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Some Considerations in the Classification of Graphite "Core" and "Structures" in the PBMR

A. Basic functions of graphite in the PBMR:

- As a moderator
- As major structural components
- As a heat sink and/or conduction path during reactor trips and transients.

In the PBMR the fuel pebbles are partially graphite; and the moderator/reflector pebbles in the central annulus of the core and the reflector blocks surrounding the core are solely graphite. All these are contained in the steel pressure vessel. The reflector external to the pebble bed serves not only to improve the neutron economy, but also structural functions such as maintaining pebble bed geometry, defining the cooling paths for the pebble bed under normal and abnormal conditions, defining the reactivity control and shutdown system access paths, and defining the defueling path.

B. Under normal operation the dimensions and material properties of the graphite components in the PBMR are changed due to:

- Fast neutron irradiation, especially in light of the high temperature gradients prevalent in the PBMR
- Thermal or radiolytic oxidation due to trace amounts of air or water ingress.

These changes lead to significant component stresses and distortions which can result in increased coolant flow bypass or blockage, neutron streaming and control channel distortion. Moreover, over time irradiation enhanced creep can lead to component failure.

C. To mitigate these adverse effects requires:

- a) Management of the residence time of the graphite components in the reactor:

To this end, the graphite components and structures fall into three basic categories:

- Fuel and moderator/reflector pebbles that are continuously replaced.
- Replaceable reflectors (these contain the control rod and coolant channels) are replaced at intervals on the order of years. Current estimates are about every 6 years.

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- "Quasi" permanent structures. These, in principle, are replaceable, but their replacement would incur a heavy economic penalty.

b) Considerations of the structure and composition of graphite components:

With regard to the reflector outside the pebble bed two things need to be kept in mind. The first is that there is no such thing as a "component" in the traditional sense; rather the reflector/components are divided into individual blocks and machined, when necessary, so as to perform a function such as a coolant channel. This block design feature is due mainly to the fact that graphite has an upper limit to block size and isotropy, and it is also required due to the load characteristics occurring in the reflector. Thus, the reflector/components are constructed by arranging the blocks in columns and ring layers. These are fixed by dowels and the individual layers are positioned by keys. Secondly, different grades of graphite are used. For example, the replaceable reflector consists of Grade 1 Nuclear graphite, while other parts such as the permanent reflector consist of Grade 2 graphite in some instances and carbon blocks in others.

The choice of a particular graphite for a block is dependent on the following parameters:

- chemical purity
- irradiation dose
- temperature
- load
- residence time

Thus, roughly, the graphite pebbles and the replaceable reflectors, which are subject to high irradiation doses and temperatures, relatively moderate loads and short residence times, consist of Grade 1 Nuclear graphite; and, thereby, also the attendant "components" such as some of the coolant and all the control channels. Similarly, the permanent graphite structures, depending on the particular combination of irradiation, thermal-hydraulic, and loading environments, consist of different grades of graphite.

D. Proposed core vs. structures classification:

The above considerations suggest that for the PBMR a classification of the graphite into core and structures on the basis of the grade of graphite employed may be viable. The grade of graphite used for each block is consistent with the specific function of the component made of those graphite blocks.

On this basis we can make the following associations:

Core -

Grade 1 Nuclear graphite

- fuel pebbles, reflector pebbles, replaceable reflectors (contain, for example, control channels)

Structures -

Grade 2 graphite

- permanent bottom reflectors (contain, for example, inlet and outlet coolant plena)

Carbon block

- permanent side reflectors (contain, for example, inlet coolant channels)