PATENT SPECIFICATION

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(72) Inventor ROBERT VINCENT INGHAM

(19)

(54) NUCLEAR REACTOR CONTROL

(71) We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, 11 Charles II St. 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 the control of nuclear reactors.

In a nuclear reactor of the kind wherein fluid coolant is circulated through the reactor core and heat exchange means by a plurality of circulators there is a risk that in the event of a reduction in the rate of coolant flow, caused by, for example, loss of a coolant circulator, the nuclear fuel will overheat. It has been the normal practice therefore to arrange for a trip signal to be initiated in response to a significant reduction in the rate or pressure of the coolant flow whereby neutron absorbing material in the form of control rods is dropped or injected into the core to effect immediate and total shut-down of the reactor. Where the reactor is used in an electricity generating station this solution to the problem is not entirely satisfactory because it means a total loss of output, requires the introduction of auxiliary services for maintaining the reactor in a safe condition and, to recommence operation of the station, involves a complex start-up procedure. Clearly, immediate and total shut-down of a station imposes a heavy financial burden on the operators.

It is an object of the invention to provide for a nuclear reactor control means which will achieve a rapid reduction in power by change of reactivity of appropriate magnitude to meet the requirements for continued safe operation following a partial reduction in coolant flow or pressure.

According to the invention in a nuclear reactor wherein fluid coolant is flowed in heat exchange over nuclear fuel and wherein control rods of neutron absorbing material are used to control the reactivity of the reactor, at least one control rod having means responsive to a trip signal whereby said control rod is arranged to be inserted into the reactor core, movement of the control rod being in two successive stages, firstly, by free fall or stored energy propulsion and, secondly, by controlled propulsion, the means comprises a first latching device for suspending the control rod above the reactor core the device being releasbly sensitive to the trip signal, a second latching device for arresting insertion of the control rod into the core and means responsive to control signals for ajusting the position of the second latching device whereby the vertical position of arrest of the control rod and subsequent controlled insertion in the reactor core can be varied.

The invention is applicable to liquid metal cooled fast breeder nuclear reactors and it provides that in the event of an emergency condition wherein the rate of coolant flow is reduced, a rapid power set-back of appropriate magnitude is achieved by causing limited injection of control rods into the reactor, the insertion being sufficient to reduce reactivity to a safe level, and, subsequently, fine control at the reduced power output is achieved by automatic control.

A construction of liquid metal cooled fast breeder nuclear reactor embodying the invention is described, by way of example only, with refernece to the drawings accompanying the Provisional Specification wherein;

Figure 1 is a sectional view of the construction, and

Figure 2 is a diagrammatic sketch of a reactivity control mechanism.

In the nuclear reactor construction shown in Figure 1 a fast breeder nuclear reactor core 1 is 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 reactor core is carried by a diagrid 6 which is supported from the cover 5 and the reactor core is housed within a shroud 7. The cover has numerous penetrations for ancillary equipment including four heat exchangers 8 and four coolant circulators 9 (only one each of heat exchanger and circulator being shown) and has a rotating shield 10. The rotating shield 10 comprises an outer rotatable member having an inner rotatable member mounted eccentrically in it, there being penetrations in the shield for control mechanisms 11 and to provide access to fuel assemblies in the core. In use, coolant at approximately 400°C is circulated from the pool region outside of the shroud 7 through the core 1 where it is heated to approximately 600°C by way of the diagrid and thence through the shroud 7 back to the pool region outside of the shroud by way of the heat exchangers 8. In the event of loss of one of the circulators thereby causing a large reduction in the rate of flow of coolant through the core it is necessary to reduce the power output of the reactor core immediately by the insertion of control rods thereby to avoid overheating.

The control mechanisms 11 are arranged in two groups, a first group being provided for normal automatic control of the reactor and a second group for emergency use in the event of a malfunction of the reactor and which could, where necessary, effect immediate shut-down of the reactor. The control mechanism 11 of the second group each comprises a telescopic assembly as shown in Figure 2. A lower section 12 of the assembly constitutes a control rod and comprises neutron absorbing material 13 such as boron steel and an upper section 14 comprises a screwed member 15. The upper section 14 is housed within a fixed tubular member 16 which has a first electromagnetic latching device 17 at its lower end. A complementary latching member 18 at the upper end of the lower section 12 of the assembly is arranged normally to be engaged with the latching device 17 to hold the neutron absorbing material above the reactor core. The lower end of the screwed member 15 has a second electromagnetic latching device 19 capable of arresting and engaging the latching member 18 when the lower section is released by the first latching device 17 and falls into the reactor core. The screwed member 15 enages a nut 20 rotatable by a drive motor 21 which is responsive to a control computer. The arrangement of the mechanism is such that the second latching device 19 is spaced from the first latching device 17 its displacement being controlled by computor signals which are a function of the initial power level.

