

FORM P8

(Lodge in Duplicate)

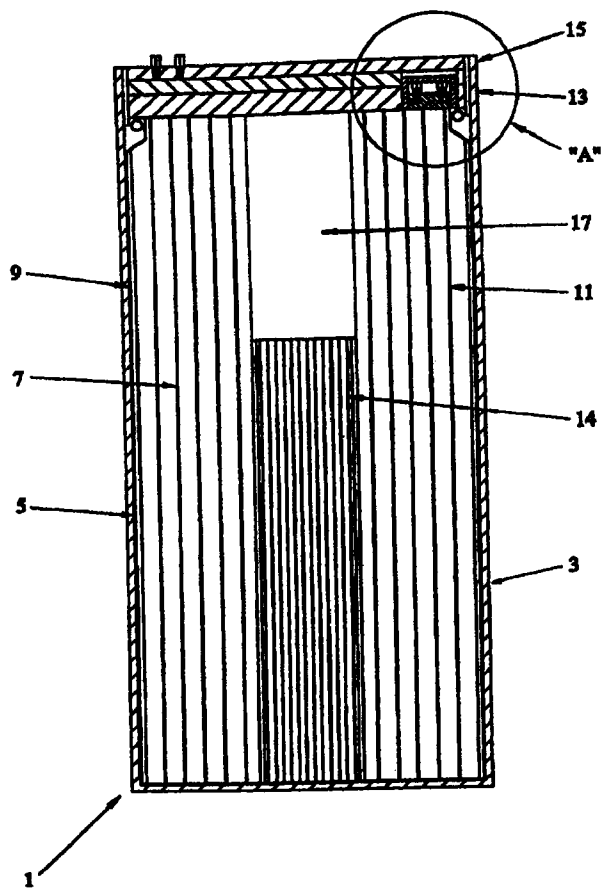
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54	Title of invention FUEL CONTAINMENT APPARATUS						
57	Abstract See next page.						
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Abstract

Apparatus for the containment of a radioactive object or material comprises an outer sealed vessel (3), and an inner sealed vessel (5) for containing the radioactive object, the inner vessel being located within the outer sealed vessel and separated therefrom by a gap (9) which is filled with an inert fluid such as helium, wherein the apparatus is self contained and thus more easily transportable, and is arranged for circulation of the inert fluid in the gap by natural convection only.



Fuel Containment Apparatus

This invention relates to containment canisters for storing nuclear waste materials in particular, although not exclusively, spent nuclear fuel.

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Nuclear fuel used in nuclear reactors is generally situated within a nuclear fuel assembly which comprises a plurality of individual fuel pins. The fuel is located inside the pins which are commonly made from a zirconium alloy such as Zircaloy (trade name) or stainless steel depending on the fuel and reactor type. When
10 irradiated fuel is stored, this cladding provides a gas tight first radiation containment barrier. This feature of the cladding of the nuclear fuel assembly is present throughout the operational life of the fuel, and subsequently when the fuel is spent. When the fuel is spent, the fuel assembly must be removed from the nuclear reactor and replaced by a new fuel assembly. The old fuel is highly radioactive and generates
15 a significant amount of heat. After cooling, the spent fuel assembly can be transported from the reactor site or moved to another location at the reactor site for interim storage.

If interim storage is the preferred option, consideration must be given to the integrity
20 of the cladding of the fuel pins. It is a common requirement of interim storage facilities that they ensure the radioactive fuel is contained within a structure which ensures at least double containment, that is, there are at least two gas tight radiation barriers between the fuel and the external environment. In some cases, the cladding can be used as a first containment barrier. However, it is costly, time consuming and
25 labour intensive to guarantee the integrity of the cladding since all the fuel pins of each nuclear fuel assembly would require to be tested to examine the integrity of the cladding. For assemblies containing pins which failed the safety test the requirement of double containment would still need to be satisfied.

30 One of the main problems associated with containment barriers has been the effectiveness of the closure mechanism, such as seals or welds. Much of the prior art

has used the idea of redundant seals or welds (as seen in the open literature of the German company GNB), this means that there is a single containment canister or casks with two lids, each of which is welded or bolted and sealed in place to the body of the canister or cask each of the welded lids acting as a fail-safe for the other. This
5 canister or cask provides only a single containment barrier, but does not allow monitoring of the integrity of the inner lid by known means such as radiometric monitoring or gas pressure monitoring.

The Sierra Nuclear Corporation also provide a canister with a double lid, but disclose
10 no means of monitoring the integrity of the lids.

