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(54) CONTROL RODS FOR NUCLEAR REACTORS

(71) We, THE ENGLISH ELECTRIC COMPANY LIMITED, of Bush House, Aldwych, London, W.C.2 (formerly of English Electric House, Strand, London, W.C.2.) a British Company, and BRITISH NUCLEAR DESIGN AND CONSTRUCTION LIMITED of Cambridge Road, Whetstone, Leicestershire, (formerly of 336 Strand, London, W.C.2.), a British Company, 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 control rods for nuclear reactors.

If a serious mechanical fault occurs in the nuclear reactor during operation, it is essential to shut-down the nuclear reactor as quickly as possible. In the case of a nuclear reactor comprising a core provided with substantially vertical control rod channels and with control rods suspended substantially in alignment with these channels in core access tubes disposed thereabove, rapid shut-down of the reactor is achieved by dropping the control rods into the channels vertically below them.

When the nuclear reactor is running at full power, the control rods are normally housed in the core access tubes and standpipes disposed at the upper ends of the control rod channels and it is possible in such a case that a serious mechanical fault could cause the core access tubes and/or standpipes to be so distorted that the control rods become jammed in the core access tubes and/or standpipes. Using control rods of known type, it would be impossible in such a case to lower the control rods into the control rod channels to shut-down the nuclear reactor.

According to the present invention a control rod comprises a plurality of hollow elements of which at least some are neutron-absorptive, disposed end-to-end and held by means of a tie-bar extending through the elements and provided at at least one of its ends with an end piece engaging a first one of the elements, wherein the tie-bar includes intermediate its two ends at least one region at which it is separable into parts when stressed transversely, and at least a second one of the hollow elements is provided internally with means for applying a localised transverse force to the said region in the event of the said second element being forced transversely relative to the tie-bar, thereby to separate the bar at the said region.

In a preferred embodiment of a control rod according to the invention, the tie-bar is constituted over at least one portion of its length, constituting the said region, by a frangible segment which is relatively easily snapped by application to it of the said localised transverse force, thereby to separate the tie-bar where the said frangible segment snaps. In such a control rod, the tie-bar may comprise a plurality of frangible segments spaced along its length, there being associated with each such segment a respective means provided internally of a respective hollow element for applying said localised transverse force.

In a control rod according to the invention, it may be further provided that at least one of the elements has housed within it and withdrawable from it an inner element connected to another of said elements for limited movement relative thereto in the longitudinal direction of the control rod.

The invention further provides a nuclear reactor comprising a core provided with substantially vertical control rod channels, core access tubes above the core and substantially aligned each with a respective one of the control rod channels, and a plurality of control rods each in accordance with the invention and suspended by means of its tie-bar

[Price 25p]

with the said one end thereof lowermost, as a clearance fit in a respective one of the core access tubes, whereby distortion of a core access tube sufficient to jam a respective control rod will also be sufficient to separate the tie-bar thereof at its said one region and thereby release at least one of its said elements to fall into the respective control rod channel.

The tie-bar may be provided with frangible sections or be arranged in sections with other means such as ball joints therebetween arranged to separate when the angular displacement of the respective adjacent sections of the tie-bar exceeds a predetermined value.

Various forms of control rods for nuclear reactors according to the invention will now be described, by way of example, with reference to the accompanying drawings in which :—

Figures 1, 3 and 5 show diagrammatically three forms of control rod according to the invention mounted in a core access tube; and

Figures 2, 4 and 6 are diagrams used to explain how the control rods of Figures 1, 3 and 5 respectively are separated when a section of the control rod becomes jammed.

The control rod of Figure 1 includes a plurality of stacked hollow sections or elements 10 of neutron absorbing material. The sections other than the lowermost each comprise a sleeve 11 and an apertured horizontal wall 12 near the lower end thereof. The lowermost section 10 is supported on a disc 13′ secured to the lower end of a tie-bar 13 which extends upwardly through the stacked sections 10 and the apertures of their walls 12. The ti-bar is, in turn, suspended from a control rod operating mechanism (not shown) mounted in a standpipe in the pile cap for the core.

