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(54) **Storage arrangements for nuclear fuel**

(57) A storage arrangement for nuclear fuel comprises a plenum chamber (1) having a base (2) pierced by a plurality of openings each of which has sealed to it an open topped tube (3) extending downwards therefrom and closed at its lower end, the plenum chamber, with the tubes, forming an air-filled enclosure associated with an exhaust system (11) for exhausing air from the system through filters (12) to maintain the interior of the enclosure at sub-atmospheric pressure, the tubes being arranged to accommodate the stored fuel and the arrangement including means for producing a flow of cooling air over the exterior of the tubes so that the latter effectively form a plurality of heat exchangers in close proximity to the fuel. The air may be caused to flow over the tube surfaces by a natural thermosyphon process.

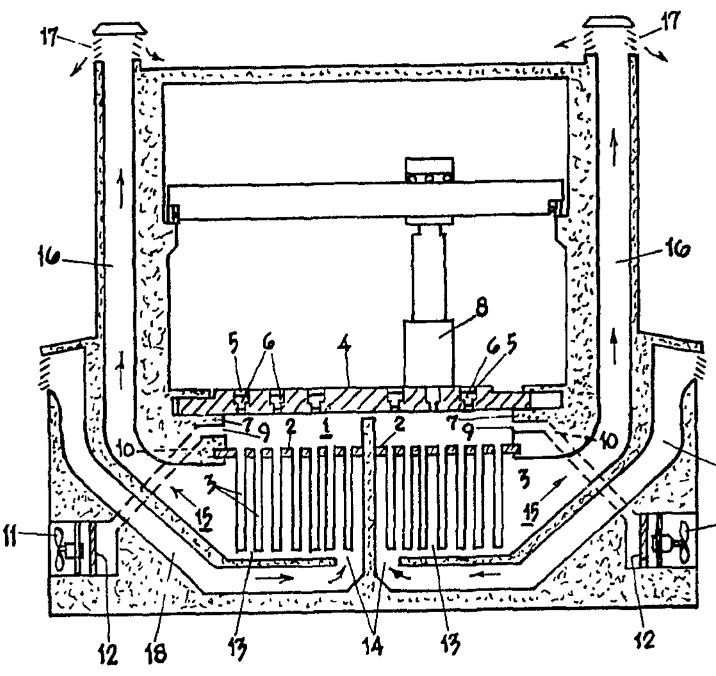

FIG. 1.

