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XENON AND SAMARIUM REACTIVITY EFFECTS ASSOCIATED WITH COOLANT LOSS

By

R. E. Heineman and D. E. Wood

Reactor Lattice Physics

PHYSICS AND INSTRUMENT RESEARCH AND DEVELOPMENT OPERATION

HANFORD LABORATORIES OPERATION

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XENON AND SAMARIUM REACTIVITY EFFECTS ASSOCIATED WITH COOLANT LOSS

I INTRODUCTION

In Hanford reactors the reactivity gain upon loss of coolant water is an important factor in the speed of control requirements. The reactivity gain in the cold, clean reactor is determined from experiments, but additional effects must be taken into account if the gain in the operating reactors is to be obtained. One of these effects is the change in Xenon and Samarium poisoning with neutron temperature, which is discussed here.

Earlier work on the relationship of operating limits to the reactivity gain upon loss of coolant is given in Reference 1. Work on this problem is continuing by Reactor Physics, IPD, but the newer work is not yet documented. In earlier calculations, the neutron temperature could only be guessed. Recent measurements of neutron temperatures[2] have indicated the magnitude of the neutron temperature change upon loss of water. This document interprets the data of Reference 2 in terms of the change in Xenon and Samarium poison to be expected on water loss under typical operating conditions.

II CONCLUSIONS

For typical operating conditions of the old Hanford reactors (B, D, F), the neutron temperature change upon water loss decreases the Xenon and Samarium poison effect by about 100 inhours. This effect increases the reactivity gain upon loss of coolant, which may be significant in terms of operating limits since some of these limits are imposed by water-loss reactivity gain.

III THE EFFECT OF NEUTRON TEMPERATURE UPON XENON AND SAMARIUM TRANSIENTS

The Xenon cross section is a complicated function of temperature, first increasing with increasing neutron temperature and then decreasing with further increases in neutron temperature. The Xenon transients are not routinely calculated as a function of the temperature; and indeed such a calculation would be so complex as to defy routine calculation. Thus, it would appear that the temperature effects of the Xenon transients will be calculated only for those particular circumstances in which they may be of importance from the point of view of safety or of obtaining precise reactivity data under operating conditions.

Some of the effects of temperature on the transients are calculated in Reference 3. This reference gives a method of using the Xenon tables in routine use in the pile areas to make such temperature dependent calculations. Reference 3 points out the fact that there is a prompt jump in the pile reactivity due to Xenon whenever there is a prompt jump in the neutron temperature. However, it is also pointed out that the equilibrium poisoning is to a large extent independent of these temperature effects since the poisoning is dependent upon the product of the Xenon cross section and the Xenon concentration. If the Xenon cross section increases or decreases because of a change in the neutron temperature then the Xenon concentration tends to decrease or increase, respectively, in partial compensation for the change in the cross section. Indeed, if Xenon were stable, like Samarium, then the Xenon equilibrium poisoning would be independent of the Xenon cross section and thus the neutron temperature.

It is our purpose to point out here that the piles are now operating in the range of graphite temperatures such that an increase in the neutron temperature results in a decrease in the Xenon cross section. Since the loss of cold coolant water increases the neutron temperature by about 200 degrees, this loss causes a prompt decrease in the Xenon, and Samarium, poison. This is in the direction of increasing the reactivity of the hot pile. The change in the poisoning effect of Xenon and Samarium is illustrated in Table I. It was assumed for the purpose of this calculation that the pile was operating with a graphite temperature of 627 C and a neutron temperature of 427 C, with a Xenon poisoning of 1000 inhours, and with a Samarium poisoning of 220 inhours. The table then gives the change in the Xenon and Samarium poisoning after a jump in the neutron temperature to some other value. For example, upon loss of cold coolant water the neutron temperature would jump approximately to the graphite temperature of 627 C, which results in a loss of 97 inhours in the Xenon and Samarium poisoning. The cross section data for these calculations come from Reference 4.

TABLE I

T(C)	g Factors Xe	g Factors Sm	Poisoning Xe	Poisoning Sm	Immediate Change in Poisoning After Temp. is Changed Xe	Immediate Change in Poisoning After Temp. is Changed Sm	Total Change in Poisoning
27	1.169	1.646	986	166	-14	-54	-68
127	1.235	1.957	1041	198	+41	-22	+19
227	1.246	2.125	1051	215	+51	-5	+46
327	1.224	2.187	1033	221	+33	+1	+34
427	1.185	2.179	1000	220	0	0	0
527	1.136	2.136	959	216	-41	-4	-45
627	1.084	2.064	915	208	-85	-12	-97
727	1.031	1.988	872	201	-128	-19	-147
827	0.980	1.903	827	192	-173	-28	-201
927	0.933	1.819	787	184	-213	-36	-249
1027	0.887	1.734	748	175	-252	-45	-297

IV THE CHANGE IN NEUTRON TEMPERATURE UPON LOSS OF WATER

In Reference 2 the neutron temperature T_n(dry) in the fuel in a dry lattice is given as

$$T_n(\text{dry}) = \frac{1.208\ T_g}{1 + 1.299 \times 10^{-4}\ T_g}$$

and that in the wet as

$$T_n(\text{wet}) = \frac{1.218\ T_g}{1 + 3.70 \times 10^{-4}\ T_g}$$

where T_g is the graphite temperature in $^{\circ}$K. If we insert T_g = 927 K, we find that the difference in the neutron temperature is

$$\Delta T_n(\text{dry - wet}) = 147\ \text{C}$$

This is the change caused by the loss of coolant in one fuel channel. It is estimated that the change caused by the loss of coolant in 8 surrounding channels is only 50% as large. Thus, the total change caused by that loss of coolant is approximately 147 + 73 = 220 C.

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(3) Czirr, J. B. and R. E. Heineman, Xe Transients as a Function of Neutron Temperature, HW-36216, p. 21.

(4) Westcott, C. H., Effective Cross Section Values for Thermal Spectra, and its Supplement, CRRP-787 and CRRP-862.

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