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COMPARISON OF DESIGN AND NUCLEAR PARAMETERS OF THE S.G.H.W. POWER REACTOR AND DIMPLE EXPERIMENT

H. R. McK. HYDER

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H. R. McK. Hyder.

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COMPARISON OF DESIGN AND NUCLEAR PARAMETERS OF THE S.G.H.W. POWER REACTOR AND THE DIMPLE EXPERIMENT

by H. R. McK. Hyder

1. The S.G.H.W. experiment in DIMPLE is designed to resemble the boiling region of a S.G.H.W. power reactor, the varying density of the coolant in the power reactor being simulated in DIMPLE by the presence of mixtures of H_2O and D_2O. By choosing suitable volume ratios of H_2O to D_2O, mixtures may be obtained which have similar moderating and neutron absorbing properties to mixtures of steam and water of densities varying from 1 to 0.2 gms/c.c.

The use of existing fuel and of pressure and calandria tubes of standard sizes made it impossible to reproduce the mechanical design of the proposed S.G.H.W. core in DIMPLE. The DIMPLE core was therefore designed to have similar nuclear properties to the power reactor core so that the neutron spectrum, resonance escape probability and other nuclear properties which would be measured in the course of the experiments should be similar to those in the power reactor (however, it is not possible in DIMPLE to reproduce effects due to the elevated temperatures in the power reactor coolant channels). The design parameters of DIMPLE and the proposed power reactor are compared in Table 1.

2. The criteria chosen for nuclear similarity are:-

(i) that the ratio of neutron absorption (barns) per moderator atom should be the same in the two cases. In this context moderator refers only to the D_2O in the calandria tank.

(ii) that the ratio of neutron absorption (barns) per "coolant" atom should be the same in the two cases. The "coolant" is water and steam in the power reactor and a mixture of H_2O and D_2O in DIMPLE. The atoms of deuterium are treated as hydrogen of lower moderating power. Considering only fast group properties, the ratio of

$$\frac{\xi\Sigma s(D)}{\xi\Sigma s(H)} = 0.117$$

and the number of D_2O molecules is therefore weighted by this factor and added to the number of H_2O molecules in the coolant channels.

Due allowance is made in the DIMPLE core for the regions at the end of each fuel cluster which do not contain fuel, so that the proportions of different materials in the core are not obtained directly from the cross-sectional areas through the middle of the fuel cluster. Because the detailed arrangement at the end of the fuel rods in the power reactor was not known no allowance has been made for these regions and the data for the power reactor therefore apply to a core with long unbroken fuel rods.

3. The conditions in the boiling zone of the power reactor which are of interest range from the initial cold condition, in which the coolant channel is full of H_2O of density 1 gm/c.c., to the burn out condition, in which the channel is full of steam at a density low enough to be neglected.

Under normal operating conditions a boiling zone fuel channel operates at 282°C and 997 p.s.i.a. The outlet mixture contains 13% steam by weight. This corresponds to a coolant density of 0.746 gms/c.c. at the inlet and 0.202 gms/c.c. at the outlet. The (arithmetic) mean coolant density for the channel is then 0.474 gms/c.c.

The ratios of neutron absorption per moderator atom and per "coolant" atom have been calculated for these coolant densities and for the extreme burn-out and cold conditions and are tabulated in Table 2 together with the equivalent ratios for the DIMPLE core containing the appropriate mixtures of D_2O and H_2O. In calculating this table a value of 1.6 Co has been assumed for the initial enrichment of the core specified in DEG Memo 304A(R).

It will be seen that if the chosen criteria for nuclear similarity are valid it will be possible to simulate all the important conditions of the power reactor in DIMPLE with sufficient accuracy using at most three different mixtures of D_2O and H_2O.

TABLE 1

COMPARISON OF DESIGN PARAMETERS

[Boiling zone of S.G.H.W. Reactor (1st and 3rd lists of parameters) and centre zone of DIMPLE experiment.]

Parameter	DEG Memo 304A (R)	DEG Memo 304B (R)	DIMPLE
1. CORE			
Fuel length	10.93 ft	10.93 ft	6.89 ft
Lattice pitch	9.5" square	9.625" square	8.375" square
2. FUEL ELEMENT ASSEMBLY			
Fuel	UO_2	UO_2	UO_2
UO_2 density	10.4 g/c.c.	10.4 g/c.c.	10.38 g/c.c.
UO_2 pellet diameter (cold)	0.55"	0.43"	0.3"
Canning material	Zircaloy 2	Zircaloy 2	Aluminium
Can O.D. and wall thickness	0.63" x 0.040"	0.50" x 0.033"	0.378" x 0.036"
Number of fuel rods per assembly	37	61	90
Number of assemblies per channel	2 or 1	3	6
Type of rod pitch	Circular	Circular	Circular
Number of rods on successive circles	1, 6, 12, 18.	1, 6, 12, 18, 24.	6, 12, 18, 24, 30.
V_{D_2O}/V_{UO_2}	6.12	6.03	6.3
V_{H_2O}/V_{UO_2}	1.11	1.30	1.91
Initial Enrichment	?	1.79 Co	1.6 Co
3. CHANNEL DESIGN			
Pressure tube material, I.D.	Zircaloy, 5.21"	Zircaloy, 5.46"	Aluminium, 5.244"
Pressure tube wall thickness	0.286"	0.31"	0.128
Calandria tube material, I.D.	Aluminium, 6.532"	Aluminium, 6.83"	Aluminium, 6.241"
Calandria tube wall thickness	0.128"	0.128"	0.192"
Width of calandria/pressure tube annulus.	0.375"	0.375"	0.370"

TABLE 2

COMPARISON OF NUCLEAR PARAMETERS

Reactor Condition	Parameter	DEG Memo 304A (R)	DEG Memo 304B (R)	DIMPLE
1. Burn Out	Coolant barns/moderator atom barns/'coolant' atom	$\rho = 0$ .617 ∞	$\rho = 0$ .685 ∞	Air $\rho = 0$ .654 ∞
2. Outlet of boiling channel	Coolant barns/moderator atom barns/'coolant' atom	Steam + H_2O, $\rho = 0.2$ .629 17.2	Steam + H_2O, $\rho = 0.2$ .707 16.3	100% D_2O .654 18.4
3. Midpoint of boiling channel	Coolant barns/moderator atom barns/'coolant' atom	Steam + H_2O, $\rho = 0.475$ .646 7.3	Steam + H_2O $\rho = 0.475$ .737 7.15	20% H_2O, 80% D_2O .673 7.54
4. Inlet to boiling channel	Coolant barns/moderator atom barns/'coolant' atom	Water, $\rho = 0.75$ .662 4.8	Water, $\rho = 0.75$ .767 4.7	40% H_2O, 60% D_2O .694 4.84
5. Cold	Coolant barns/moderator atom barns/'coolant' atom	Water, $\rho = 1.0$ .677 3.71	Water, $\rho = 1.0$ .793 3.67	60% H_2O, 40% D_2O .715 3.62
6. Light Water in DIMPLE	Coolant barns/moderator atom barns/'coolant' atom	- - -	- - -	100% H_2O .755 2.47

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