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EXPERIMENTAL TEST OF THE FREVAP-8 CODE FOR CALCULATING METAL FISSION PRODUCT RELEASE FROM HTGR FUEL ELEMENTS

by

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1. SUMMARY

In the FREVAP-8[1] calculation it is assumed for simplicity that the migration of fission product metals such as strontium and barium through the fuel free graphite that separates HTGR fuel from its helium coolant can be represented by steady-state diffusion equations. The external boundary condition contains the metal adsorption isotherms and mass transfer coefficients derived using known heat transfer correlations. We seek to test these and other more detailed assumptions by comparing observed and calculated releases from experimental fuel elements irradiated in the PLUTO loop at Harwell for Dragon Project [2, 3] and in the General Atomic (GAIL) loop in GETR at Vallecitos[4].

That a steady state had been reached in the two PLUTO experiments is shown by the forms of observed radial concentration gradients in their 1.3 mm fuel free zones (Fig. 1A). Similar examination of the GAIL element indicated clearly that steady state had not been achieved for the longer-lived strontium isotopes in the thicker graphite between fuel and coolant (Fig. 1B).

Release rates for the fuels and diffusion coefficients used in the calculations were derived from unpublished measurements made on components of these and other experiments, both in and out of pile. The adsorption isotherms used were those determined at Gulf General Atomic for a nuclear grade (TS-688) graphite[5].

Table 1 describes the experiments; Table 2 the results of the comparisons between experiment and calculation. Analyses of the coolant gas showed that the rates of release of Kr^{89}, Kr^{90}, Xe^{140} were insufficient to account for the Sr^{89}, Sr^{90}, and Ba^{140} found in the PLUTO coolant circuits.

The FREVAP-8 calculation for the GAIL element yielded Sr releases which were very much higher than those observed. Here neglect of transient diffusion for strontium has resulted in a calculated strontium release > 100 times that observed. For the short-lived Ba^{140} the situation is reversed because the calculation predicts that effectively all the Ba^{140} will decay during its passage through the thick fuel tube, as is in fact found experimentally, whereas in reality there is a small release of Ba^{140} as Xe^{140}. Confirmation that Xe^{140} release can account for observed Ba^{140} has been obtained from GAIL and other experiments with similar thick fuel tubes.

We conclude that estimates of release from HTGR fuel elements, in general, were quite conservative. Methods of calculation taking into account transient behavior are recommended so that economic penalties from overdesign or the overestimation of hazards associated with Sr^{90} in the coolant will be avoided.

2. ACKNOWLEDGEMENTS

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2. REFERENCES

1. Zumwalt, L. R., "FREVAP-8 Code for Estimating the Release of Metallic Fission Products from HTGR Fuel Elements," USAEC Report GAMD-7535, General Dynamics Corporation, General Atomic Division, (Dec. 1966).

2. Brown, P. E., deNordwall, H. J., "Post Irradiation Radiochemical Analysis of Charge 8 for PLUTO Loop A," UKAEA Report, AERE-R 5040 (1965).

3. deNordwall, H. J., Brown, P. E., Davis, I. J., Heap, C. R., "Post Irradiation Radiochemical Analysis of Charge 15 at PLUTO Loop A," UKAEA Report, AERE-R 5404 (1967).

4. Bell, W. E., Anderson, E. E., Milstead, C. E., "Post-Irradiation Chemical Examination of the GAIL IV Fuel Element," USAEC Report, Gulf General Atomic Incorporated, GA-8588 (1968).

5. Norman, J. H., Bafus, D. A., Milstead, C. E., Staley, H. G., unpublished data. Gulf General Atomic Incorporated.

Table 1

Description of In-Pile Loop Experiments

Experiment	Fuel Coating	Irradiation Time Days	Peak Fuel Temperature °C	Peak Surface Temperature °C	Fuel Free Zone Thickness (L) mm	Coolant Flow Rate g sec^{-1}
PLUTO 8	PyC/SiC/PyC	173	1400	1350	1.25	18
PLUTO 15	PyC/PyC	162	1370	1320	1.25	18
GAIL 4	PyC/PyC	400	1450	1100	$\leq$6.35	35

PyC - Pyrocarbon.

Note: L^2/D for a PLUTO element is > 1/23 that for GAIL 4 - hence a PLUTO element is that much closer to steady state. Alternatively a PLUTO element represents the behavior of an element with a 6 mm fuel free zone after > 10 years irradiation - other things being equal.

