ANALYSIS FOR THE SELECTION OF EXPERIMENTAL CONFIGURATIONS FOR HETEROGENEITY AND Be MULTI-LAYERED EXPERIMENTS OF U.S.DOE/JAERI COLLABORATIVE PROGRAM ON BLANKET NEUTRONICS

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ABSTRACT

Phase IIC of the experimental program is to begin in fall of 1988. An extensive pre-analysis has been carried out to select the experimental configurations. The investigations were confined to looking at the effect of (i) multi-layer arrangement of Be multiplier, (ii) the presence of contiguous layers of structure and coolant, (iii) the introduction of protective graphite armor in front of the first wall, on tritium production rate (TPR) in a Li_2O assembly. The basic materials and geometrical structure of the assembly, are derived from that of the Phase IIA. The structure is simulated by stainless steel (SS) and the coolant is either polyethylene (PE) or water. Generally, the heterogeneities strongly distort the local T_6 and T_7 distributions; their effect on global TPR is less marked. One of the two selected configurations has Be, in edge-on layered arrangement with Li_2O, as multiplier. In the second configuration, three coolant channels (SS+PE) will be incorporated to simulate structural heterogeneity.

I. INTRODUCTION

After the completion of Phase IIB experiments[1-3] of the ongoing collaborative program on fusion blanket neutronics between the U.S.(DOE) and Japan (JAERI), the stage is set for Phase IIC in fall 1988. After broad assessment of a range of experimental issues requiring attention, it was decided to concentrate on the analysis of geometrical and material arrangements that would bring out the effects of spatial heterogeneity.

Conceptual designs of fusion reactor blankets include a heterogeneous arrangement of different components, namely, first wall, multiplier, tritium breeder, coolant and associated structural materials. The homogenization of heterogeneous arrangements may not always be valid as is amply proved by the continuing research effort in conventional reactor physics. It is well known that the heterogeneities can considerably distort the neutron energy spectrum around them. The presence of such heterogeneities could affect considerably the local tritium breeding profiles and, perhaps, the global tritium breeding in a fusion blanket. The existence of heterogeneous interfaces involving one or more materials subject to uncertainties in cross-sectional data complicates the issue further. This leads us to check the modeling against specially tailored experiments.

For the pre-analysis we have confined ourselves to looking at the heterogeneities arising from: (i) multi-layer arrangement of beryllium as multiplier, and (ii) double layers of structure and coolant, (iii) protective graphite armor in front of cooled first wall. It is to be stressed here that the presence of heterogeneities does not necessarily lead to fall or rise in the global tritium breeding in spite of the large local variations. The global effects will, in general, be dependant on the detailed composition of assembly under investigation. The local effects, on the other hand, will be broadly dictated by the neutronics' characteristics of the materials present around the heterogeneities and, thus can be expected to be present in other designs too. There is, of course, a variable degree of interaction between these two effects, depending on the design.

II. SIMULATION OF HETEROGENEITY EFFECTS

The basic experimental configuration for the pre-analysis is derived from that of the Phase IIA. Full experimental configuration of the phase IIA was closed geometry type and consisted of a 60 cm-thick Li_2O test assembly placed inside a rectangular enclosure made of 20.5 cm-thick Li_2CO_3 and 5 cm-thick polyethylene[1-4]. This enclosure also housed the beam target which, in turn, faced the front side of the Li_2O assembly. The experimental configuration with Li_2O in the whole 60 cm-thick test region and without any liner, on the inner surface of the cavity where the the D-T beam target is located, is referred to as reference assembly in the following part of this work.

II.1. Layered Arrangements of Beryllium

The quest for the conditions leading to advantageous intermixing of beryllium multiplier and solid breeder is one of the cherished goals of a blanket designer. With a view to simulate some candidate arrangements the following four arrangements have been considered: (a) multi-layer, (b) edge-on, (c) ring, and (d) homogeneous. Fig. 1 shows all these. The beryllium layers of the heterogeneous configurations are constituted by arranging beryllium bricks of 5.08 x 5.08 x 5.08 cm dimensions each. In the arrangement (d), equal volumes of Be and Li_2O are homogeneously mixed in the first 20.3 cm part of the assembly. The total quantity used in the pre-analysis is constrained by the amount available for the earlier experiments. The total amount of Be was practically the same in all four arrangements, being equivalent to 578, 544, 543 and 578 bricks respectively. A reference arrangement of Li_2O, where Be is replaced by the same volume of Li_2O, was also considered.