The control rod is disposed within a core access tube 14 which connects a standpipe with the respective control rod channel 15 in the core 16.

Adjacent to the aperture in each horizontal wall 12 the tie-bar 13 is provided with a release mechanism 17. Preferably each release mechanism 17 is constituted by a frangible segment which snaps if subjected to a transverse force applied by the respective wall 12 if the control rod is itself subjected to a transverse force urging the stacked elements 10 out of alignment by more than a predetermined amount. If the release mechanisms are frangible segments, these may be, for example, of frangible ceramic material such as sintered alumina. However, it will be appreciated that the release mechanisms 17 may be provided by any other suitable means. For example, the tie-bar could consist of a plurality of sections with ball joints therebetween which are arranged to separate when the angular displacement of the respective sections of the tie-bar exceeds a predetermined value.

If a srious mechanical fault occurs in the nuclear reactor it is necesary to drop the control rods as quickly as possible to shutdown the nuclear reactor. However, it is possible that the fault could distort the core access tubes 14 as shown in Figure 2, and with previously known control rods this could have prevented the control rods being dropped into the core. Using the control rod shown in Figure 1, however, this risk of complete failure is greatly diminished. It is arranged that, if the core access tube 14 is sufficiently distorted (Figure 2) to jam one of the sections 10 in the tube, then the tie-bar 13 will separate at the release mechanism 17 adjacent the horizontal wall 12 of the jammed section 10 thereby allowing all of the sections below the jammed section to fall into the core. By such an arrangement it is possible to ensure that at least part of the control rod will fall into the core provided, of course, that the jammed section is not the lower-most section.

Although the invention has been described with reference to the control rods when disposed in core access tubes it will be appreciated that the invention is equally applicable to control rods which become jammed in the stand-pipes.

When a section of the control rod becomes jammed it is desirable that the length of control rod dropped into each control rod channel be as long as possible. The length of the control rod may be increased by using a control rod as shown in either Figure 3 or Figure 5

In Figure 3 the lowermost section 10 of the control rod houses a further inner element or section 18 of neutron absorbing material which rests on the disc 13′ at the lower end of the tie-bar 13. At its upper end the section 18 has a pair of coiled chains 19 or similar supporting means which are secured to the section 10 immediately above the lowermost section. If the core access tube 14 is distorted as shown in Figure 4, the tie-bar 13 is once again separated to release the sections 10 below the jammed section. In addition, the inner element 18 will also fall into the control rod channel 15 and be suspended from the jammed section if this section is that immediately above the lowermost section.

If desired, elements 10 other than the lowermost may similarly be provided with respective inner elements; and any of the elements 10 (and particularly the lowermost) may house two or more inner elements telescoped within one another and flexibly secured either to one another or to the element 10 above, in such manner that if the element 10 above an element housing a

plurality of inner elements becomes and remains jammed the plurality of inner elements and the element 10 in which they were housed will fall to such varied extents that all will occupy different axial parts of the control rod channel into which they all drop.

In the embodiment of a control rod according to the invention shown in Figure 5, the lowermost section 10 again houses a further section 18. However, this section 18, instead of having a pair of chains, is releasably secured at its upper end by a weak link 20 to the section 10 immediately above the lowermost section 10. Furthermore, an interlock mechanism is provided for the lowermost section 10 and the further section 18, one part 21 of the mechanism being provided at the top of the lowermost section 10 while the other part 22 of the mechanism is provided at the bottom of the section 18.

In operation, if the section 10 immediately above the lowermost section 10 is trapped the tie-bar 13 is again separated and the lowermost section 10 falls into the control rod channel 15. The inner section 18 is at first held stationary by the weak link 20 securing it to the next section 10; but, as the parts 21 and 22 of the interlock mechanism engage one another, the momentum of the falling lowermost section 10 provides a force which is enough to lock together the parts 21 and 22 and also to sever the weak link 20 and allow the section 18 to fall into the control rod channel. The lowermost section 10 and the section 18 thus fall together locked in an un-telescoped relationship; and the interlock mechanism maintains this relationship between them when the falling section 10 reaches the bottom of the channel and is brought to rest.

