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(19)(CA) **CANADIAN PATENT** (12)

(54) Moderator for Nuclear Reactor

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TITLE

MODERATOR FOR NUCLEAR REACTOR

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ABSTRACT

There is disclosed a moderator for a nuclear reactor, comprising a composition of heavy water and at least one of the following components:

a solid particulate material

a gaseous agent

wherein such other component(s), e.g. graphite, zirconium oxide or air, must exhibit a low neutron absorbance. This partial substitution of the heavy water volume by the other component(s) results in a reduced cost of the moderator without a significant decrease in its moderating properties, nor a significant increase in its overall absorbance.

Background of the Invention:

This invention relates to a moderator for a nuclear reactor and more specifically, to a composite moderator.

A moderator is designed to slow down, or thermalize, neutrons which are released during nuclear reactions in the reactor fuel. Pure or almost pure materials like light water, heavy water, beryllium or graphite are used singly as moderators at present. All these materials, are used widely. Graphite has a good mechanical strength at high temperatures encountered in the nuclear core and therefore is used as both the moderator and core structural material. It also exhibits a low neutron-capture cross section and high neutron scattering cross section. However, graphite is susceptible to attack by carbon dioxide and/or oxygen where applicable, and releases stress energy (Wigner dislocation energy) under certain circumstances, although under normal operating conditions these reactions can be controlled.

Heavy water is free of the above drawbacks but its cost is significantly higher than that of graphite. All types of nuclear reactors known to the applicants at present employ essentially unary moderator systems whether based on a liquid, e.g. heavy water, or a solid, e.g. graphite.

Dispersions of carbon in water have been made for a number of years and used for various applications ranging from fuel (dispersions of coal in water and oil) to the protection of metal surfaces (by spraying a colloidal suspension of graphite in water on a metal surface and subsequent drying) to solar energy capture and transfer (described e.g. in French patent no. 2392333).

Summary of the Invention:

It is now proposed to use a composition comprising heavy water and at least one other material, as a moderator for a nuclear reactor core. The other material or materials should be capable of slowing down neutrons and must have a low neutron absorbance. In other words, the invention proposes to substitute, a part of the heavy water volume in the moderator with another material that forms a composition with heavy water, the other material(s) having moderating qualities and low absorbance.

While it is conceivable, within this general concept, to provide a liquid phase mixture of heavy water with another liquid (other than light water), such other liquids are not known to the applicant at present.

Accordingly, the invention provides a moderator comprising a composition of heavy water and at least one of the following low-absorbance components:

a solid comminuted material

a gas distributed in heavy water.

The size and form of the solid particles may vary in a wide range; this is of little importance provided that the heavy water can circulate freely in the nuclear reactor system.

Heavy water/gas mixtures may be embodied by heavy water/air froth.

Detailed Description of the Invention:

In a heavy water nuclear reactor, the heavy water is circulated between the moderator tank (calandria) and a heat exchanger via piping and pumps. Filters may also be installed in that system to remove any solid impurities from the heavy water.

As stated above, the moderator of the invention may comprise, beside heavy water, solid particles, gas bubbles or a combination thereof. A number of solid substances having a low neutron absorbance may be

utilized as a component of the composite moderator of the invention. By way of example, the following may be considered:

graphite,

beryllium oxide,

zirconium oxide.

These substances may be utilized in a form ranging from a colloidal dispersion in heavy water to a mixture of heavy water and solid particles up to and above ca.2 cm in size. The particles, or pellets, may be homogeneous or heterogeneous. In the latter case, they may be hollow or porous with air or another gas trapped in the cavities or pores. In the case of a colloidal dispersion in heavy water it is necessary to ensure the moderator can circulate freely without clogging the filters, if any, and without plating the circulation piping. In this case, periodic or continuous agitation of the dispersion may be recommendable. In the case where the solid or hollow solid particulate components is macroscopic in size, the heavy water filling the interstitial spaces or voids must be free to circulate without encumbrance. The use of screens or other retaining devices will be needed to keep material from leaving the calandria.