II.2. Structure and Coolant Channels

The structure and coolant occupy important fraction of any fusion blanket design. The coolant channels too are accompanied by some structure. It is instructive to have a comparative look at the local as well as the global tritium production rate profiles in the heterogeneous and homogenized configurations. To simulate various situations, the following configurations have been taken up: (i) the reference arrangement without any structure, coolant, or multiplier as previously, (ii) a layer each of iron (Fe structure, 1 cm-thick) and water (H_2O coolant, 1 cm-thick) introduced in the void just in front of the reference arrangement; this double layer simulates a cooled first wall, (iii) two additional double layers of Fe + H_2O introduced in the middle (30 cm) and three quarters inside (45 cm) the Li_2O part; each of these represents a coolant channel with accompanying structure. Fig. 2 shows the configuration (iii). Additional configurations identical to (ii) and (iii) excepting the substitution of H_2O by polyethylene (PE) have also been analyze as it is easier to build an experimental configuration incorporating the latter. The effect of an inner liner for the lithium carbonate shell around the source of the region is simulated by comparing three cases: no liner, 5 cm-thick beryllium layer, and 5 cm-thick water liner.

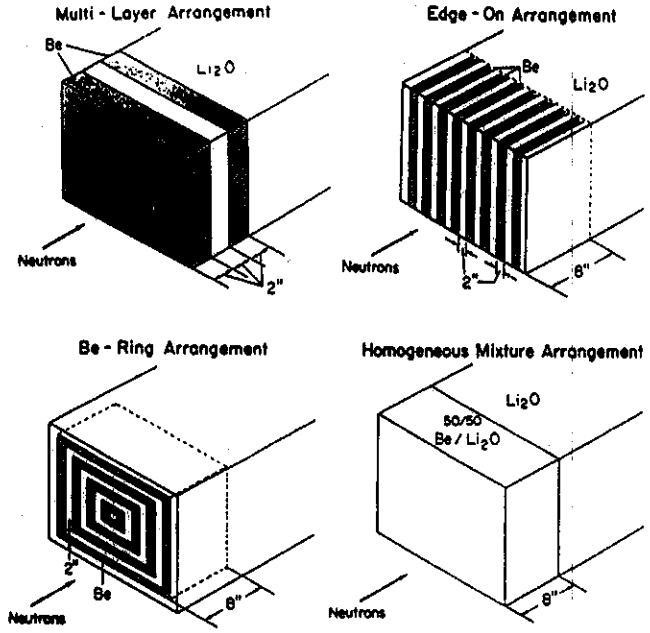

Fig. 1: The four layered arrangements of beryllium (1" ≡ 2.54 cm)

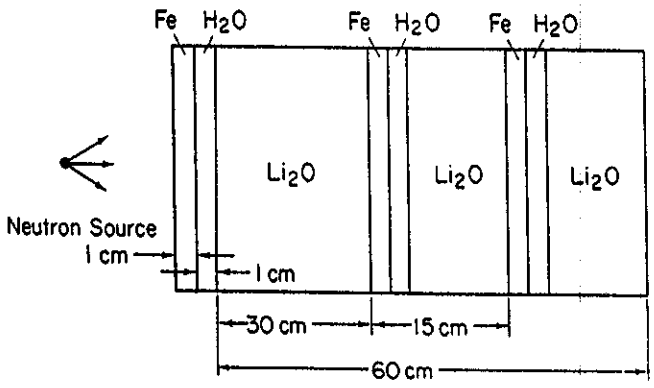

Fig. 2: The arrangement with the first wall and coolant channels

II.3. Graphite Protection

The current trend in the planning of next phase of large tokamaks is towards including a graphite or SiC protection for a metallic first wall[5]. This trend has been largely shaped by the experience with currently operational large tokamaks[5-8]. It is estimated that a low-density and a low-Z refractory material protection of at least one centimeter thickness is required[5] to handle the energy deposition by the plasma and runaway electrons during startup and disruptions. Also, it provides the protection against the neutral beam shine-through; ameliorates purity control; promotes the installation of the permeation barriers on the first wall surface. The absence of this protection could engender serious thermomechanical effects that could lead to drastic reduction in fatigue life and rapid splashing away of the melted regions of the first wall due to repetitive plasma disruptions[5]. The graphite materials are preferred over others because of their unique high-temperature capability and excellent thermal shock resistance.

The effect of the graphite protection has been investigated by intercomparing the following configurations: (1) the reference assembly, (2) 1 cm-thick Fe first wall plus 1 cm-thick H_2O coolant in front of the reference case, (3) 2.5 cm-thick graphite tile in front of the reference, (4) the graphite tile plus the cooled first wall in front of the reference assembly. Fig. 3 displays a schematic representation of the last configuration.