Another previously suggested option for containment was individual confinement of each assembly in a separate container within the outer containment vessel. Such an assembly is disclosed in US 4521372 (Nuclear Monitoring Systems & Management
15 Corporation), in which an assembly of two or four nested containers, each spaced from an adjacent container by a gap, is stored within a metal and concrete lined bore extending down into the earth. Monitoring fluid, for example a fluid which scintillates in response to radioactivity, is disposed in at least one gap, and this gap is coupled to a remote circulating pump on the earth surface by umbilical conduits. One
20 or more sensors at the earth surface detect leakage of radioactive material into the gap by monitoring scintillation of the circulated fluid, any scintillation caused by direct radiation from the stored material through the containment walls having by that time decayed to a negligible level.

25 Such an arrangement is not practically movable or transportable. Furthermore, the containment means at the foot of the bore is not entirely self contained, since the umbilical conduits extend from with such means, and themselves present a source of weakness in the containment system. For example, in the case of a heavy leak of radioactive material into the gap being monitored, only the relative vulnerable
30 umbilical conduits, and associated pipework and pumps prevent leakage into the environment.

Moreover, since storage lifetimes of over 50 years may be required in this sort of application, the choice of an inert monitoring fluid is particularly important. It is particularly necessary to avoid corrosion of the containing vessels, or at least the acceleration of corrosion thereof, due to such agencies as erosion by the monitoring
5 fluid, vessel material contamination by the monitoring fluid, or the presence of impurities in the monitoring fluid, and it is not clear that the monitoring fluid used in this prior art arrangement necessarily meets this requirement.

The present invention provides apparatus for the containment of a radioactive object
10 or material, the apparatus comprising an outer sealed vessel, and an inner sealed vessel for containing the radioactive object which inner vessel is located within the outer sealed vessel and separated therefrom by a gap, wherein the gap is filled with an inert fluid and the apparatus is arranged for circulation of the inert fluid in the gap by natural convection only. In this way, substantially all heat generated within the inner
15 vessel is transferred to the outer vessel by radiation and by conduction and natural convection afforded by the inert fluid.

This means that the apparatus can be self contained and transportable, and accordingly the invention also provides self contained apparatus for the containment
20 of a radioactive object or material, the apparatus comprising an outer sealed vessel, and an inner sealed vessel for containing the radioactive object which inner vessel is located within the outer sealed vessel and separated therefrom by a gap, wherein the gap is filled with an inert fluid.

25 The invention extends to a method of storing a radioactive object or material, wherein said object or material is sealed within an inner vessel and said inner vessel is sealed within an outer vessel with a gap between the inner and outer vessels, wherein said gap is filled with an inert fluid and wherein said method includes the step of allowing circulation of said inert fluid always by natural convection alone.

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The invention also extends to a method of storing a radioactive object or material, wherein said object or material is sealed within an inner vessel and said inner vessel is sealed within an outer vessel with a gap between the inner and outer vessels, wherein said gap is filled with an inert fluid and wherein said outer vessel is substantially self
5 contained.

Other features of the invention will become apparent on a reading of the following general and particular description, and the appended claims, to which the reader is referred.

10

The radiation containment may be for the storage of irradiated nuclear fuel.

Preferably the inert fluid is a gas.

15 Preferably the inert gas is helium. Helium has a relatively high thermal conductivity, and provides a relatively efficient heat path via convection and conduction, from the inner, or first, vessel to the outer, or second, vessel.

A further need is to provide effective monitoring of the integrity of each of the
20 vessels. Use of an inert fluid in the gap allows the integrity of the vessels to be monitored, since leaks in the second vessel will be apparent from a change in pressure, composition and/or radioactivity of the inert fluid. Since the inert fluid can flow around substantially all of the space between the first vessel and the second vessel, it is possible to more accurately determine the overall integrity of the
25 containment provided by the apparatus, since leaks from substantially all parts of both the first and second vessels can be detected.

Thus, where an inert gas such as helium is provided, leaks in the second vessel will be apparent from a change in pressure, and/or a change in the composition of the inert
30 gas showing a greater proportion of oxygen, nitrogen or carbon dioxide, i.e. those

gases found in air. Leaks in the first vessel will be detected by an increase in the radioactivity of the inert gas.

5 Preferably the detector or all the detectors are located outside the gap and are connected or connectable to the gap by means of gas connectors. Optionally the detector, or some or all of the detectors, may be located inside the gap, or adjacent thereto and in fluid connection therewith.

10 Filling of the gap with the inert fluid may be performed using a backfilling valve mounted in a wall (for example the lid) of the outer vessel. Advantageously, the valve is recessed into the wall to protect it from mechanical damage.

After use, and where no detectors are provided, or where the detector or detectors all within the gap, the valve may be protected and/or sealed by the securing of a plate
15 thereover, for example by welding. This construction is regarded as particularly secure, and so monitoring may be deemed unnecessary, at least in some cases. If monitoring is required, some means of accessing the detectors (for example, electrical, such as leads, or optical, such as a plain window or a coherent or incoherent fibre optic bundle) needs to sealingly penetrate the wall or lid of the outer vessel.