Table 2

Comparison of Observed vs FREVAP Calculated Sr and Ba Activity Release (in curies) for PLUTO 8, PLUTO 15 and GAIL IV

Nuclide	Experimental Data	Based on FREVAP
	PLUTO 8	
Sr^{90} - To FFZ*	2.7×10^{-2}	8.4×10^{-3}
Sr^{90} - To coolant	7.3×10^{-3}	6.9×10^{-3}
Sr^{89} - To FFZ	1.2	3.4×10^{-1}
Sr^{89} - To coolant	3.2×10^{-1}	2.7×10^{-1}
Ba^{140} - To FFZ	5.2×10^{-2}	3.4×10^{-2}
Ba^{140} - To coolant	2.2×10^{-3}	1.8×10^{-5}
	PLUTO 15	
Sr^{90} - To FFZ	Not determined	7.0×10^{-1}
Sr^{90} - To coolant	Not determined	6.5×10^{-1}
Sr^{89} - To FFZ	4.4×10^{1}	3.6×10^{1}
Sr^{89} - To coolant	3.5×10^{1}	3.3×10^{1}
Ba^{140} - To FFZ	4.8	9.2
Ba^{140} - To coolant	5×10^{-2}	5.0
	GAIL IV	
Sr^{90} - To FFZ	4.7	6.4×10^{1}**
Sr^{90} - To coolant	2.8×10^{-2}	5.2
Ba^{140} - To coolant	$(3 \text{ to } 12) \times 10^{-5}$	5.8×10^{-11}

* FFZ - fuel free zone (to FFZ signifies the total quantity entering zone).

** Based on a conservative (high) estimate of "release constants". A calculated release of 2.4 curies is obtained using release data from in-pile experiments.