In the event of a rapid reduction in the rate of coolant flow or pressure a trip signal is inititated to release the latch mechanism 17 of each assembly and to allow free fall of the control rods into the core to an extent determined by the position of the second latching devices which arrest the fall of the control rods. The partial insertion of the neutron absorbing material in the core affects an immediate reactivity change to cause a power set-back to a safe limit. The safe limit at any particular instance is assessed by the computor and the corresponding position of the second latching device is affected by the control computor. Thereafter the lower section 12 of each assembly supported by the second latching device, is variably inserted in the reactor core by means of the drive motor and screw mechanism under automatic control signals derived from the computer. When the adverse condition giving rise to the emergency has been cleared, for example, when the rate of coolant flow has been restored to its normal value, the drive motor is arranged to lift the lower section 12 in a safely controlled manner to re-engage the latching member 18 with the electromagnetic latching device whereby the neutron absorbing material is held out of the core.

The limited free fall of the control rod ensures a fast response to an emergency such as a sudden reduction in the rate of coolant flow and avoids the necessity of taking the reactor and associated power plant completely off-load for all emergencies.

Whilst the described construction provides for a single latching device 19 for arresting the free fall of the neutron absorbing material, a series of second latches could be used, each latching device bein sensitive to a different reactor parameter so that in the event of an emergency an appropriate latching device can be arranged by means of a computer initiated signal to engage with the latching member 18 and arrest the fall of the control rod. The second latches may be arranged so that the lower control rod section 17 is arranged to slide freely over them unless energised in response to a control parameter.

Alternatively the control rods could be arranged to be propelled into the reactor core by means of stored energy (instead of relying on free fall) thereby to reduce the response time.

WHAT WE CLAIM IS:—

1. A nuclear reactor wherein fluid coolant is flowed in heat exchange over nuclear fuel and wherein control rods of neutron absorbing material are used to control the reactivity of the reactor, at least one control rod having means responsive to a trip signal

whereby said control rod is arranged to be inserted into the reactor core, movement of the control rod being in two successive stages, firstly, by free fall or stored energy propulsion and, secondly, by controlled propulsion, the means comprising a first latching device for suspending the control rod above the reactor core the device being releasably sensitive to the trip signal, a second latching device for arresting insertion of the control rod into the core and means responsive to control signals for adjusting the position of the second latching device whereby the vertical position of arrest of the control rod and subsequent controlled insertion in the reactor core, can be varied.

2. A nuclear reactor according to claim 1 wherein the means for adjusting the position of the second latching device is capable of restoring the control rod to the initial first latching device engaged position.

3. A nuclear reactor according to claim 2 wherein the latching devices are of the electro-magnetic kind releasable by interruption of the power supply to the latching devices.

4. A nuclear reactor according to claim 3 having a plurality of second latching devices arranged in series, each second latching device being responsive to a reactor parameter.