20

Alternatively, the valve may be left available, and this is particularly relevant where it is desired to connect a detector to the fluid within the gap for monitoring purposes. Where the stored material comprises spent fuel rods, for example, monitoring may not need to be effected very often, say around once a year, so that there is little risk of
25 material from the valve escaping into the environment.

Preferably the gap contains a first spacer used to ensure that the first vessel and second vessel are substantially concentric and separated.

30 Preferably the gap may contain a second spacer situated between the load bearing surfaces of the first and second vessels. The second spacer may be generally in the

form of a flat plate. Preferably the second spacer is made of or comprises ceramic material. Optionally, the ceramic material may contain vents or gas passages to allow the inert gas to pass between the load bearing surfaces of the first vessel and the second vessel. The vents or gas passages may be formed by constructing the second
5 spacer from a number of ceramic tiles individually spaced from one another.

Preferably the first vessel is filled with helium or other inert gas.

The apparatus may optionally be used to provide multiple containment barriers since
10 further such barriers may be present within the first vessel as, for example, further containment vessels, the innermost of which may contain the radiation source. It is an advantage of the present invention that no reliance is placed upon the integrity of the cladding of the nuclear fuel assembly since the radiation barriers are contained within the structure of the vessels. This allows the spent fuel elements to be stored without
15 the need to monitor the integrity of the cladding on the fuel pins.

In order that the present invention may be more fully understood, examples will now be given by way of illustration only with reference to the accompanying drawings, of which:

20

Figure 1 shows a cross section in elevation of a double containment canister assembly according to the present invention;

25

Figure 2 shows an expanded view taken of detail "A" from Figure 1 of the spacer and welds used to secure the first vessel in place inside the second vessel to provide a double containment canister having a gap as claimed in the present invention;

30

Figure 3 shows a schematic cross section in elevation of the second vessel or outer containment canister; and

Figure 4 which shows a plan view of an example of an arrangement of fuel assemblies which form a radiation source inside the first vessel or inner containment canister.

5 Figure 1 shows a double containment canister 1. The general features and dimensions are as follows. The entire structure is cylindrical measuring 4.135m in length and 1.85m in diameter, these dimensions are those of the outside surfaces of the outer containment vessel or second sealed vessel 3. The inner containment vessel 5 or first sealed vessel is constructed to fit inside the outer containment vessel. The wall of the
10 outer containment vessel 3 is 0.025m thick. The wall of the inner containment vessel is .005m thick. Both structures are constructed from carbon steel of a known specification. The inner containment canister 5 is fitted with a shield lid 13 which is 0.2m thick. The outer containment canister 3 is fitted with a structural lid 15 which 0.075m thick.

15

A gap 9 exists between the inner containment vessel 5 and the outer containment vessel 3. This gap is illustrated clearly in Figure 2.

The inner containment vessel contains the fuel basket 7 into which the spent nuclear
20 fuel is loaded for interim storage. The fuel basket 7 contains a number of parallel fuel assembly guide tubes 11 in which the spent nuclear fuel is placed inside the fuel basket 7. These guide tubes 11 are constructed of carbon steel of a known specification and are 4.02m long. The fuel basket also contains lengthening bar guide tubes 14. These tubes are used to contain the lengthening or hanger bar component of
25 the spent fuel assembly.

Figure 2 shows an expanded view of the lids and the gap between the inner containment vessel and the outer containment vessel 3. The cylindrical wall of the inner containment vessel 5 and the cylindrical wall of the outer containment vessel 3
30 are shown and the gap 9 between the vessels is clearly visible and is 0.01m wide. A spacer 21 is provided to ensure the inner containment vessel 5 is substantially

concentric with the outer containment vessel 3. The spacer 21 is 0.007m in width and therefore leaves a gap 23 between the outer containment vessel and the inner containment vessel of 0.003m in the region of the spacer 23. The width of the gap 9 below the spacer is 0.01m. The shield lid 13 is welded to the inner containment vessel at 25 and the structural lid 15 is welded to the outer containment vessel at 29.

Quick release connectors incorporating gas inlet valves 31 are situated below a steel plate 27 which is welded in place after the inner containment vessel 5 is dried and back filled with helium. Similar connectors are located on the structural lid 15.

10

Figure 3 shows the outer containment vessel 5. The thickness of the bottom surface of the vessel 41 is shown as 0.03m.

A ceramic support spacer 43 is positioned on top of the bottom surface of the vessel, this prevents the bottom steel surface 45 of the inner containment vessel from reacting with the bottom steel 41 surface of the outer containment vessel and also allows circulation of Helium between the bottom surfaces of vessels 3 and 5. This figure also shows quick release connectors incorporating gas inlet valves 47 and 49 used to backfill the gap 9 with helium gas. In addition, a pressure sensor 42, gas composition sensor 44 and radiation detector 46 are shown.

