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A METHOD FOR CALCULATING PLUTONIUM SOURCE LMFBR ACCIDENTS

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A METHOD FOR ESTIMATING PLUTONIUM SOURCE IN LMFBR ACCIDENTS

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In liquid-metal fast breeder reactors (LMFBR's) the more abundant uranium-238 isotope is converted to plutonium, which can be utilized as a fissionable nuclear fuel. The fuel in LMFBR's is a mixture of about 20% plutonium and 80% uranium-238. Current generation LMFBR's use UO_2-PuO_2 fuel.

A major concern in LMFBR safety analysis is the release of biologically hazardous plutonium aerosols to the environment in the event of a large accident. The plutonium-vapor source term determines the initial conditions of plutonium transport as particulate aerosols. These plutonium aerosols could result from condensation of plutonium vapor that has been vaporized during the accident. The rate of aerosol production will be directly related to the rate of vaporization. Experimental and analytical results show that sizes for condensed plutonium particles before agglomeration and coagulation are less than 1µm[1,2]. These submicron-size particles are the primary radiological source available for leakage to the environment.

The objective of this work was to estimate upper limits for the generation of vaporized plutonium during disassembly and during subsequent expansion of the fuel in a large core-disruptive accident. Fuel-vapor generation during disassembly was calculated using the VENUS-II code[3]. The expansion after disassembly was assumed to be isentropic. The fuel was allowed to expand to low pressure; and in this process further fuel vapor was formed. Heat transfer and mixing prior to expansion might reduce fuel-vapor source while at the same time generating sodium vapor.

In VENUS-II the fuel density in each mesh cell is calculated during disassembly. By using the fuel properties, described in Reference(4), the quality and, hence, the mass of fuel vapor in each cell during disassembly were calculated. Fuel-vapor generation during isentropic expansion was calculated from the initial conditions of the fuel at the end of disassembly and the final conditions at the end of an expansion to a specified final pressure. The amount of plutonium vaporized in each mesh cell is the product of the plutonium atom fraction in the fuel($\sim$20%) and the total mixed-oxide fuel vaporized. It was assumed that PuO_2 acts like UO_2. Then plutonium-vapor inventory for the whole core is equal to the sum of the plutonium vaporized in each mesh cell.

The analytical method was applied to the test case calculation of Jackson and Nicholson[3], which was a core-disruptive accident with sodium present, based on Fast Flux Test Facility geometry. Cases were also calculated with sodium removed or partially removed from the core, but the reduction in the doppler constant from -0.0040 to -0.0025 where sodium was completely removed. The results are given in Table 1. Little vapor generation was calculated for the sodium present case but a sizable fraction of the fuel vaporized in the sodium removed cases. Vaporized plutonium-time histories are shown in Fig. 1.

These results represent one step in the estimation of the plutonium source term. Only a small fraction of these results, after condensation, can escape from the primary system to the containment building.

TABLE 1

Percentages of the Total Plutonium Vaporized[x]

Case	End of Disassembly	Isentropic Expansion to Pressure P p=100 atm.	p=30 atm.	p=10 atm.	p=1 atm.
1 (sodium-in)	10^{-4}	10^{-4}	10^{-4}	0.004	0.4
2 (partially voided)	0.1	1.2	3.7	6.0	8.9
3 (sodium-out)	0.4	2.9	6.4	8.7	11.6

[x]Total Plutonium Mass ~689 Kg.

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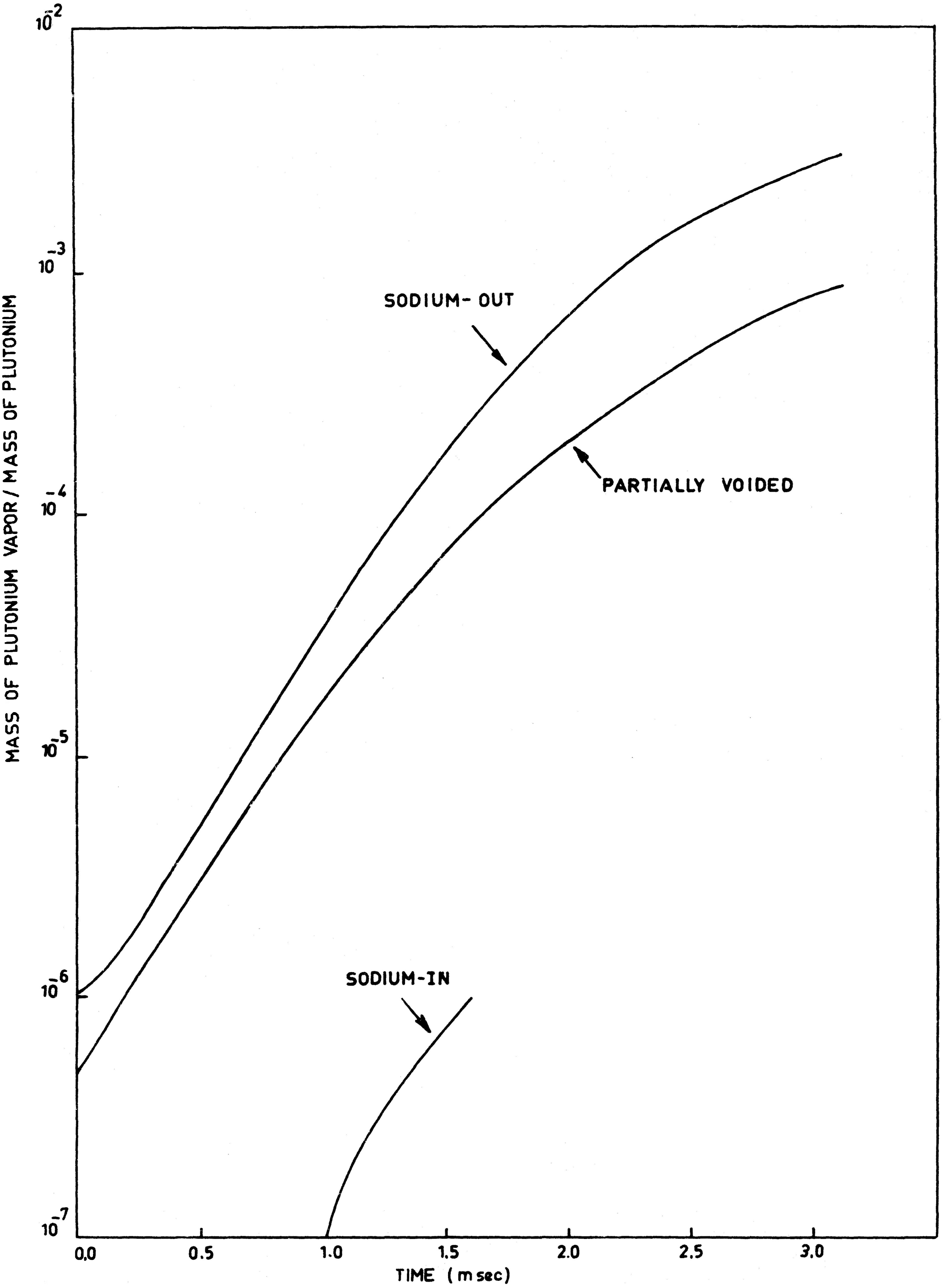

Fig. 1 Relative mass of plutonium vapor produced during disassembly.