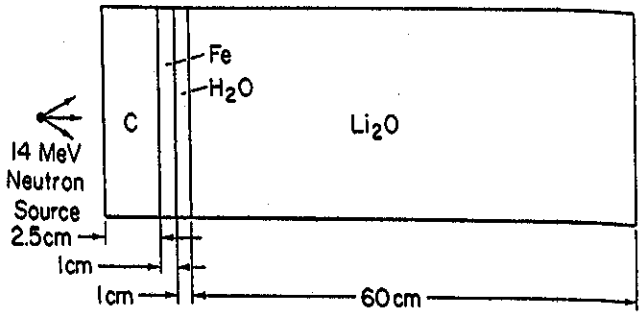

Fig. 3: Graphite armor protection (test region)

III. ANALYSIS

As the present analysis is basically a kind of scoping study for determining the relevant experimental configurations, the strategy consists in doing only two dimensional (2-D) computations unless it is judged necessary to take recourse to three dimensional (3-D) modeling. The 2D analysis was done using twin codes GRTUNCL4.3[9] (uncollided flux and first collision source evaluator) and DOT5[9]. GRTUNCL was used with point source option to mitigate ray effect associated with the discrete ordinates method used in DOT. The P_3-S_8 approximation was employed for discrete ordinates transport computations in R-Z geometry while using 30 group MATXS5 cross-section library[10]. This library has originated from ENDF/B-V rev.2. The neutron source was molded as a monoenergetic (13.5-15 MeV) point source at an axial distance of 78 cm from the facing surface of the Li_2O test region in the reference arrangement. Both local and global tritium breeding rates have been computed.

The analysis for multilayer arrangements of beryllium has been accomplished by 3D modeling through MCNP[11]. The pointwise cross-section data from ENDF/B-V rev.2 has been used in the calculations. Kinematics of a 30 KeV deuteron beam incident on a tritium-absorbing thin titanium layer on water-cooled copper backing has been taken into account as usual to define the energy-angle distribution of the source neutrons. Only global tritium rates have been evaluated.

IV. RESULTS AND DISCUSSION

The detailed results for the three types of heterogeneities are discussed herein separately.

IV.1 Multiple Be Layers

Table I displays globally averaged tritium atoms produced per natural lithium atom in the lithium oxide segment. The individual contributions, T_6 (from ^6Li) and T_7 (from ^7Li), are also provided along with their sum T_N. These values are also graphically represented in Fig. 4. One can note the significant enhancement in T_6 accompanied by a drop in T_7 due to the addition of beryllium in the first 8" of the lithium oxide segment. As T_6 makes dominant contribution to T_N, there is net improvement in global tritium breeding. It is to be underlined that both the edge-on and the ring cases register the largest changes in the range of 30%-similar to the homogenized arrangement. This is all the more interesting in view of the largest (n,2n)-multiplication value of 1.107(±0.1%) obtained in the multi-layer arrangement as shown in Table II. Partial explanation for this apparent discrepancy could come from this table itself. The number of the neutronic captures in ^6Li is the largest in the lithium carbonate part- the shell enclosing the lithium oxide segment- of the arrangement for the multi-layer. Thus, one might infer from this arrangement that, on average, the source neutrons suffer most collisions in the beryllium yielding highest (n,2n) such that the largest contingent of the multiplied neutrons escapes into the lithium carbonate to get captured there.

The effect on beryllium brick size on globally averaged (over lithium oxide) tritium production over source neutron has also been looked into. The base assembly has the edge-on arrangement. Four

Table I: Global TPR Comparison of Five Configurations

Configuration	T_6	T_7	T_N	T_N increase relative to no-Be Case (%)
no-Be	2.424-30*, **	1.187-30*	3.611-30*	—
multi-layer	3.619-30	6.724-31	4.292-30	18.8
edge-on(5.08cm)	3.855-30	8.135-31	5.668-30	29.3
Be-ring	3.891-30	8.159-31	4.707-30	30.3
homogeneous -mixture	3.866-30	7.911-31	6.410-30	29.0

* Tritium production rate per natural Li atom per source neutron averaged over the Li_2O test assembly. Tritium production in Be zone is not included. Also, read as 2.424 x 10^{-30}. Statistical error is about 0.1%
**Relative abundance of ^6Li = 7.4059%.