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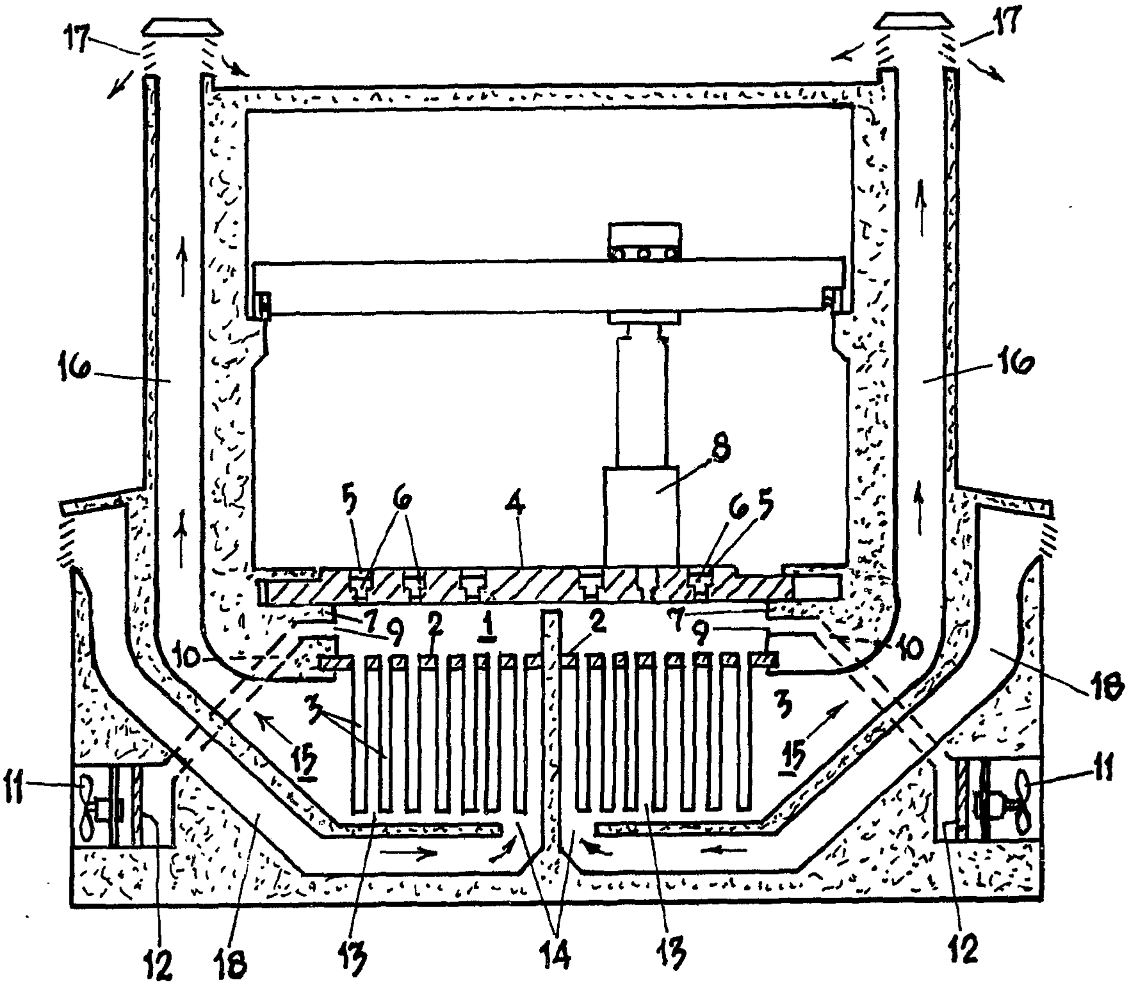

FIG. 1.