5. A liquid metal cooled fast breeder nuclear reactor substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

L. A DUNNILL,
Chartered Patent Agent.
Agent for the Applicants.

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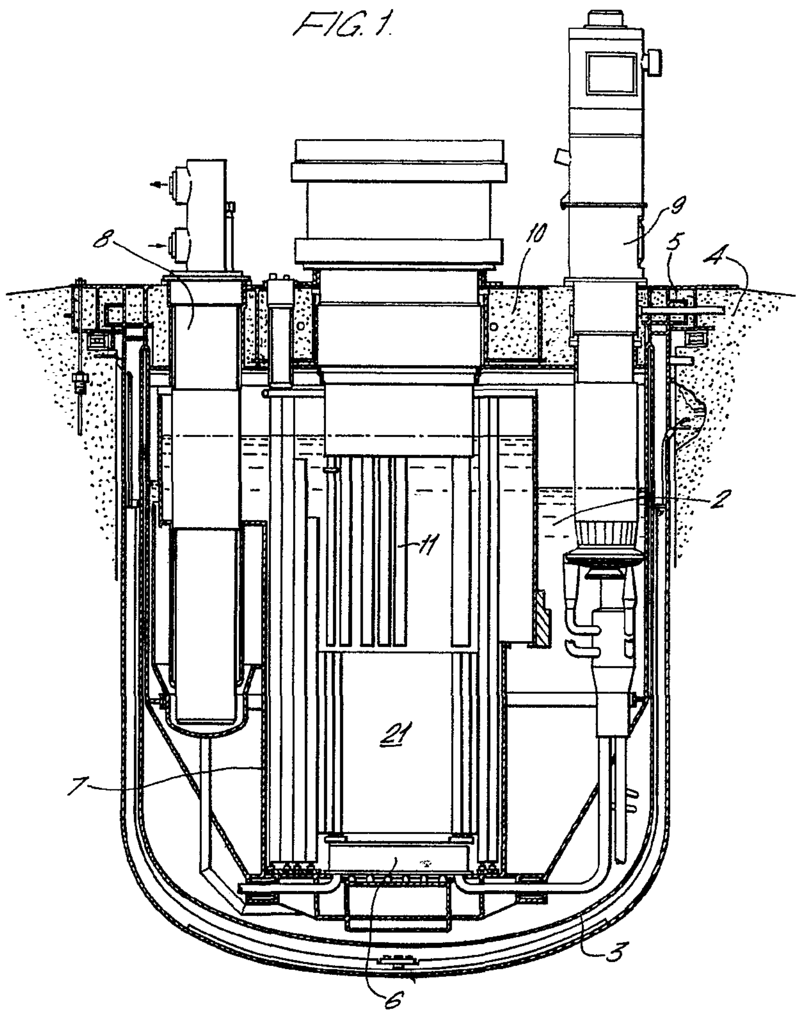
1521615 PROVISIONAL SPECIFICATION

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

Sheet 1

FIG. 1.



1521615 PROVISIONAL SPECIFICATION
2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*
Sheet 2

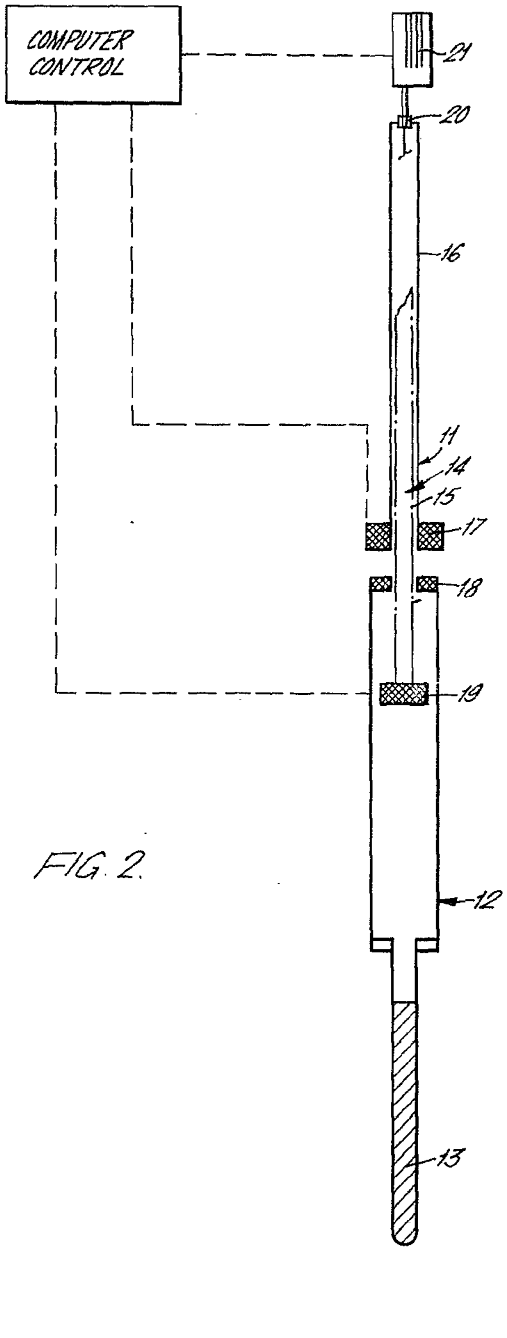


FIG. 2.