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(54) LIQUID METAL COOLED NUCLEAR REACTOR

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to liquid metal cooled nuclear reactors.

In a liquid metal cooled nuclear reactor, a typical example of which is the liquid sodium cooled fast breeder reactor known as the Prototype Fast Reactor (PFR) at Dounreay in Scotland, liquid metal coolant, hereinafter referred to as the primary coolant is flowed successively through the reactor fuel assembly and a plurality of heat exchangers in heat exchange with a secondary liquid sodium coolant. In such a reactor it is desirable to provide means for promoting efficient mixing of the primary liquid sodium coolant leaving the fuel assembly so as to minimise the generation of zones of excessively high temperature within the primary coolant.

According to the invention in a liquid metal cooled nuclear reactor wherein coolant is arranged to be flowed upwardly through the fuel assembly there is provided one or more baffles located above the coolant exit of the fuel assembly and arranged so as to convert the upwardly directed motion of liquid metal coolant leaving the fuel assembly into a substantially horizontal motion.

In the Prototype Fast Reactor which is a nuclear reactor of the pool kind wherein the fuel assembly is submerged in a pool of primary coolant, the pool is contained within a primary vessel which is suspended from the roof of a containment vault. The roof of the vault is penetrated by a rotating shield which enables irradiated fuel sub-assemblies to be exchanged for new fuel sub-assemblies and the control rods to be inserted into or withdrawn from the fuel assembly. The fuel sub-assemblies and control rods are movable vertically in tubes depending downwardly from the rotating access shield and these tubes are supported and located by means of a skirt depending from the shield. The invention will therefore reside in such a liquid metal cooled fast breeder nuclear reactor of the pool kind wherein a skirt depending from the roof structure houses one or more baffles located above the coolant exit of the fuel assembly and arranged so as to convert the upwardly directed motion of liquid metal coolant leaving the fuel assembly into a substantially horizontal motion. In such a reactor construction the tubes in which the fuel assemblies and control rods move may penetrate the one or more baffles to provide access to the core.

Constructional embodiments of the invention will now be described by way of example with reference to the drawings accompanying the Provisional Specification wherein:

Figure 1 is a sectional view of a liquid metal cooled nuclear reactor,

Figure 2 is a diagrammatic cross-sectional view of a skirt on line II—II of Figure 1 showing the position of one baffle assembly, and

Figure 3 is a diagrammatic side view of the skirt of Figure 2 showing one baffle assembly.

The nuclear reactor illustrated in Figure 1 is a liquid sodium cooled fast breeder reactor of the pool kind comprising a fuel assembly 1 submerged in a pool 2 of liquid sodium contained within a primary vessel 3. The vessel 3 is housed in a concrete containment vault 4 having a cover 5 from which the primary vessel 3 depends. The fuel assembly 1 is carried by a diagrid 6 supported from the cover 5 and there is a shroud 7 surrounding the fuel assembly 1. Above the fuel assembly the shroud 7 has upper regions *7a*, *7b* of increased cross-section and the walls of the region of increased cross-section extend above the level of liquid sodium in the vessel 3. The cover 5 has numerous penetrations for ancillary equipment such as heat exchangers 8 and circulators 9 and has a central rotating shield 10 comprising an outer totatable member having an inner rotatable member mounted eccentrically in it. The rotating shield 10 is penetrated to provide access for the control rods and fuel assemblies (not shown) the control rods and fuel assemblies being movable vertically inside tubes 11 which are contained within a skirt 12. The lower end of the skirt 12 houses one or more baffles 13 located above the coolant exit of the fuel assembly and arranged so as to convert the upwardly directed motion of coolant leaving the fuel assembly into substantially horizontal motion as will be described in greater detail hereinafter.

In use of the reactor, liquid metal coolant is circulated from the region outside the shroud 7 by the circulator 9 through the fuel assembly by way of the diagrid 6 the majority of the coolant leaving the fuel assembly 1 travelling in an upward direction and being deflected by the baffles 13 so that the upward motion is converted into a horizontal swirling motion within the upper regions *7a*, of the shroud 7. From the upper regions *7a*, *7b* of the shroud 7 the coolant passes into that part of the vessel 3 outside the shroud 7 by way of the heat exchanger 8. The temperature of the liquid sodium in the part of the vessel 3 outside the shroud 7 is approximately 400°C whilst the temperature of the sodium within the shroud 7 after being passed through the fuel assembly 1 is approximately 600°C. A layer of thermal insulation 14 is interposed between the wall of the vessel 3 and the wall of the vault 4.