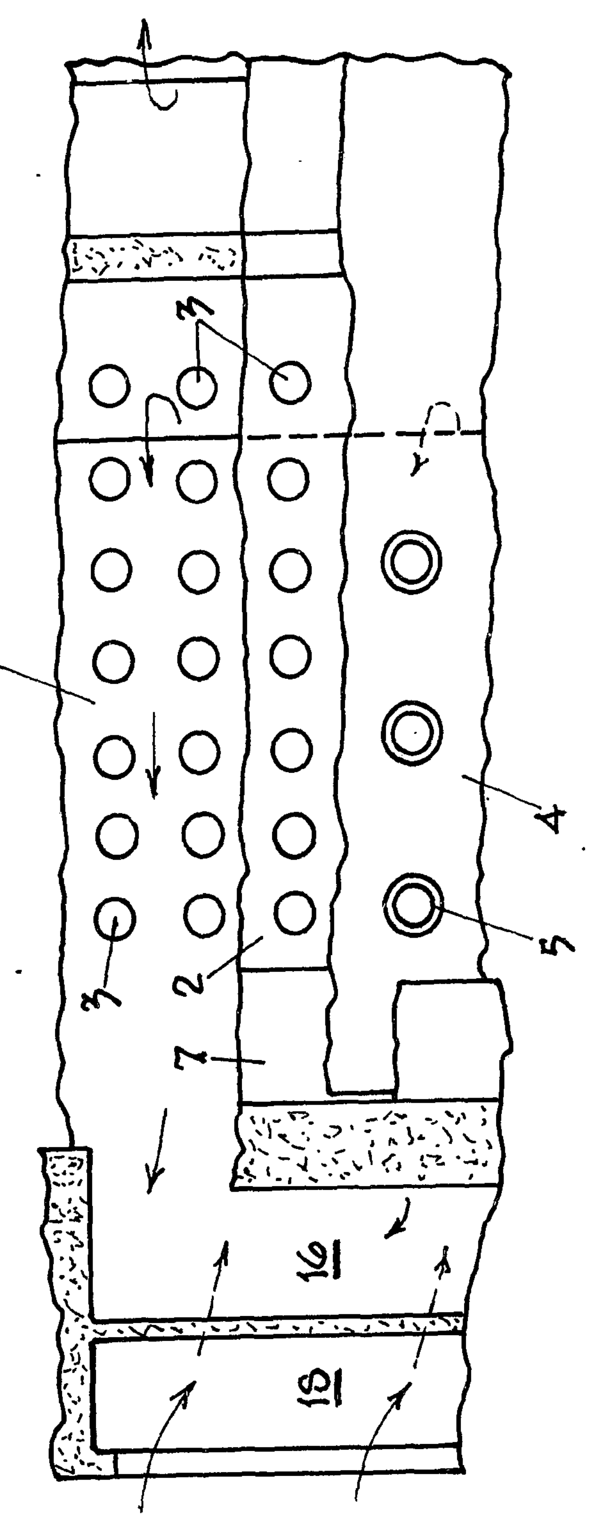

FIG. 2.

SPECIFICATION

Storage arrangements for nuclear fuel

This invention relates to storage arrangements for irradiated fuel following its removal from nuclear reactors. The invention can also relate to the storage of pre-irradiated fuel and also vitrified waste after spent fuel reprocessing.

It is a common practice to store spent fuel under water, in what are generally known as pond stores, for periods that are long enough to allow the decay heat and radiation levels to reduce sufficiently to allow the fuel to be transported with safety. However the use of a pond store is not entirely satisfactory where the fuel needs to be stored for any considerable length of time.

Thus the ability to store the fuel safely for protracted periods in a water environment is very dependent upon the materials of the cladding in which the fuel is accommodated, the irradiation history of the fuel and/or the cladding, the integrity of the cladding, and the quality of the water in which the fuel is stored. Thus cooling and shielding functions can be carried out completely satisfactorily whilst the fuel cladding remains intact, and whilst the water is present. However if the fuel cladding is perforated by corrosion or handling, then fission products can escape and both fission products and corrosion products that are radioactively contaminated are then able to float and permeate to the surface of the water, which could result in high dose rates to operators. In addition it is possible for these fission products and corrosion/contamination products to adhere to the walls of the pond. Variations in the pond water level, due to evaporation or leakage, could allow these products to dry out, when they could then become airborne, causing possible ingestion hazards to operators and the risk of atmospheric pollution.

Moreover in order to maintain adequate cooling and shielding the pond integrity must be assured to very high limits. Small leaks could give rise to minor contamination problems, and larger leaks, resulting in loss of cooling water may result in a serious district hazard.

As safety requirements for nuclear installations become more rigorous, and the allowable dose rates to operators continue to decrease, the need to design storage systems and other nuclear installations to even higher orders of integrity becomes essential, particularly as for various reasons it is now becoming necessary to store spent nuclear fuel for longer periods than was originally anticipated.

In our co-pending United Kingdom patent application No. 8027066 (Serial No. 2061798) there is described and claimed an alternative form of storage arrangement which substantially avoids the above-mentioned disadvantages. Such a storage arrangement comprises an enclosure for the fuel that utilises air as its storage medium; an exhaust system for exhausting this air from the enclosure through filters so as to maintain the interior of the enclosure at sub-atmospheric pressure; and a transfer mechanism for transferring fuel into and from the enclosure.

Maintaining a depression within the enclosure could eliminate the need for a high integrity envelope for the enclosure, as any leakage that might occur will be into the enclosure, and accordingly the invention provides an inherently safer store than the usual water filled pond. Moreover the fuel does not require to be first accommodated in fuel bottles, which is an added advantage, as bottling removes the ability to check the fuel easily. In addition, as the fuel is stored in air rather than water, the risk of corrosion is reduced, and consequently the need for an operator to maintain the water chemistry at precise levels in order to prevent the generation of corrosion products and the possibility of atmospheric pollution is thereby avoided.

