referred to as the internal blanket assemblies) are interspersed with driver fuel assemblies. The heterogeneous core has a low sodium void worth relative to a homogeneous core<sup>2</sup> which was previously considered in the design. Furthermore, the heterogeneous core has a significant share of the Doppler and sodium voidworth distributed in the internal blanket assemblies. This paper discusses the impact of such heterogeneous core characteristics on the progression of a hypothetical, unprotected (without scram) LOF event.

The values of the Doppler and sodium void worth at the lowest and highest burnup condition in the fuel reloading cycles are given for both the heterogeneous and homogeneous cores in Table 1.<sup>3</sup> Examination of this table shows that the total sodium void worth in the fuel assemblies of the heterogeneous core is -0.35\$ at BOC-1, and 1.1\$ at EOC-4, as compared with 2.6\$ to 2.8\$ for the homogeneous core. However, it is noted that the internal blanket assemblies contain a significant positive worth. This means that the effective void worth for the heterogeneous core would be quite low (even negative at BOC-1) depending upon whether or not sodium voiding in the internal blanket assemblies occurs in the accident progression. As for the Doppler, the total Doppler coefficient for the heterogeneous core is substantially higher than that for the homogeneous core. As

in the case of sodium void worth distribution, a significant portion of the Doppler coefficient is distributed in the internal blanket assemblies. Again, this means that the effective Doppler feedback would be affected by thermal conditions of the internal blanket assemblies.

An analysis of the response to the LOF event in the heterogeneous core has been performed by the authors<sup>3</sup> using the SAS3D code.<sup>5</sup> The results of this analysis up to initiation of fuel motion are presented and compared with the results for the homogeneous core<sup>4</sup> to indicate how the Doppler and sodium worth characteristics affect the progression of the LOF event in the heterogeneous core. It is noted that the flow coastdown characteristics used in the heterogeneous core analysis are taken to be exactly the same as those used in the homogeneous core analysis.

Table 2 shows the chronology of sodium boiling and fuel motion in the heterogeneous core, and the Doppler and sodium reactivity feedback at initiation of such events. It can be seen that propagation of sodium boiling to all fuel assemblies takes 6 seconds at EOC-4 and more than 9 seconds at BOC-1 from its inception, as compared with 3 seconds at EOEC and 5 seconds at BOEC in the homogeneous core. On the other hand, during normal operation the homogeneous core has a similar or higher degree of nonuniformity in the distribution of power-to-flow ratios among the fuel assemblies, relative to the heterogeneous core.

Such a slow, incoherent response of the heterogeneous core to the LOF event results from a low sodium reactivity feedback during the transient, which, in turn, is due to its lower sodium void worth and the role of the internal blankets. As the flow coastdown proceeds, sodium boiling initiates in the assemblies having the highest power-to-flow ratio. Subsequent sodium boiling in other assemblies accelerates or slows down depending upon the

sodium void reactivity of the assemblies being voided relative to the negative Doppler reactivity feedback. As shown in Table 2, the sodium void reactivity for the heterogeneous core is negative at BOC-1, and moderately positive at EOC-4 throughout the transient period of interest. The maximum combined reactivity from the Doppler and sodium during this period is negative at BOC-1 and 0.70\$ at EOC-4, as compared with 1.42\$ at BOEC and 1.29\$ at EOEC for the heterogeneous core. It is noted that the Doppler reactivity for the heterogeneous core at EOC-4 is higher than for the homogeneous core, while the sodium reactivity is lower than for the homogeneous core.

It is of interest to examine how the internal blanket assemblies affect the reactivity feedback in the accident progression, as they have both a significant sodium void worth and Doppler coefficient (Table 1). In the BOC-1 core, the internal blanket assemblies do not heat up significantly during the transient because their power-to-flow ratio is very low. Consequently, the sodium and Doppler reactivities from these assemblies are negligible; the heterogeneous core at BOC-1 acts like a homogeneous core which has a smaller sodium worth (see Table 1). On the other hand, at EOC-4 the internal blanket assemblies are expected to heat up during the transient as their power-to-flow ratio is comparable to the fuel assembly power-to-flow ratio. A breakdown of the reactivity contributions between the fuel and internal blanket assemblies is shown in Table 2. The internal blanket provides a substantial Doppler reactivity, while maintaining a relatively low sodium reactivity. Sodium boiling in the internal blanket is delayed until just before initiation of fuel motion because of the blanket's lower power density; no significant sodium reactivity from the internal blanket assemblies is expected during the transient period of interest, although they contain a significant void worth. However, the

temperature rise in the internal blanket, combined with its higher Doppler coefficient (Table 1), is high enough to cause a significant Doppler reactivity.

In summary, the reactivity effects during the initial progression of a hypothetical unprotected LOF event would be less severe for the heterogeneous core than for the homogeneous core in view of the lower sodium void worth and the Doppler and sodium void worth contributions of the internal blanket assemblies.

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1. CRBRP Preliminary Safety Analysis Report, Project Management Corporation.
  2. "Hypothetical Core Disruptive Accident Considerations in CRBRP; Energetics and Structural Margin Beyond the Design Base," CRBRP-3, Vol. 1.
  3. S. K. Rhow, et al., "An Assessment of HCDA Energetics in the CRBRP Heterogeneous Reactor Core, CRBRP-GEFR-00523, October 1981.
  4. J. L. McElroy, et al., "An Analysis of Hypothetical Core Disruptive Events in the Clinch River Breeder Reactor Plant," CRBRP-GEFR-00103, April 1978.
  5. W. R. Bohl, et al., "An Analysis of the Unprotected Loss-of-Flow Accident in the Clinch River Breeder Reactor with an End-of-Equilibrium-Cycle Core," ANL/RAS 77-15, May 1977.

Table 1\*

Comparison of Doppler Coefficient and Core Region Sodium  
Void Worth between Current Heterogeneous and Previous  
Homogeneous Cores for CRBRP

	Heterogeneous		Homogeneous	
	BOC-1	EOC-4	BOEC	EOEC
Sodium Void Worth, \$				
Fuel	-0.35	1.10	2.6	2.8
IB	0.95	1.11	-	-
Total	0.60	2.21	2.6	2.8
Doppler with Sodium In, $T \frac{dk}{dT} \times 10^2$				
Fuel	-0.29	-0.28	-0.52	-0.59
IB	-0.42	-0.44	-	-
Total	-0.71	-0.72	-0.52	-0.59
Doppler with Sodium Out, $T \frac{dk}{dT} \times 10^2$				
Fuel	-0.19	-0.18	-0.33	-0.38
IB	-0.34	-0.34	-	-
Total	-0.53	-0.52	-0.33	-0.38

\*Values from References 3 and 4

Table 2

Doppler and Sodium Reactivity Feedback at Initiation  
of Sodium Boiling and First Fuel Motion during  
LOF Event in Heterogeneous Core

	BOC-1 Core			EOC-4 Core		
	Time, sec	Reactivity Feedback*, \$		Time, sec	Reactivity Feedback(Fuel/IB), \$	
		Sodium	Doppler		Sodium	Doppler
Boiling Initiation in First Fuel Channel	11.15	-0.01	-0.04	12.65	-0.10 (0.05/0.05)	-0.14 (-0.05/-0.09)
Boiling Initiation in Last Fuel Channel	>20.14	-	-	18.80	1.07 (0.99/0.08)	-0.41 (-0.20/-0.21)
Initiation of Fuel Motion	20.14	-0.36	-0.20	19.60	1.17 (1.08/0.09)	-0.55 (-0.26/-0.29)

\* The sodium and Doppler reactivities from the internal blanket are negligible in the BOC-1 core.