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## 1. INTRODUCTION

Two semi-isotropic graphites based on coaltar pitch coke have been developed for use as a moderator in HTGRs. This paper summarizes the dimensional changes and the evolution of the physical and mechanical properties of  $P_3JHAN$  and  $P_3JHA_2N$  graphites under the effect of neutron irradiation.

#### 2. MATERIALS

 $P_{3}JHAN$  and  $P_{3}JHA_{2}N$  graphites based on coal tar pitch coke are manufactured by extrusion according to a classical process. Their physical and mechanical properties are described in table I. The anisotropy factor of these graphites falls between 1.3 and 1.4, with coefficients of thermal expansion (CTE) between those of anisotropic petroleum coke graphites and gilsocoke graphites. If the thermal conductivity is slightly lower than that of petroleum coke graphites, the density and mechanical characteristics are improved due to the excellent compatibility between the filler and the binder /1/.

# 3. BEHAVIOUR UNDER NEUTRON IRRADIATION

More than 1200 samples of  $P_3JHAN$ , taken from both the axial and radial directions, have been irradiated in the Osiris (Saclay), HFR (Petten), and ORR (Oak Ridge) reactors. The maximum fluence thus far reached is  $12 \times 10^{-1} n.cm^{-2} \phi FG^{\ddagger}$  in the case of  $P_3JHAN$  and  $4 \times 10^{2-1} n.cm^{-2}$  for  $P_3JHA_2N$ . Irradiation temperatures for both graphites have ranged from 400°C to 1400°C.

## 3.1. Dimensional changes

The dimensional behaviour of  $P_3JHAN$  and  $P_3JHA_2N$  graphites is shown in figures 1 and 2. No significant effect of the impregnation has been observed between the two graphites.

The maximum axial shrinkage is 4,5% at 1350°C with a turnaround near  $7.10^{21}n.cm^{-2}$   $\phi$ FG. At lower temperatures, between 500 and 1100°C, shrinkage continues up to  $10^{22}n.cm^{-2}$   $\phi$ FG.

In the radial direction, the maximum shrinkage is about 2.2% at 1350°C and  $5 \times 10^{21} n.cm^{-2}$ . The turnaround occurs at higher fluences when the irradiation temperature is decreased. Expansions are observed above approximately  $10^{22} n.cm^{-2}$  ¢FG as new porosity is generated /2/.

#### 3.2. Evolution of physical properties

The CTE's measured between 25 and 425°C, increase slowly with fluence at low temperatures and decrease at temperatures higher than 700°C. The variation does not exceed 10%.

# graphite damage fluence =
1.25 fluence E > 0.18 MeV =1.85 EDN fluence

Figures 3 and 4 show the degradation of the thermal conductivity of  $P_3JHAN$  graphite in the axial and radial directions, respectively. A saturation appears at approximately  $2 \times 10^{21}$ n.cm<sup>-2</sup>  $\phi$ FG.although the decrease in conductivity is smaller at increased irradiation temperatures.

### 3.3. Variation of mechanical properties

The fraction

versus fluence for  $P_3$ JHAN graphite is shown on figure 5. The increase in the modulus of elasticity is greater when the irradiation temperature is lower.

Stress-strain curves have been drawn from irradiated specimens. We observed two different types of behaviour depending on the irradiation temperature. Between 500 and 900°C the graphite strains with a constant energy /3/, while above 900°C the energy changes without strain variation /4/.

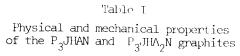
#### 4. CONCLUSION

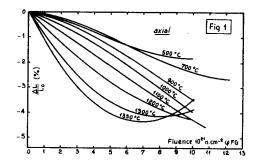
The pitch coke graphites studied are less stable than petroleum coke graphites of comparable CTE and anisotropy. This seems to indicate that the fibrous structure of the coke has a preponderant effect under neutron irradiation. This study of characterization before and after irradiation has allowed to specificy the conditions under which these graphites may be used in HTGRs.

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Graphite				
	P <sub>3</sub> JHAN		P <sub>3</sub> 'JHA <sub>2</sub> N	
Direction	axial	radial	axial	radial
Bulk density g.cm <sup>-3</sup>	1.73	1.73	1.79	1.79
Thermal expansion $\overline{\alpha} \begin{array}{c} 525^{\circ}C\\ 25^{\circ}C \end{array} \begin{array}{c} 10^{-6} \circ C^{-1} \end{array}$	3.05	4.21	3.08	4.23
Thermal conductivity W cm <sup>-1</sup> °C <sup>-1</sup>	1.54	1.18	1.70	1.29
Young Modulus daN mm <sup>-2</sup>	1005	709	1143	772
Tensile strength daN mm <sup>-2</sup>	1.12	0.76	1.44	0.98





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