An object of the present invention is to provide a form of such a storage arrangement which has particular advantages as will be apparent from the following description.

According to the invention a storage arrangement for nuclear fuel comprises a plenum chamber having a base pierced by a plurality of openings each of which has sealed to it an open-topped tube extending downwards therefrom and closed at its lower end, the plenum chamber, with the tubes, forming an air-filled enclosure associated with an exhaust system for exhausting air from the storage enclosure through filters so as to maintain the interior of the enclosure at sub-atmospheric pressure, and the arrangement including means for producing a flow of cooling fluid over the exterior surfaces of the tubes, and means for transferring fuel into and from the tubes through the roof of the plenum chamber.

Such an arrangement has the advantage of the storage arrangement above described, and has the further advantage that the storage tubes themselves effectively form a plurality of heat exchangers which are in close proximity to the stored fuel.

It will, of course, be understood that the remainder of the enclosure around the main chamber should be of sufficient thickness to provide adequate radiation shielding.

The cooling fluid is preferably air, and the tubes preferably extend downwards into a chamber having at least one lower opening and at least one upper opening so located with respect to each other and to the tubes such that the air is caused to flow over the tube surfaces by a natural thermosyphon process. For a given store geometry the amount of air flow is governed by the heat generated within the store, so that the cooling system is self regulating. As the cooling system is entirely separated from the plenum chamber housing the fuel no filtering of the cooling air is necessary, and the heated air can be discharged directly to the atmosphere.

Moreover as cooling is effected by purely natural processes, it will therefore be unaffected by breakdown of any external power supplies as would be the case if electrically driven fans or blowers were employed to produce a flow of air over the tube surfaces.

A further advantage of the present invention is that the stored fuel can readily be inspected through the loading openings in the plenum roof.

Conveniently the latter may comprise a plate supported for sliding movement on the side walls of the plenum chamber, and having a series of penetrations less than the number of storage tubes, each of which penetrations is normally closed by a plug, and the degree of movement of the plate and the positions of the penetrations are such that the plate is movable to a position in which a penetration is immediately over a selected storage tube, to allow fuel to be placed into or removed from the tube by a transfer mechanism located above the plenum chamber.

Monitors are preferably provided for detecting any rise in radiation levels within the plenum chamber and storage tubes, and also within the exhaust system. It will be understood that the filters associated therewith must, of course, be of a kind suitable for preventing escape of radiation and contamination from the enclosure as in the case of the arrangements described in our earlier application referred to above.

One form of storage arrangement in accordance with the invention will now be described by way of example with reference to Figures 1 and 2 of the accompanying schematic drawings, in which

Figure 1 represents in diagrammatic form and not to scale a transverse section through the storage arrangement, and

Figure 2 an enlarged sectional plan view of part of the arrangement.

The storage arrangement comprises a shallow plenum chamber 1 the base 2 of which is pierced by a series of openings into each of which is sealed the upper end of an open-topped metal storage tube 3, the lower end of which is closed. The top of the plenum chamber 1 is in the form of a thick plate 4 having a number of penetrations 5 which are closeable by removable plugs 6. The plate 4 is slidably supported by the side walls 7 of the plenum chamber so that a penetration 5 can be located immediately over a selected storage tube 3 to allow fuel to be deposited into or removed from the storage tube, following removal of the respective plug 6, by a movable transfer machine 8 supported above the plate 4.

The side walls 7 of the plenum chamber 1 are formed with a number of outlet openings 9 connected to ducts 10 through which air is arranged to be withdrawn from the chamber by exhauster fans shown schematically at 11 to maintain the interior of the plenum chamber 1, and hence of the tubes 3, at sub-atmospheric pressure, the air passing to the fans through suitable filters 12.