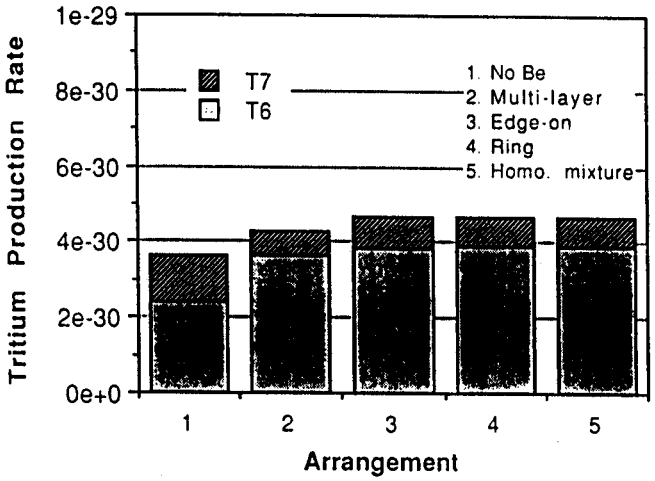

Fig. 4 Global tritium production rate

brick sizes have been studied.: 10.16, 5.08, 2.54 and 0 cm (homogenized). Note that in analyzing these cases, Li_2O layers also consisted of bricks of 10.16, 5.08, 2.54 and 0 cm (homogenized) in thickness and thus the ratio Be/Li_2O was kept constant (50/50). The total volume of the beryllium was the same for all four cases. Going up from 0 to 10.16 cm, only 5% drop in the tritium production is observed; the drop in (n,2n) multiplication is 0.5%. The brick size of 5.08 cm is already very close to the homogenized arrangement as is brought out by Table I. It is to be pointed out here that we, in fact, find that the average TPR drops by 1% in going from 0 to 2.54 cm brick size, only to rise again by 1% at 5.08 cm; then it drops by 5% for 10.16 cm. This kind of apparently anomalous behavior as a function of Be brick size is not entirely new; similar behavior has been observed in the domain of storage of fresh or used fuel elements wherein one finds two distinct processes competing with each other: self-multiplication in a fuel element and neutronic coupling of two fuel elements of the stored array[12-13]. Whereas self-multiplication is a function of the dimensions of the fuel element, the coupling between two elements depends not only on the distance between the two elements, but also on the properties of the intervening material. Thus one may even end up in a supercritical array for intermediate dimensions of a fuel element in spite of the array being subcritical for the neighboring size elements[12-13]. In the present case, a beryllium brick may be likened to a fuel element as it too multiplies higher energy neutrons through (n,2n) reactions.

IV.2. Structure and Coolant

The impact of the addition of the water-cooled iron first wall in front of the lithium oxide is found to be considered on the global tritium production. Further insertion of the two water-cooled iron channels inside the Li_2O does not bring about any drastic additional

Table II Comparison of Arrangements via Physical Events[1]

arrangement	Net Neutron multiplication	Number of Collisions w/Be per Source	Neutron capture reaction with ^6Li[(2)]	
			Li_2O	Li_2CO_3
No Be	1.047	0	0.0611	0.375
Multi-layer	1.107	3.11	0.0770	0.403
Edge-on (5.08 cm)	1.094	2.03	0.0818	0.383
Be-ring	1.092	2.16	0.0826	0.391
Homogeneous mixture	1.099	2.89	0.0835	0.383

1) Statistical error is about 0.1%
2) The values are weighted less due to cpature and are a measure of the amount of $^6Li(n,\alpha)T$ reactions

change in the global values. This is quite surprising in view of the fact that 4 cm-thick part of the Li_2O has actually been removed altogether for introducing the two water-channels inside. For example, the global T_N values go up respectively by 11.6 and 13.1% for the first wall alone and the structured water channels' cases; the T_6's rise by 19.7% and 23.4%; the T_7's drop by 4.5 and 7.2%. It is interesting to point out here that in an additional study, wherein the first 2 cm of the Li_2O are replaced by the same thickness of the water-cooled first wall, it is found that the global tritium production hardly changes with respect to the reference arrangement. In fact, T_N goes up by 0.1%; T_6 goes up 12%; T_7 drops by 24%. In view of the latter results, one understands the earlier ones.

The local effect of the introduction of the water-cooled first wall and the additional two layers of $Fe+H_2O$ inside the Li_2O is brought out in Tables III to V. The tritium values per source neutron per lithium atom are provided for the reference configuration; for the other arrangements, only the relative values with respect to the corresponding reference zones of the central drawer are provided. It is to be underlined here that there are large changes both in T_6 and T_N near the heterogeneities. Near the first wall, there is more than 60% increase in T_N; T_6 more than doubles; T_7 remains practically the same. Near the two inner channels too, there are large changes both in T_N and T_6 around heterogeneities; T_7 drops immediately following the heterogeneities but tends to improve somewhat as one moves away. Broadly, it can be stated that as one moves more than 5 cm away from a given heterogeneity, its impact on local $T_6/T_7/T_N$ gets largely dissipated. The three tables also display the tritium values for the case where polyethylene replaces the water as coolant everywhere including the first wall. One can observe the same trends as the water coolant cases.