WHAT WE CLAIM IS :—

1. A nuclear reactor control rod comprising a plurality of hollow elements of which at least some are neutron-absorptive, disposed end-to-end and held by means of a tie-bar extending through the elements and provided at at least one of its ends with an end piece engaging a first one of the elements, wherein the tie-bar includes intermediate its two ends at least one region at which it is separable into two parts when stressed transversely, and at least a second one of the hollow elements is provided internally with means for applying a localised transverse force to the said region in the event of the said second element being forced transversely relative to the tie-bar, thereby to separate the tie-bar at the said region.

2. A nuclear reactor control rod as claimed in Claim 1, wherein the tie-bar is constituted over at least one portion of its length, constituting the said region, by a frangible segment which is relatively easily snapped by application to it of the said localised transverse force, thereby to separate the tie-bar where the said frangible segment snaps.

3. A control rod as claimed in Claim 2, wherein the tie-bar comprises a plurality of frangible segments spaced along its length and each segment has associated with it a respective means provided internally of a respective hollow element for applying said localised transverse force.

4. A control rod as claimed in any of Claims 1 to 3, wherein at least one of the elements has housed within it and withdrawable from it an inner element connected to another of said elements for limited movement relative thereto in the longitudinal direction of the control rod.

5. A control rod as claimed in any of Claims 1 to 3, wherein at least one of the elements constitutes an outer element which has housed within it and withdrawable from it an inner element releasably connected to an adjacent one of said elements, the inner element and the outer element in which it is housed having co-operating means which prevent complete withdrawal of the inner element and which, in doing so, lock the inner element and the outer element together in extended relationship.

6. A nuclear reactor comprising a core provided with substantially vertical control rod channels, core access tubes above the core and substantially aligned each with a respective one of the control rod channels, and a plurality of control rods each as claimed in any of Claims 1 to 5 and suspended by means of its tie-bar, with the said one end thereof lowermost, as a clearance fit in a respective one of the core access tubes, whereby distortion of a core access tube sufficient to jam a respective control rod will also be sufficient to separate the tie-bar thereof at its said one region and thereby release at least one of its elements to fall into the respective control rod channel.

7. A nuclear reactor as claimed in Claim 6, wherein at least one of the control rods is as claimed in Claim 4 and the said inner element thereof housed in the said one of the elements is connected for limited movement relative to the next element thereabove, whereby if the said next element remains jammed in the core access tube the extent of the inner element's fall into the control rod channel is limited.

8. A nuclear reactor as claimed in Claim 6, wherein at least one of the control rods is as claimed in Claim 5 and the said inner element thereof housed in the said outer element is releasably connected to the next element thereabove by means which, if the said outer element falls and becomes locked together with the inner element, will release

the inner element in response to the force exerted thereon by the falling outer element.

9. A nuclear reactor, or a control rod, substantially as described herein with reference to Figures 1 and 2, Figures 3 and 4, or Figures 5 and 6 of the accompanying drawings.

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1,295,283 COMPLETE SPECIFICATION
3 SHEETS