The baffles 13 shown schematically in Figure 1 convert the vertical motion of the primary coolant leaving the fuel assembly 1 into a substantially horizontal motion within the upper larger cross-section portions *7a*, *7b* of the shroud 7. Several designs and arrangements of baffle are envisaged to achieve this conversion feature but in one arrangement, illustrated in Figures 2 and 3, four baffle assemblies 13 (one only of which being shown in Figures 2 and 3) are disposed within the base region of the skirt 12, each of the baffle assemblies 13 serving to deflect upward flow of coolant from one quadrant 14 of the cross-section of the shield so that it enters the larger cross-section portions *7a*, *7b* of the shroud 7 in a substantially horizontal direction through a port 15 in the wall of the skirt 12. Each baffle assembly 13 comprises two flow deflecting members 16, 17. The flow of coolant entering the larger cross-section regions *7a*, *7b* through the ports 15 of the baffle assemblies tends to induce circular motion of the coolant in those portions. Circular motion of the coolant within the shroud 7 minimises the occurence of zones of excessively high temperatures within the coolant it being preferable to pass the primary coolant into the heat exchanger at substantially uniform temperature.

More efficient mixing within the larger cross-section regions *7a*, *7b* may be achieved by providing sets of baffles which tend to cause the coolant to circulate in different directions. For example, in an alternative construction of nuclear reactor (not shown in the drawings) two layers of co-axial, vertically spaced baffle assemblies are provided within the skirt 12 wherein a first lower layer of baffle assemblies is of a smaller diameter than the skirt and causes the vertical movement of the central portion of the upwardly moving coolant flow to be converted into a horizontal flow which may be caused to flow out of the skirt through ports in the skirt. Ducts or further flow deflectors may be provided to direct the horizontal flow of coolant through the ports. A second layer of baffle assemblies of the same diameter as the skirt and co-axial with but vertically spaced above the first layer converts the vertical flow of the outer part of the coolant flow which bypasses the smaller first layer of baffle assemblies into a horizontal flow passing through further ports in the skirt which tends to cause the coolant outside the skirt to circulate in a direction opposed to that caused by the coolant emitted from the lower ports associated with the first layer of baffles. The baffle assemblies 13 are penetrated by the tubes 11 so that control rods and fuel assemblies 13 are penetrated by the tubes 11 so that control rods and fuel assemblies may be inserted into and removed from the fuel assembly.

An additional advantage accrues to a nuclear reactor construction according to the invention in that the provision of the baffles 13 also provides a safety feature operable in the unlikely event of an extreme emergency situation developing within the fuel assembly of the reactor and which could result in rapid vaporisation of some of the coolant or fuel. Rapid vaporisation could give rise to a bubble of vapor within the coolant and if such a bubble expanded rapidly in a conventional reactor the coolant could be propelled vertically upwardly by the expansion of the bubble sufficient to impinge on the tubes 11 or the roof 5 for the vault 4 and cause serious damage. Embodiment of baffles in accordance with the present invention would reduce the risk of serious damage in such an emergency situation by diverting the rapidly ascending flow of coolant caused by the bubble into the larger mass of sodium held within the larger cross-section regions within the shroud. Here the energy would be dissipated by causing circular movement of the larger mass of sodium, the energy so dissipated eventually being manifested in the form of heat but as the heat capacity of the coolant is very large the resulting rise in temperature would not be excessive.

The baffles are preferably placed as close to the coolant exit from the fuel assembly as possible so that as large a proportion as possible of the coolant passes over them. In the above mentioned extreme emergency condition a position close to the fuel assembly minimises the risk of severe forces being transmitted to the roof of the reactor by way of the skirt 12 because the relatively small amount of coolant disposed between the fuel assembly and the baffles travels only a short distance before impinging on the baffles and the kinetic energy it has to transmit to the baffles and the skirt is therefore of small amount. Furthermore, only a small degree of bubble expansion will occur before the bubble leaves the fuel assembly and hence the coolant velocity will be low immediately above the fuel assembly.

The baffles themselves may be designed to fail progressively in an emergency situation under applied forces less than those at which damage to the roof structure of the reactor would occur. The baffles are arranged to occlude the gore of the skirt and no coolant is present within the skirt above the baffles in normal use, so that when the baffles fail the gas bubble is able to expand into the interior of the skirt. Vent holes may be provided in the skirt wall above the coolant level to minimise excessive pressure in this region. Any coolant above the fuel assembly will be diverted by way of the baffles early in the development of any emergency situation so that should the baffles fail vapour only will pass into the skirt minimising the risk of sodium metal impact on the roof structure of the reactor.

The invention has been illustrated by reference to a liquid metal cooled reactor of the pool type but it is applicable also to loop reactor systems.

WHAT WE CLAIM IS: —

1. A liquid metal cooled nuclear reactor wherein coolant is arranged to be flowed upwardly through a fuel assembly and having one or more baffles located above the coolant exit of the fuel assembly, the baffles being arranged so as to convert the upwardly directed motion of liquid metal coolant leaving the fuel assembly into a substantially horizontal motion.