By maintaining a depression within the plenum chamber and tubes the need for a high integrity sealed envelope could be avoided, as any leakage that occurs will be inwards. The number and capacity of the exhauster fans are such as to provide adequate redundancy, to provide adequate integrity during breakdown and servicing, and by arranging a plurality of said outlet openings 9 to the exhauster fans at spaced positions around the enclosure, a sub-atmospheric pressure may be maintained within the plenum chamber even in cases where a region of its envelope becomes damaged to an extent which would otherwise give rise to significant leakage problems. It will also be seen that the plugs 6 do not need to seal the penetrations 5 in the plate 4.

Monitors (not shown) are provided at suitable positions within the plenum chamber and storage tubes, and in association with each of the fan ducts in order to detect any significant rise in the level of radiation and contamination.

The storage tubes 3 extend downwards into chambers 13 (two of which are shown in Figure 1), each chamber having an air inlet opening 14 at the bottom and one side, and an outlet opening 15 at the opposite side communicating with an upwardly extending vertical duct 16 open to the atmosphere through louvres 17 at its top end.

The inlet openings 14 are also in communication with the atmosphere through inlet ducts 18 and in use of the arrangement decay heat from spend fuel within the storage tubes 3 is transferred to the walls of the tubes by conduction, convection and radiation, and the heat is removed from the tubes to the atmosphere by a natural thermosyphon process, the heated air rising within the ducts 16 by convention, and being replaced by cooler air drawn into the chambers 13 through the inlet openings 14 and ducts 18, as indicated by the arrows, the inlet and outlet openings 14, 15 being disposed so that the air traversing the chambers 13 passes between the tubes 3.

It will be seen that the amount of air flow is governed by the heat generated within the store, and the arrangement is such that the cooling achieved is adequate to maintain the interior of the store at a safe temperature under all normal circumstances.

Stand-by fans or blowers may, however, be provided to give additional forced cooling should an abnormal temperature rise occur.

As the fuel elements are not bottled, inspection can be readily carried out, and removal of fuel from the store, should this become necessary, can be speedily effected.

The storage tubes 3 will normally be of circular cross section, but this is not essential and other shapes may alternatively be employed. In some cases the tubes may carry external cooling fins, preferably extending in a generally lengthwise direction along the tubes.

CLAIMS

1. A storage arrangement for nuclear fuel comprising a plenum chamber having a base pierced by a plurality of openings each of which has sealed to it an open-topped tube extending downwards therefrom and closed at its lower end,

the plenum chamber, with the tubes, forming an air filled enclosure associated with an exhaust system for exhausting air from the storage enclosure through filters so as to maintain the interior of the enclosure at subatmospheric pressure, and the arrangement including means for producing a flow of cooling fluid over the exterior surfaces of the tubes, and means for transferring fuel into and from the tubes through the roof of the plenum chamber.

2. A storage arrangement according to Claim 1 wherein the cooling fluid is air, and the tubes extend downwards into a chamber having at least one lower opening and at least one upper opening so located with respect to each other and to the tubes such that the air is caused to flow over the tube surfaces by a natural thermosyphon process.

3. A storage arrangement according to Claim 2 wherein the or each said upper opening communicates with an upwardly extending duct open to the atmosphere at its upper end.

4. A storage arrangement according to Claim 1, 2 or 3 in which the roof of the plenum chamber comprises a plate supported for sliding movement on the side walls of the plenum chamber, and having a series of penetrations less than the number of storage tubes, each of the penetrations normally being closed by a plug, and the degree of movement of the plate and the positions of the penetrations being such that the plate is movable to a position in which a penetration is immediately over a selected storage tube, to allow fuel to be placed into or removed from the tube by a transfer mechanism located above the plenum chamber.

5. A storage arrangement according to any preceding Claim wherein monitors are provided for detecting any rise in radiation levels within the plenum chamber and storage tubes, and also within the exhaust system.

6. A storage arrangement according to any preceding claim wherein the tubes are provided with external cooling fins.

7. A storage arrangement according to Claim 6 wherein the cooling fins extend in a generally lengthwise direction along the tubes.

8. A storage arrangement for nuclear fuel substantially as shown in and as hereinbefore described with reference to Figures 1 and 2 of the accompanying drawings.

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