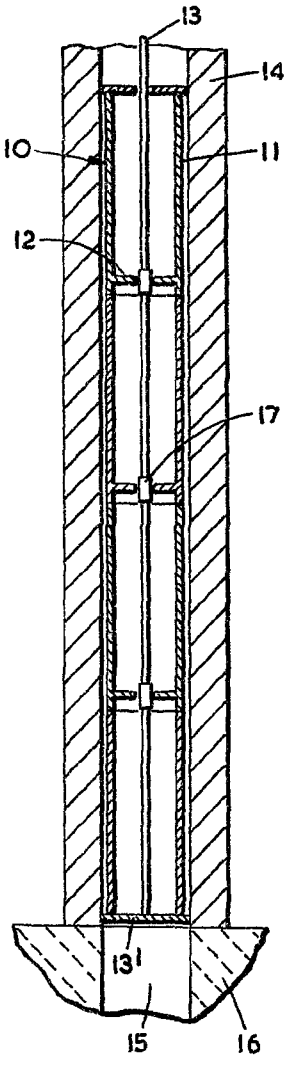

FIG. 1

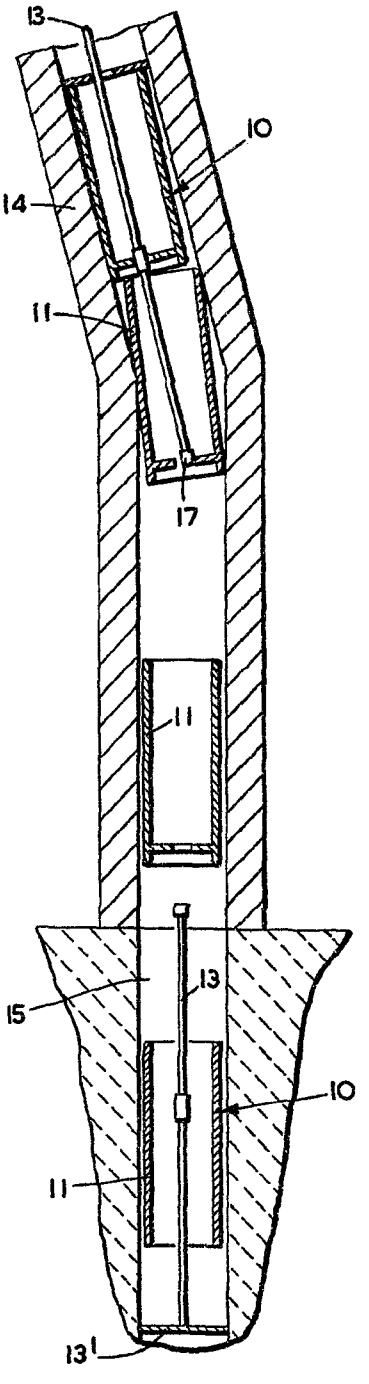

FIG. 2

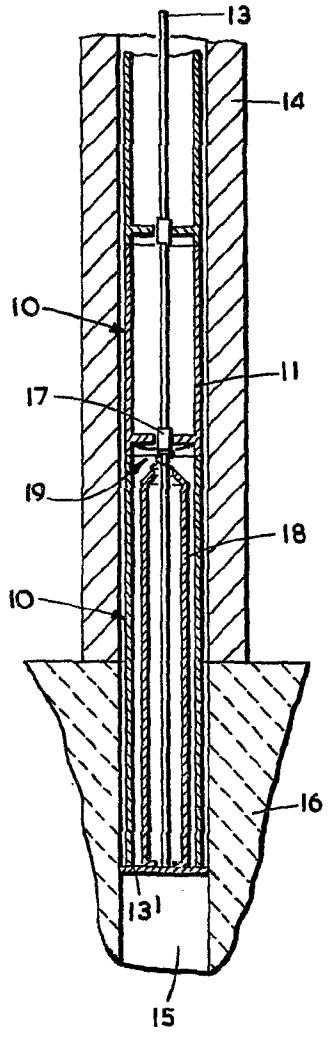

FIG.3

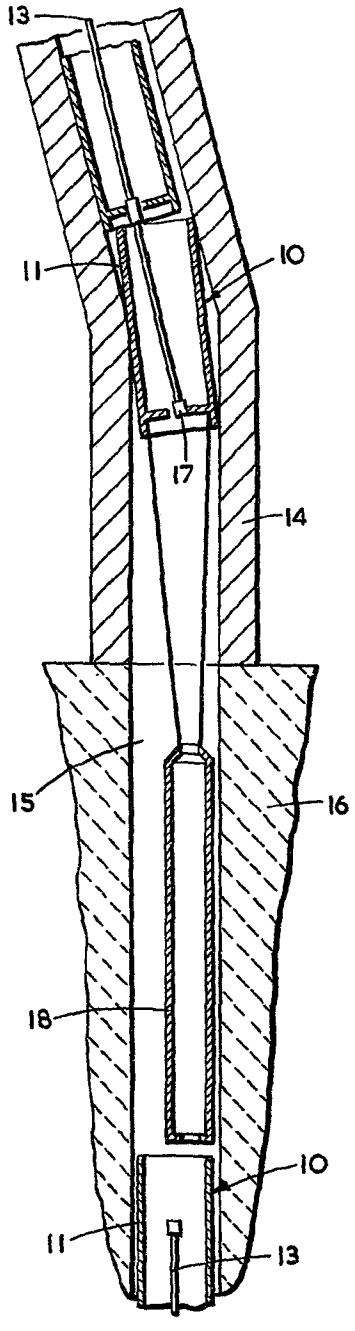

FIG.4

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3 SHEETS

