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(54) Nuclear plant

(57) The invention resides in operating a thermal nuclear reactor (2) and a fast nuclear reactor (4) in close adjacency with means (17) for transferring fuel elements from the thermal reactor into the fast reactor for a re-enrichment period during which fissile (by thermal neutrons) isotopes are formed and then replacing the re-enriched fuel element in the thermal reactor.

Fig. 3.

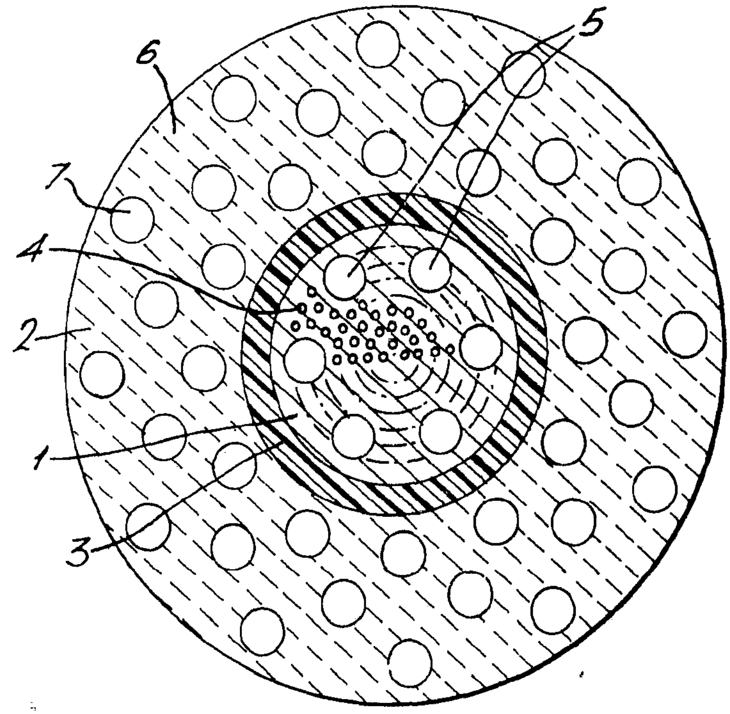

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Fig. 1.

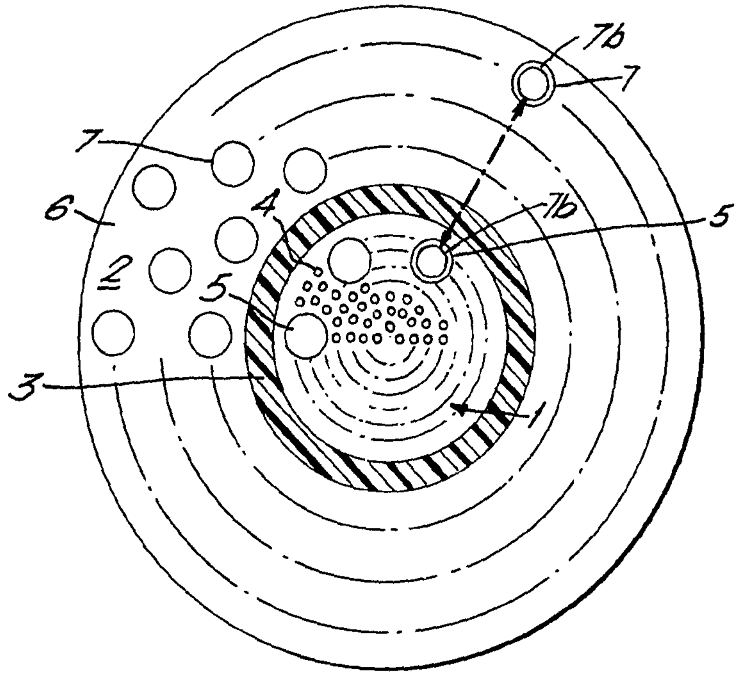


Fig. 3.