Table III Relative Changes in T_N Profiles in the Central Drawer due to the First Wall and the Structured Coolant Channels in Li_2O

Zone No.	Zone bounds	T_N per Li Atom in Ref. assembly	T_N ratios		
			First Wall Alone ($Fe+H_2O$)	H_2O Channels	PE Coolant Channels
1	0-5 cm	1.033-29[a]	1.63	1.64	1.70
2	5-10 cm	8.182-30	1.05	1.05	1.01
3	10-15 cm	6.502-30	0.97	0.96	0.92
4	15-20 cm	5.154-30	0.95	0.92	0.87
5	20-25 cm	4.071-30	0.94	0.93	0.87
6	25-30 cm	3.200-30	0.93	1.20	1.19
7a	30-32 cm	2.500-30	0.93	0.0	0.0
7b	32-35 cm			1.97(1.18)[b]	2.05(1.23)[b]
8	35-40 cm	1.942-30	0.93	0.98	0.91
9	40-45 cm	1.501-30	0.93	1.01	0.94
10a	45-47 cm	1.161-30	0.93	0.0	0.0
10b	47-50 cm			1.47(0.88)[b]	1.44(0.86)[b]
11	50-55 cm	9.099-31	0.93	0.68	0.59
12	55-60 cm	7.535-31	1.06	0.52	0.44

[a]read as 7.517×10^{-29}
[b]averaged over the whole 5 cm-thick zone

Table IV Relative Changes in T_6 Profiles in the Central Drawer due to the First Wall and the Structured Coolant Channels

Zone No.	Zone bounds	T_6 per Li Atom in Ref. assembly	T_6 ratios		
			First Wall Alone (Fe+H_2O)	H_2O Channels	PE Coolant Channels
1	0-5 cm	7.517-29[a]	2.18	2.16	2.30
2	5-10 cm	6.143-29	1.12	1.11	1.06
3	10-15 cm	5.282-29	1.00	0.97	0.92
4	15-20 cm	4.541-29	0.96	0.92	0.87
5	20-25 cm	3.852-29	0.94	0.93	0.87
6	25-30 cm	3.213-29	0.93	1.31	1.30
7a	30-32 cm	2.637-29	0.93	0.0	0.0
7b	32-35 cm			2.31(1.38)[b]	2.42(1.45)[b]
8	35-40 cm	2.132-29	0.93	1.03	0.95
9	40-45 cm	1.704-29	0.93	1.05	0.98
10a	45-47 cm	1.355	0.93	0.0	0.0
10b	47-50 cm			1.60(0.96)[b]	1.56(0.94)[b]
11	50-55 cm	1.090-29	0.92	0.67	0.58
12	55-60 cm	9.296-30	1.05	0.50	0.42

[a]read as 7.517×10^{-29}
[b]averaged over the whole 5 cm-thick zone

Table V Relative Changes in T_7 Profiles in the Central Drawer due to the First Wall and the Structured Coolant Channels in Li_2O

Zone No.	Zone bounds	T_7 per Li Atom in Ref. assembly	T_7 ratios		
			First Wall Alone (Fe+H_2O)	H_2O Channels	PE Coolant Channels
1	0-5 cm	5.109-30[a]	0.98	1.02	0.99
2	5-10 cm	3.895-30	0.95	0.97	0.95
3	10-15 cm	2.773-30	0.94	0.94	0.92
4	15-20 cm	1.914-30	0.93	0.92	0.90
5	20-25 cm	1.298-30	0.94	0.90	0.88
6	25-30 cm	8.707-31	0.94	0.87	0.85
7a	30-32 cm	5.789-30	0.94	0.0	0.0
7b	32-35 cm			0.71(0.43)[b]	0.69(0.41)[b]
8	35-40 cm	3.820-31	0.94	0.79	0.76
9	40-45 cm	2.504-31	0.95	0.78	0.75
10a	45-47 cm	1.633-31	0.96	0.0	0.0
10b	47-50 cm			0.64(0.38)[b]	0.61(0.37)[b]
11	50-55 cm	1.056-31	0.97	0.71	0.68
12	55-60 cm	6.586-32	1.13	0.73	0.69

[a]read as 5.109×10^{-30}
[b]averaged over the whole 5 cm-thick zone

We have also carried out computations for the homogenized configurations wherein the whole mass of the inner water channel is homogenized with the remaining mass of the Li_2O over its original volume. Fig. 5 and Table VI highlight the local changed in tritium production rates that would be missed in homogenization procedure. Fig. 5 displays the relative profile for the heterogeneous configuration with respect to the homogenized one. Again, the large changes in the tritium production around the heterogeneities stand out.

The impact of the inner liner of the lithium carbonate is discussed in Table VII and graphically represented in Fig. 6. The case with water liners refers to a case wherein 5.08 cm thick Be liner is replaced by the same thickness of water. It is to be noted that even as the absolute tritium profiles are quite different, the magnitude of relative change entailed by the homogenization procedure is quite comparable all along.