COMPLETE SPECIFICATION

This drawing is a reproduction of the Original on a reduced scale.

SHEET 3

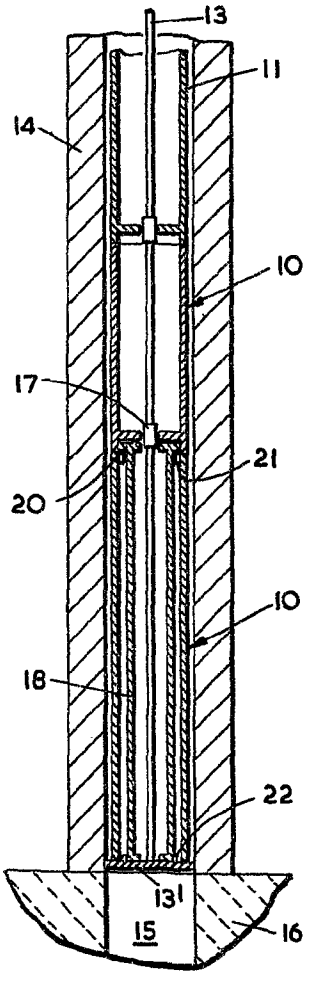

FIG. 5

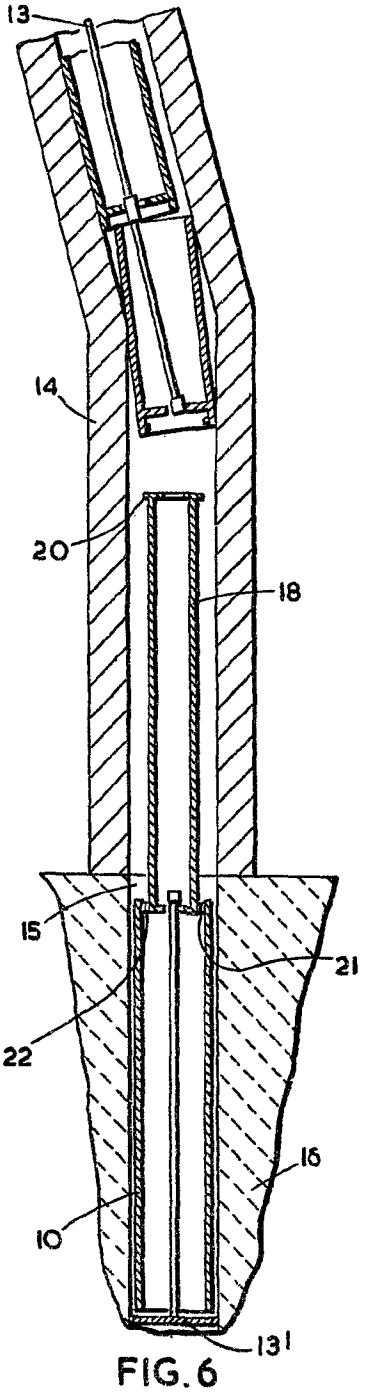

FIG. 6