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The Impact and Control of Reactivity Mechanisms of a CANDU-6 Reactor

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ABSTRACT

The control problems of achieving a desired reactivity balance and spatial power distribution in a CANDU-6 reactor are unusual due to the enormous core volume, on-power refueling and intrinsic sensitivity to xenon-induced spatial flux oscillations. The objective of the paper is to investigate the operational characteristics of the CANDU-6 reactivity control mechanisms, their individual effect on the core reactivity balance and the control logic performed by the Reactor Regulating System (RRS) to command these devices under normal, load-following and upset conditions.

This work rigorously assesses the hierarchical coordination between the RRS and the physical reactivity devices. The RRS continually calculates bulk power errors and local zone tilts utilizing feedback from out-of-core ion chambers, prompt in-core flux detectors and flux-mapping detectors. The results show how the RRS smoothly turns on several mechanisms to maintain the global reactivity balance. The primary short-term bulk and spatial control is accomplished by continually regulating the light water level across the compartmentalized Liquid Zone Control (LZC) assemblies to suppress regional flux tilts and to accommodate modest routine perturbations. In the event that the reactivity requirements surpass the normal control range of the liquid zones, the RRS automatically orders the mechanical devices, driving them at varying speeds directly proportionate to the effective power error. To compensate for positive reactivity deficits—such as during xenon buildup following a power reduction or a reactor trip—normally inserted adjuster rods are withdrawn in banks to supply positive reactivity while maintaining an optimal flattened flux profile. Conversely, when excess positive reactivity drives average liquid zone levels toward their upper operational limits, normally poised Mechanical Control Absorbers (MCAs) are driven into the core to supply necessary negative reactivity. Long-term reactivity balance is sustained through on-power refueling operations and the controlled addition or removal of soluble poisons in the moderator. Furthermore, the RRS integrates Setback and Stepback routines that override normal control to automatically ramp down power or release MCA clutches for rapid gravity insertion, mitigating transients without requiring a full reactor trip.

In essence, maintaining a successful stable reactivity balance in a CANDU-6 core depends on the RRS dynamically assigning control authority between continuous fluidic absorption in the LZC units and discrete mechanical shim adjustments from the

adjuster and absorber banks. The RRS adjusts the actuation speed and functional limits of each mechanism according to the power error on the core, thereby mitigating spatial xenon transients, keeping the liquid zones in their optimum control range and preserving both reactor safety and operational flexibility.