2. A liquid metal cooled fast breeder nuclear reactor of the pool kind wherein a skirt depending from the roof structure of a reactor containing vault houses one or more baffles located above the coolant exit of the fuel assembly, the baffles being arranged so as to convert the upwardly directed motion of liquid metal coolant leaving the fuel assembly into a substantially horizontal motion.

3. A liquid metal cooled fast breeder nuclear reactor according to claim 2 wherein the baffles each comprise an assembly having a pair of flow deflecting members which co-operate to bound a stream of coolant and direct the flow through ports in the skirt.

4. A liquid metal cooled fast breeder nuclear reactor according to claim 3 wherein each baffle comprises four baffle assemblies each arranged to convert the direction of flow of coolant passing through a complementary quadrant of the skirt.

5. A liquid metal cooled fast breeder nuclear reactor according to either of claims 3 and 4 wherein there are a plurality of co-axial layers of baffle assemblies, the layers being vertically spaced.

6. A liquid metal cooled fast breeder nuclear reactor according to claim 5 wherein there are two co-axial layers of baffle assemblies, the lower layer of assemblies being of smaller diameter than the skirt, the upper layer being of substantially the same diameter as the skirt, the lower and upper layers being arranged to deflect the flow through ports in the skirt and to induce rotational flows of opposite direction outside the skirt.

7. A liquid metal cooled fast breeder nuclear reactor substantially as hereinbefore disclosed with reference to the drawings filed with the Provisional Specification.

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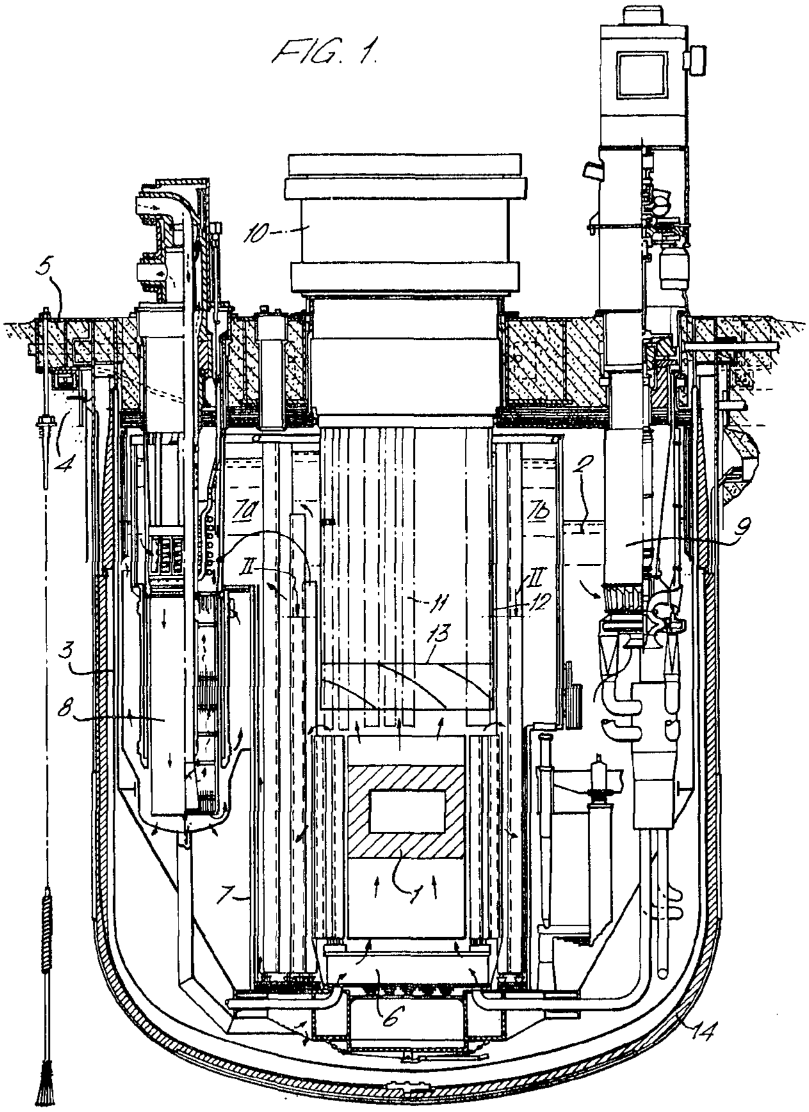
1580446 PROVISIONAL SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

FIG. 1.



1580446 PROVISIONAL SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 2

FIG. 2.

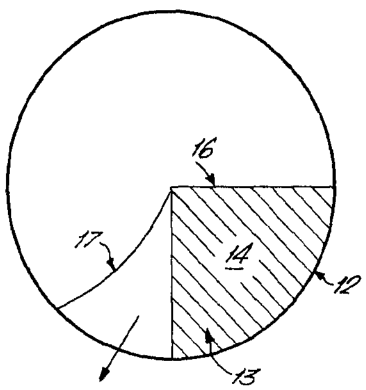


FIG. 3.