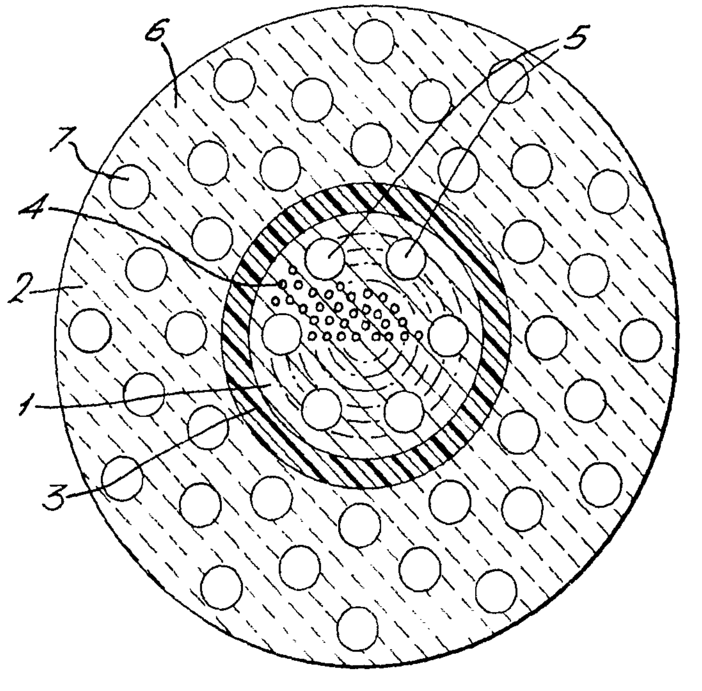
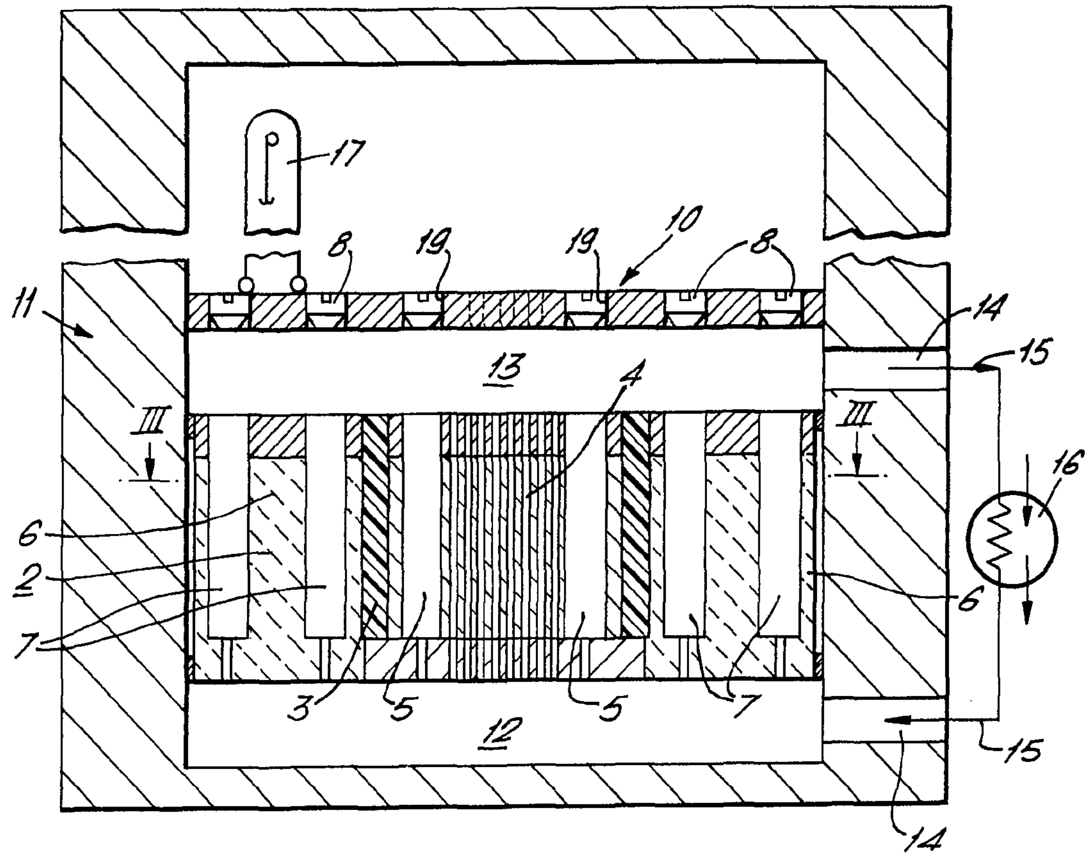


Fig. 2.



SPECIFICATION

Nuclear plant

This invention relates to nuclear plant for using fuel of low enrichment in fissile isotopes. When determining a fuel cycle for low enriched fuel a decision is made on how the fuel elements are to be treated when they have been subjected to burn-up sufficient to depelete the fissile content and the reactivity of the reactor core declines. Usually the choice lies between leaving the fuel element in the core until it is making an insignificant contribution to reactivity or removing the fuel element when it is seen to be more economic to reprocess the fuel, separating the valuable isotopes for re-use from those to be disposed of. The present invention provides a nuclear plant which allows this choice of procedures to be widened.