In one embodiment of the invention, the moderator comprises a colloidal dispersion of graphite in heavy water. The dispersion contains about 25% by weight of micro colloidal particles of graphite and about 75% by weight of heavy water (D_2O). A dispersant such as tannic acid may be used optionally. The dispersion is expected to be substantially stable under irradiation in the nuclear core through continuous redispersing of the circulating fluid.

It will be appreciated that the stability of the dispersions of the invention, i.e. their homogeneity, may be supported by the provision of agitating means, such as mixers, ultrasonic vibrators or other similar commonly known means. This provision may eliminate the use of dispersing agents.

In another embodiment of the invention, hollow or solid pellets of zirconium oxide are disposed in the calandria in the amount of about 63% by volume of the moderator, the balance being heavy water. The pellets may contain air in their hollow spaces or a solid material such as graphite and are prevented from circulating with the heavy water by screens, or similar means.

In still another embodiment of the invention, the moderator comprises a froth of air and heavy water.

the froth is sustained by continuous dispersing of air in the heavy water. Dispersants or foaming agents may be used optionally.

In should be noted that the presence of an absorbing component, for example carbon, entails a certain loss in burnup and therefore the moderator of the invention would possibly require fuel enrichment. A series of graphite dispersions has been considered and the strength, burnup reduction and other properties are set out in Table 1.

Table 1. Properties of graphite/heavy water dispersions

ξ	0	0.1	0.2	0.3
M_I/M	1	0.794	0.632	0.500
H_2O weight fraction	0.0025	0.00199	0.00158	0.00125
D_2O weight fraction	0.9975	0.7924	0.6304	0.4992
ρ	1.073	1.216	1.359	1.501
k_∞	1.1146	1.1030	1.0911	1.0790
K_{eff}	1.0845	1.0744	1.0639	1.0530
leakage (mk)	30	28.6	27.2	26.0
Burnup using NU (MWd/Mg)	7500	6400	5200	3500
Enrichment (atom %) to maintain burnup	0.72	0.74	0.77	0.80

wherein:

ξ = volume carbon/total volume

M_I/M = weight fraction D_2/H_2O mixture to total

ρ = density of slurry (g /cc) assuming density of graphite = 2.5 g/cc

It will be readily appreciated by those skilled in the art that the full range of parameters for a proper operation of the moderator of the invention can be determined by calculations or some experimentation while not departing from the scope of the invention as defined in the appended claims.

THE EMBODIMENTS OF THE INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A moderator for a nuclear reactor, comprising heavy water admixed with at least one other gaseous and/or solid component having a low neutron absorbance.

2. A moderator according to claim 1, wherein the other component is a gas dispersed in the heavy water.

3. A moderator according to claim 1, wherein the other component is a solid particulate material dispersed in the heavy water.

4. A moderator for a nuclear reactor comprising a mixture of heavy water and a solid material wherein said heavy water and solid material form a colloidal dispersion.

5. A moderator according to claim 3, wherein the solid particulate material is a plurality of porous solid particles.

6. A moderator according to claim 3, wherein the solid particulate material is a plurality of hollow solid particles.

7. A moderator according to any one of claims 3 to 6 wherein the solid material is chosen from the group consisting of graphite, beryllium oxide and zirconium oxide.

8. A moderator according to any one of claims 3 to 6 wherein the solid material is graphite.

9. A moderator according to claim 2 wherein the gas is chosen from the group consisting of air or any of its gaseous components.

10. A moderator for a nuclear reactor comprising a colloidal dispersion of graphite particles in heavy water wherein the graphite particles are present in an amount of about 25% by weight of the moderator.

11. A moderator for a nuclear reactor comprising a colloidal dispersion of hollow or solid pellets of zirconium oxide in heavy water wherein the pellets are present in an amount of about 63% by volume of the moderator.

12. A moderator according to any one of claims 3, 4, 5, 6, 10 or 11 further comprising a dispersant.

13. A moderator according to claim 12 wherein the dispersant is tannic acid.

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