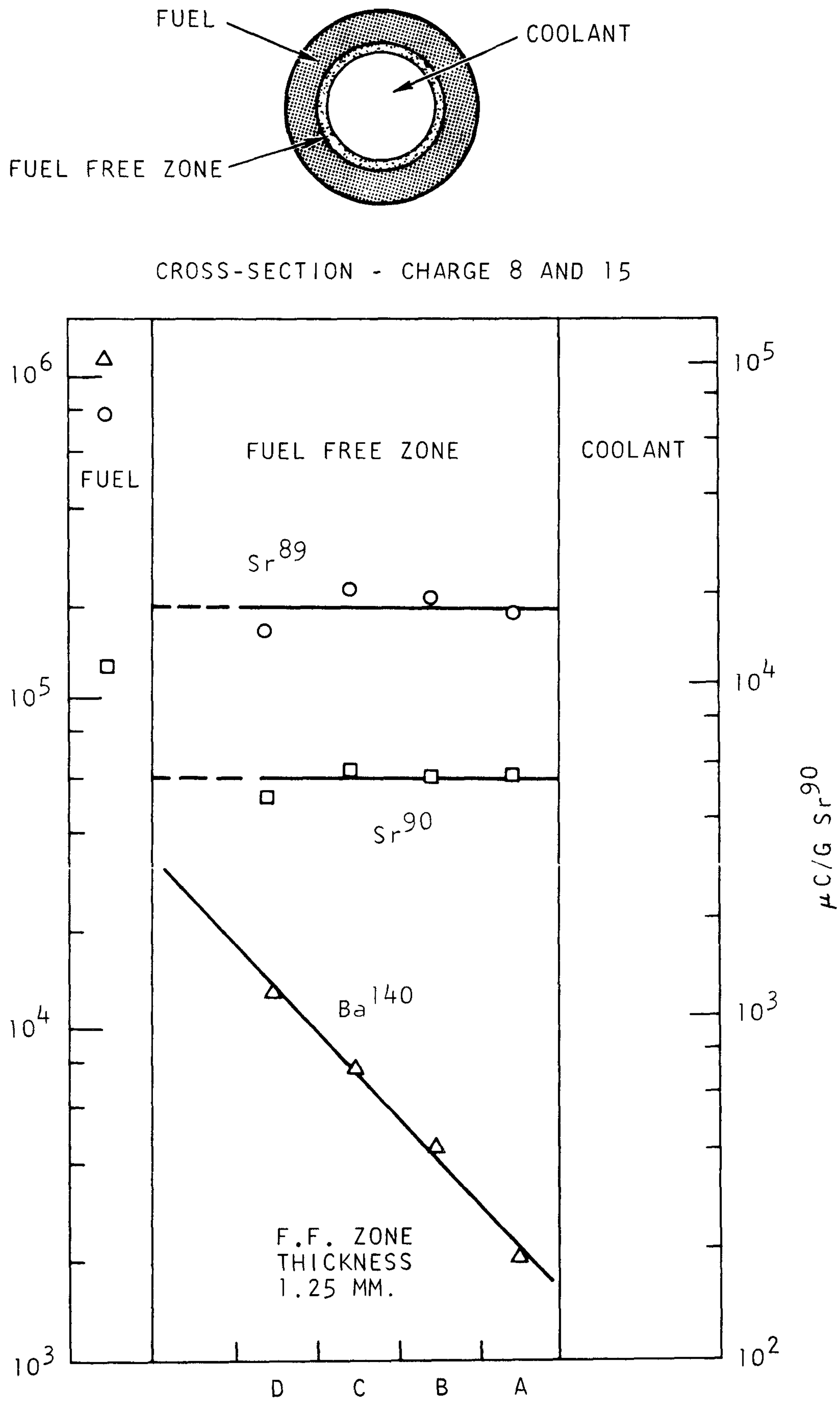

Fig. 1A. PLUTO fuel element configuration and data

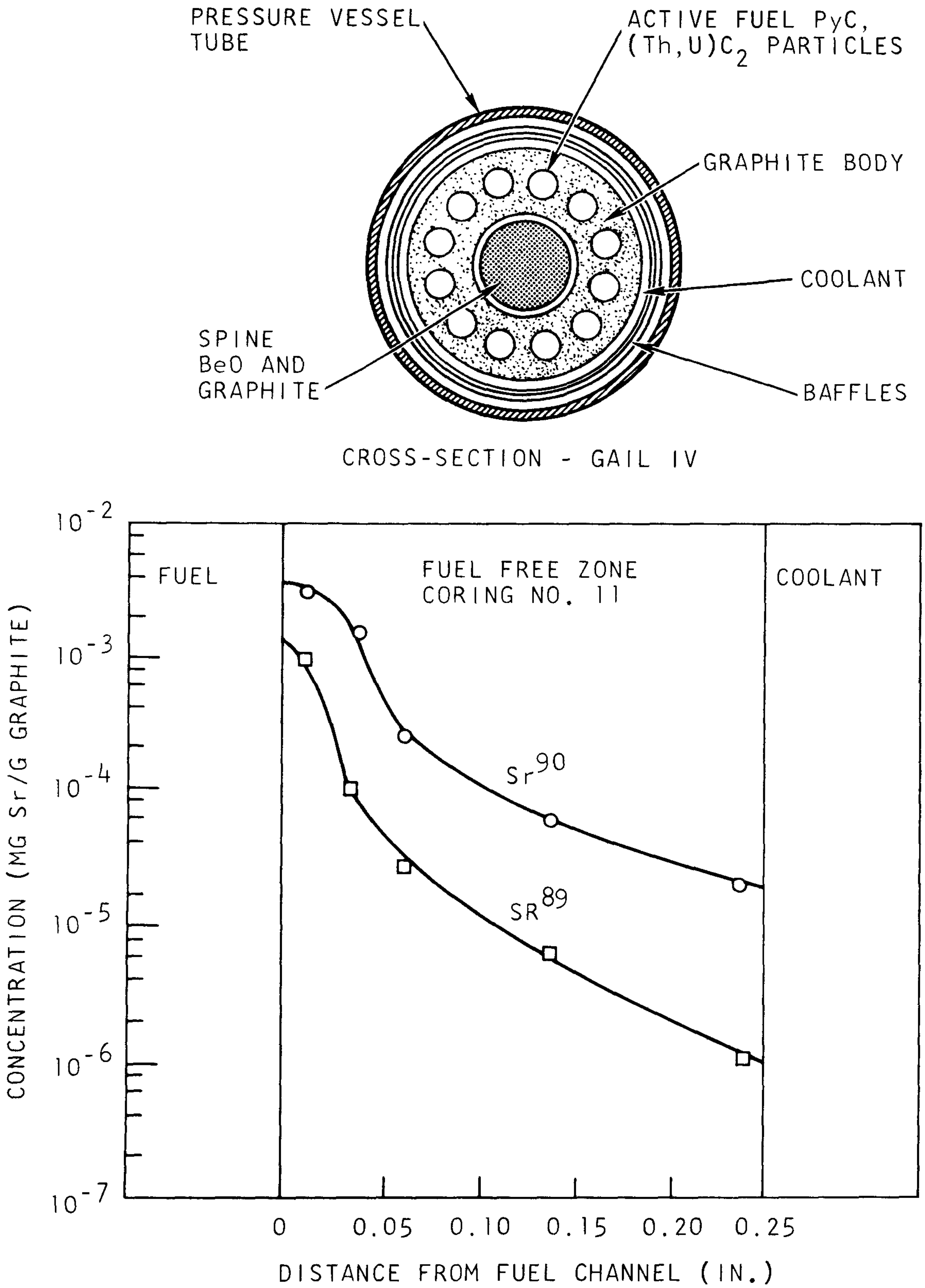

Fig. 1B. GAIL IV fuel element configuration and data