According to the present invention a nuclear plant includes a thermal nuclear reactor comprising a moderator and individually transportable nuclear fuel elements which contain fuel of initially low enrichment, a closely adjacent fast nuclear reactor containing no moderator and fuel elements of initially high enrichment and nuclear fuel element transfer means positioned for transferring nuclear fuel elements from the thermal nuclear reactor into the fast nuclear reactor for re-enrichment and returning the re-enriched fuel elements to the thermal nuclear reactor over a common charge face.

A common coolant is preferable for both thermal and fast reactors and although the choice for the fast reactor lies between liquid metal and gas, a gas coolant is advantageous. The neutron spectrum of a gas cooled fast reactor is particularly advantageous because the capacity for breeding is greater than the liquid metal cooled fast reactor and hence the enrichment or conversion of the depleted species in the thermal reactor fuel elements may be more efficiently carried out. Hence the fuel in the gas cooled fast reactor would have a long reactivity lifetime.

Preferably the nuclear plant or, at least, that part comprising the thermal reactor, the fast reactor and the fuel element transfer means is all housed in a single containment building structure which provides an outer containment and an outer biological shielding. In one advantageous configuration the invention takes the form of a central fast reactor core surrounded by an annular thermal reactor core. In such a configuration the fuel element transfer means is an overhead charge/discharge machine operating over the common charge floor. Alternatively, the two nuclear reactors may be cubic structures arranged side by side.

Advantageously therefore the invention provides a nuclear plant comprising contiguous or closely adjacent fast and thermal nuclear reactors within a common containment building and having a charge/discharge face common to both the fast and thermal reactors, the thermal reactor having transportable fuel elements, the fast reactor being adapted to provide voids, or channels, for reception of visiting fuel elements from the thermal nuclear reactor. The invention also resides in an operational method for the prolongation of the in-core life of a fuel element of low enrichment in fissile material, the method comprising operating a thermal reactor and a fast reactor adjacent to one another; irradiating the fuel element in the thermal reactor until the initially enriching fissile species becomes partially depleted and isotopes fissionable by above thermal neutrons are formed, transferring partially depleted fuel elements to the core of the fast nuclear reactor wherein they are subjected to an above-thermal neutron flux, maintaining the fuel element in said flux until at least a portion of the fast-neutron fissionable species are converted to isotopes fissionable by thermal neutrons and then returning the fuel element to the thermal nuclear reactor. Thus for a thermal reactor fuel element having a low enrichment in U235 which undergoes partial depletion, irradiation in an above thermal neutron flux by a visit to the fast reactor will readily convert U238 to Pu239. The fuel element thus enriched is returned to the thermal reactor for further burn-up. The process may be repeated several times until the fuel element becomes a net consumer of neutrons when it is replaced.

In order that the invention may be better understood one embodiment thereof will now be described by way of example with reference to the accompanying diagrammatic drawings in which

Figure 1 is a diagram for illustrating the invented fuel system for the use of low enriched fuel elements in a nuclear plant and

Figures 2 and 3 are respectively elevation and plan diagrammatic views of one form of nuclear plant embodying the invention,

Referring firstly to Fig. 1 there is shown a fast reactor core 1 surrounded by a thermal reactor core 2 and separated from the core 1 by a buffer zone 3 which may be depleted uranium. Each core contains sufficient fuel to sustain a critical condition. The core 1 contains no moderator and is fuelled with fuel elements in the form of highly enriched fuel rods 4 which sustain an above thermal neutron flux. It also contains channels 5 adapted to receive visiting fuel elements from the reactor core 2. The core 2 contains moderator 6 with spaced fuel channels 7 containing transportable fuel elements having an initially low enrichment in a fissile species say U235. Both fast and thermal nuclear reactors are started up and operated initially in a known manner. It is an intrinsic property of the fast reactor core 1 that its power will remain high. However, owing to depletion of the fissile material in the thermal reactor core, the latter will tend to become sub-critical. After a predetermined period of operation determined by calculation, empirically or by on site flux instrumentation (or all three) and before subcriticality is reached, at least one of the fuel elements 7b in the thermal reactor channel is transferred to an enrichment channel in the fast reactor for a brief period. During its visit (and it need not be detached from its transfer machine) the partial depleted thermal reactor fuel element is enriched by the U238 + n→ Pu239 reaction. The re-enriched fuel element is then returned to the thermal reactor so restoring reactivity in the thermal reactor for a further period of burn-up. Each thermal fuel element is given several spells in the fast reactor re-enrichment channels. A continuous charge/discharge process takes place. In this way fuel of initially low enrichment is taken to very high burn-ups without the need to reprocess.