It is interesting to look at the regionwise impact of the heterogeneities. Table VII gives the relative distribution of tritium production rate (TPR) in the Li_2O and the Li_2CO_3 regions for four cases. It is to be remarked that the introduction of the Be liner increases the TPR values in all parts of the assembly. The T_N in the Li_2O goes up by 80%; this is essentially due to (n,2n)-multiplication in beryllium. Except for the Be-liner case, the change in the total TPR over both the Li_2O and the Li_2CO_3 is within 7% with respect to the reference assembly; this is understandable as the heterogeneities are introduced only inside the Li_2O part.

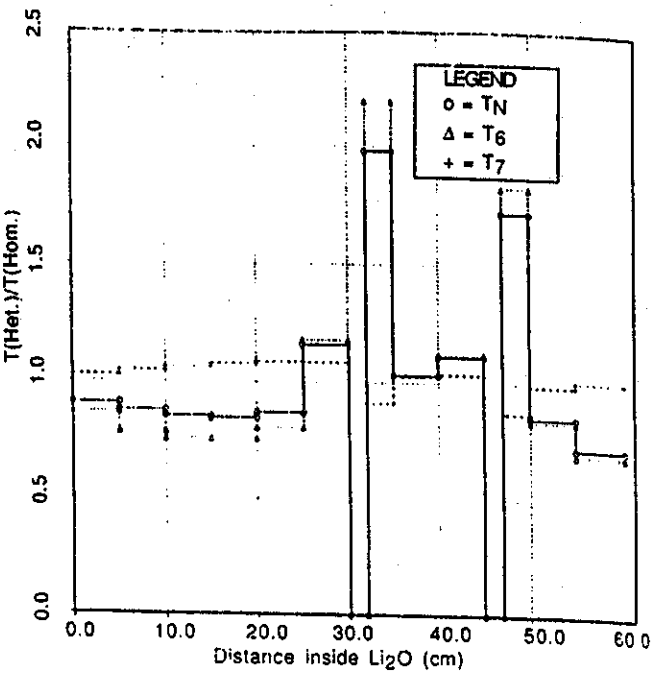

Fig. 5: Heterogeneity effect: H_2O Coolant/No Liner

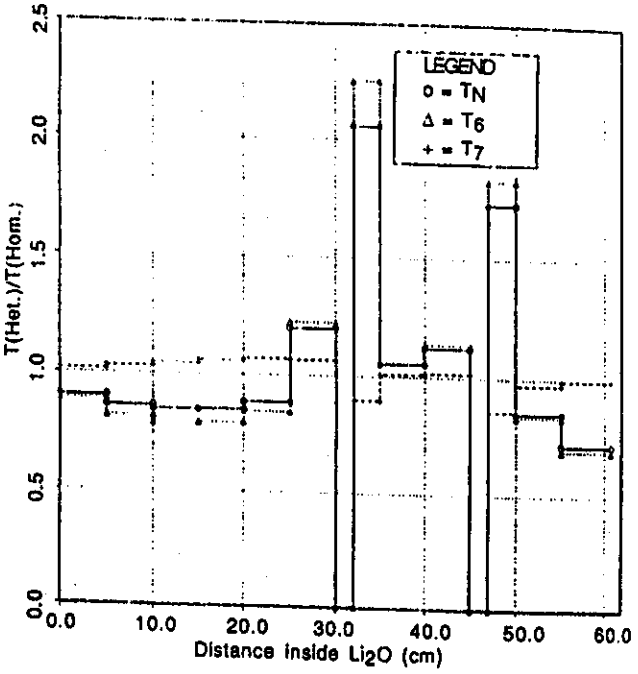

Fig. 6: Heterogeneity effect: H_2O Coolant and Be Liner

IV.3. Graphite Armor

Table VIII intercompares the axial profiles averaged over the 5 cm long central drawer segments for T_N for the other three cases as a function of the values for the reference configuration. Figures 7 and 8 display the spatial profiles for T_6 and T_7. It is to be noted that the introduction of the 2.5 cm armor alone has small effect on the T_N profile and it remains within ~3 to 10% of the reference case. The largest variations are seen just behind the armor and in the last zone of the central drawer. The inclusion of 1 cm Fe + 1 cm H_2O in front of the Li_2O part has relatively large impact on the T_N profile. The variation with respect to the reference is between ~7% and 63%. The largest difference is located in the first segment of the central drawer just

Table VI
Comparison of Zonal T_N per atom Li in the Central Drawer in the Heterogeneous and the Homogenized Arrangements in Different Configurations