Referring now to Figs. 2 and 3 which employ the same reference numerals as have been used in Fig. 1 for the same features, the cylindrical fast reactor core 1 and annular thermal reactor core 2 share a common charge face 10 and are enclosed in a common containment structure 11 affording pressure containment and biological shielding. Both reactor cores 1, 2 are gas-cooled, the gas entering a bottom plenum chamber 12 passing through both cores and being withdrawn from a hot gas plenum 13. Penetrations 14 lead to ducts 15 communicating the gas plenums with external plant 16. Although shown here as sharing the same coolant circuit separate circuits may be employed.

The fast reactor core contains high enriched fuel elements 4 and a number of channels 5 which are adapted to receive low enriched fuel elements from the surrounding thermal reactor according to the invented fuel cycle. The thermal reactor has its fuel element channel 7 dispersed in graphite moderator blocks 6.

In the drawing a single charge/discharge machine 17 is shown on the charge face 10. The machine 17 is a trolley mounted flask containing lifting gear which runs on a track above the change face and is positionable over seal plugs in the charge floor for servicing both reactor cores including the enrichment channels.

The seal plugs 8 form part of the biological shield afforded by the charge floor and an AGR type charge machine may be used. In the thermal reactor, seal plugs 8 are located in the floor coincident with the fuel element channels beneath. Similar shield plugs 19 are set in the charge floor at positions coinciding with the enrichment channels in the fast reactor and above the fast reactor fuel elements.

The operation of the nuclear plant described according to the operational cycle explained with reference to Fig. 1 needs little explanation.

Thermal reactor fuel elements of low enrichment in U235 are removed periodically from their fuel channels 7 by the charge machine 17 and lowered into a vacant enrichment channel 5 in the fast reactor. After a predetermined dwell time this element becomes enriched in Pu239 and is returned to the same or another vacant thermal reactor fuel channel wherein it helps to restore reactivity to the thermal reactor. After a further period of burn-up the same fuel element is moved again to visit an enrichment channel, for a further period to replenish its enrichment in Pu239. The movement of the fuel elements is repeated periodically so long as useful enrichment may be obtained. The spent fuel element is then removed. Although the invention has been particularised above with reference to U235/U238/Pu239 cycle it is equally applicable to the Th232/U233 cycle.

CLAIMS

1. A nuclear plant including a thermal nuclear reactor having a moderator and individual transportable fuel elements which contain fuel of initially low enrichment, a closely adjacent fast nuclear reactor containing substantially no moderator and fuel elements of initially high enrichment and fuel element transfer means positioned for transferring fuel elements from the thermal nuclear reactor into the fast nuclear reactor for re-enrichment and for transferring the re-enriched fuel elements to the thermal nuclear reactor over a common charge face.

2. A nuclear plant as claimed in claim 1 in which the closely adjacent thermal and fast nuclear reactors share a common containment building and a common coolant.

3. A nuclear plant as claimed in claim 2 in which the coolant is a gas.

4. A method for the prolongation of the in-core life of a nuclear fuel element of initially low enrichment in fissile material, the method comprising

(1) operating a thermal nuclear reactor and a fast nuclear reactor adjacent to one another

(2) irradiating the fuel element in the thermal nuclear reactor until the initially enriched fissile (by thermal neutrons) species become partially depleted and isotopes fissionable by above thermal neutrons are formed

(3) transferring a partially depleted fuel element into the core of the fastnuclear reactor wherein said elements are subjected to flux of fast neutrons

(4) maintaining the transferred fuel element in said flux until at least a portion of the fast neutron fissionable species are con-

verted to isotopes fissionable by thermal neutrons and then returning the fuel element to the thermal reactor.

5. A method as claimed in claim 4 in which the nuclear fuel element is transferred between the thermal nuclear reactor and the fast nuclear reactor and back repeatedly until the fuel element becomes almost a net consumer of neutrons when it is replaced.

6. A nuclear plant substantially as described herein with reference to the accompanying drawings.

7. A method of prolonging the in-core life of a nuclear fuel element of low enrichment as claimed in claim 4 or claim 5 and substantially as herein described.

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