Zone No.	Zone bounds	Fe/H_2O (No Liner)			$Fe/H_2O/Be$ (Be liner)			$Fe/H_2O/H_2O$ (Water liner)		
	Inside Li_2O	Het.	Hom.	% diff[a]	Het.	Hom.	% diff[a]	Het.	Hom.	% diff[a]
1	0-5 cm	1.692-29	1.866-29	10.3	3.975-29	4.414-29	11.0	1.775-29	1.944-29	9.5
2	5-10 cm	8.572-30	9.781-30	14.1	1.358-29	1.575-29	16.0	7.247-30	8.283-30	14.3
3	10-15 cm	6.231-30	7.306-30	17.3	8.932-30	1.056-29	18.2	5.346-30	6.326-30	18.3
4	15-20 cm	4.477-30	5.621-30	18.5	6.431-30	7.588-30	18.0	4.118-30	4.959-30	20.4
5	20-25 cm	3.752-30	4.324-30	15.2	4.891-30	5.546-30	13.4	3.283-30	3.870-30	17.9
6	25-30 cm	3.836-30	3.297-30	-14.1	4.860-30	4.055-30	-16.6	3.367-30	2.981-30	-11.5
7a	30-32 cm	0.0			0.0			0.0		
7b	32-35 cm	4.916-30	2.482-30	-49.5	6.061-30	2.946-30	-51.4	4.329-30	2.262-30	-47.7
8	35-40 cm	1.908-30	1.866-30	-3.2	2.246-30	2.126-30	-5.3	1.710-30	1.692-30	-1.1
9	40-45 cm	1.510-30	1.357-30	-10.1	1.713-30	1.523-30	-11.1	1.363-30	1.250-30	-8.3
10a	45-47 cm	0.0			0.0			0.0		
10b	47-50 cm	1.708-30	9.908-31	-42.0	1.878-30	1.086-30	-42.2	1.550-30	9.156-31	-40.9
11	50-55 cm	6.179-31	7.260-31	17.5	6.616-31	7.803-31	17.9	5.655-31	6.776-31	19.8
12	55-60 cm	3.895-31	5.381-31	38.2	4.078-31	5.685-31	39.4	3.573-31	5.025-31	40.6

[a] for homogeneous over heterogeneous arrangement

behind the added materials. It could be inferred that the neutron spectrum-softening due to the presence of the first wall and coolant dominates in determining the tritium production around the heterogeneity. The addition of 2.5 cm graphite before the Fe leads to even larger changes in the profile. The relative change for this profile is situated between ~21% to 66%. The T_N profile undershoots that of the preceding case right from the second zone onwards. Thus the addition of the protective graphite armor in front of the iron first wall leads to considerable degradation in tritium production in the central drawer. The relative fall in the local T_N values as much as 15% in most of the drawer.

It is instructive to note that the variations in T_6 are significantly larger than those in the T_N for the first 5 cm zone. For the more profound zones, the T_6 profile follows closely the T_N. The T_7 profile for the fourth assembly, having graphite protection in front of the iron first wall, is the farthest removed from the reference case. The largest drop in the local T_7 value is 23% and is practically flat from 15 to 55 cm inside Li_2O part. The T_7 profiles for the other two assemblies are generally close to each other and differ by as much as 15% in the plateau region with respect to the $C+Fe+H_2O$ containing assembly.

The addition of the graphite armor in front of the first wall leads to a 9% fall in the global tritium production in the Li_2O part alone. However, there is no change in the tritium production in the surrounding 25.5 cm-thick Li_2CO_3 shell which contributes as much as 85% towards the tritium production in the entire assembly. Both the T_6 and T_7 are lower in the Li_2O in the presence of the graphite protective armor.

V. CONCLUSIONS

The heterogeneities associated with the multiplier, the first wall, the coolant channel and the armor introduced both local and global

Table VII

Relative Distribution of TPR in the Whole Assembly

Case	Arrange.	T_6			T_7			T_N		
		Li_2O	Li_2CO_3	Total	Li_2O	Li_2CO_3	Total	Li_2O	Li_2CO_3	Total
Reference (no liner & S/C)	Hom.	0.0576	0.3532	0.4108	0.0292	0.1604	0.1896	0.0868	0.5136	0.6004
Fe/H_2O (no liner)	Het.	0.0711	0.3659	0.4370	0.0271	0.1655	0.1926	0.0982	0.5314	0.6296
	Hom.	0.0751	0.3631	0.4382	0.0245	0.1653	0.1898	0.0996	0.5284	0.6280
$Fe/H_2O/Be$ (Be liner)	Het.	0.1293	0.7579	0.8872	0.0263	0.1080	0.1343	0.1556	0.8659	1.0215
	Hom.	0.1349	0.7538	0.8887	0.0241	0.1079	0.1320	0.1590	0.8617	1.0207
$Fe/H_2O/H_2O$ (H_2O liner)	Het.	0.0607	0.4441	0.5048	0.0253	0.1085	0.1338	0.0860	0.5526	0.6386
	Hom.	0.0644	0.4423	0.5067	0.0247	0.1084	0.1331	0.0891	0.5507	0.6398

Table VIII: Relative Effects of Graphite Armor, First Wall plus Coolant on T_N Profile in the Central Drawer

Zone No.	Zone Bounds Inside Li_2O	T_N per Li Atom in Ref. Assembly	T_N Ratios		
			$Fe+H_2O$	C	$C+Fe+H_2O$
1	0-5 cm	1.033-29[a]	1.63	1.08	1.66
2	5-10 cm	8.182-30	1.05	1.03	0.95
3	10-15 cm	6.502-30	0.97	1.01	0.87
4	15-20 cm	5.154-30	0.95	1.01	0.87
5	20-25 cm	4.071-30	0.94	1.00	0.81
6	25-30 cm	3.200-30	0.93	0.99	0.81
7	30-35 cm	2.500-30	0.93	0.99	0.80
8	35-40 cm	1.942-30	0.93	0.99	0.80
9	40-45 cm	1.501-30	0.93	0.98	0.79
10	45-50 cm	1.161-30	0.93	0.97	0.79
11	50-55 cm	9.099-31	0.93	0.97	0.79
12	55-60 cm	7.535-31	1.06	1.10	0.90

[a] read as 1.033×10^{-29}

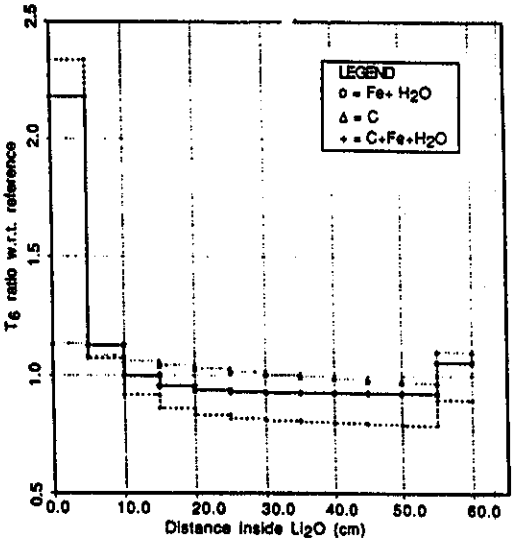

Fig. 7: Effect of C-armor, Fe, H_2O on T_6 profile (Phase IIC)

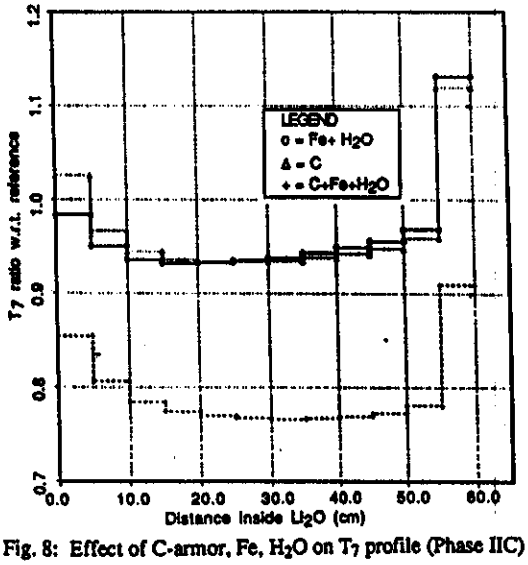

Fig. 8: Effect of C-armor, Fe, H_2O on T_7 profile (Phase IIC)

variations in the TPR. The extent of variation, of course, is different for each case. The local variations for the iron-structured water coolant channel and the water-cooled first wall are quite large. The degree of validity of the homogenization procedure for some of the simulated assemblies has also been looked into; here too the local variations are found to be quite high around the heterogeneities.

Two configurations have, finally, been selected for the experimental measurements due to commerce in fall 1988. These configurations have been so chosen as to strike an acceptable compromise between the desirability of experimentally characterizing the heterogeneity effects and the material availability. In the first configuration, 5.08 cm Be and Li_2O layers will be used to realize an edge-on arrangement up to a distance of 30 cm deep inside the assembly. The remaining 30 cm of the test region will be filled up with the Li_2O as in the earlier phases. In the second configuration, three coolant channels will be incorporated at 0, 10 and 30 cm in the 60 cm long Li_2O test region; each channel will consist of 0.7 mm stainless steel. There will also be a 0.5 cm thick first wall of SS. The measurements will relate to: neutron spectrometry, tritium production and multi-foil activation.

ACKNOWLEDGEMENTS

This work was supported by U.S. DOE Grant No. DE-FG03-88ER52150.

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