20

Figure 4 illustrates a plan view of the arrangement of spent fuel assemblies within the canister for one type of fuel. The central portion of the arrangement is filled with the lengthening or hanger bars, which are put in the lengthening bar guide tubes (51).

25 The space surrounding these tubes is filled with fuel assembly guide tubes.

Referring to Figure 1, in use, the inner containment vessel 5 is filled with fuel assemblies which are located in the fuel assembly guide tubes 11 and with lengthening bars which are located in the lengthening bar guide tubes. The void 17 can be filled with other waste material.

30

Once the inner containment vessel 5 is filled, the shield lid 13 is welded 25 on and inspected, then the steel plate 27 (Figure 2) is welded in place over the quick release connectors 31 after evacuation and backfilling. The structural lid 15 is then welded in place 29.

5

The gap 9 is subsequently filled with helium by means of a sealable gas connector 47 (Figure 3) located in the structural lid. In addition, a second gas connector 49 is used as an exhaust for gases displaced by the helium. These exhaust gases are monitored either continuously or periodically (monitoring apparatus not shown) and when the
10 helium content of the gap gas is at a known high level, approximately 99.99%, the inlet pipe 47 and exhaust pipe 49 are sealed.

Thereafter, the helium in the gap can be monitored in at least three distinct ways either by using the detectors 42, 44, 46 located in the gap, as shown in Figure 3, or by
15 connecting monitoring apparatus to the gas inlet valves continuously or as and when desired. Detector 42 is a pressure monitor 42 for enabling an indication of any change in the gas pressure. Such a change of pressure would arise if a crack or other fault in the outer containment vessel occurred. The resultant change in pressure would indicate such a malfunction.

20

In addition, the composition of the gas inside the gap can be monitored. If the amount of oxygen or nitrogen in this gas increased, as determined by detector 44, this would also give a good indication that a breach in the outer containment vessel had occurred.

25

The third detector 46 is made up of a number of detectors which can measure the effects of radioactivity. In particular the level of radionuclides in the gas is examined. The level of ionisation of the He gas would indicate the amount of radiation escaping from any part of the vessel since the helium gas fills almost the entire gap with the
30 exception of that part of the gap which is occupied by the ceramic base plate. Also γ

detection may be used to indicate a breach in the shield lid 23. In addition, neutron monitoring equipment can be included in the radioactivity detector.

It can be seen, therefore that this example of the present invention provides apparatus
5 which allows double containment of the radioactive source (in this case spent nuclear
fuel assemblies) and, because of the extent of the gap between the inner containment
vessel 5 and the outer containment vessel 3, it also allows monitoring of the integrity
of the whole of both containment vessels. The apparatus is self-contained, and can be
moved or transported with relative ease. The natural convection and conduction
10 afforded by the helium filling effectively transfers heat from the spent fuel rods to the
outer vessel.

In a second example, referring to Figure 3, the ceramic support 43 used to fill the gap
between the load bearing surfaces of the inner containment vessel 45 and the outer
15 containment vessel 41 contains a number of vents which allow the helium gas to
circulate around the gap between the load bearing surfaces.

It should be noted that the internal structure of the inner vessel 5 in the above
example is dictated by the particular form of fuel assembly being stored. The internal
20 structure may be changed to accommodate other designs of fuel assembly without
departing from the principle or scope of the present invention.

CLAIMS

1. Apparatus for the containment of a radioactive object or material, the
5 apparatus comprising an outer sealed vessel, and an inner sealed vessel for containing
the radioactive object which inner vessel is located within the outer sealed vessel and
separated therefrom by a gap, wherein the gap is filled with an inert fluid and the
apparatus is arranged for circulation of the inert fluid in the gap by natural convection
only.
10
2. Self contained transportable apparatus for the containment of a radioactive
object or material, the apparatus comprising an outer sealed vessel, and an inner
sealed vessel for containing the radioactive object which inner vessel is located within
the outer sealed vessel and separated therefrom by a gap, wherein the gap is filled
15 with an inert fluid.
3. Apparatus according to claim 1 or claim 2 wherein the inert fluid is a gas.
4. Apparatus according to claim 3 wherein the gas is or comprises helium.
20
5. Apparatus according to any preceding claim wherein the gap between non-
load bearing surfaces of the inner and outer vessels is maintained with at least one
first spacer.
- 25 6. Apparatus according to any preceding claim wherein the gap between non-
load bearing surfaces of the inner and outer vessels is in the range 0.001 to 0.20
metres.
7. Apparatus according to any preceding claim wherein the gap between load
30 bearing surfaces of the inner and outer vessels is maintained with at least one second
spacer.

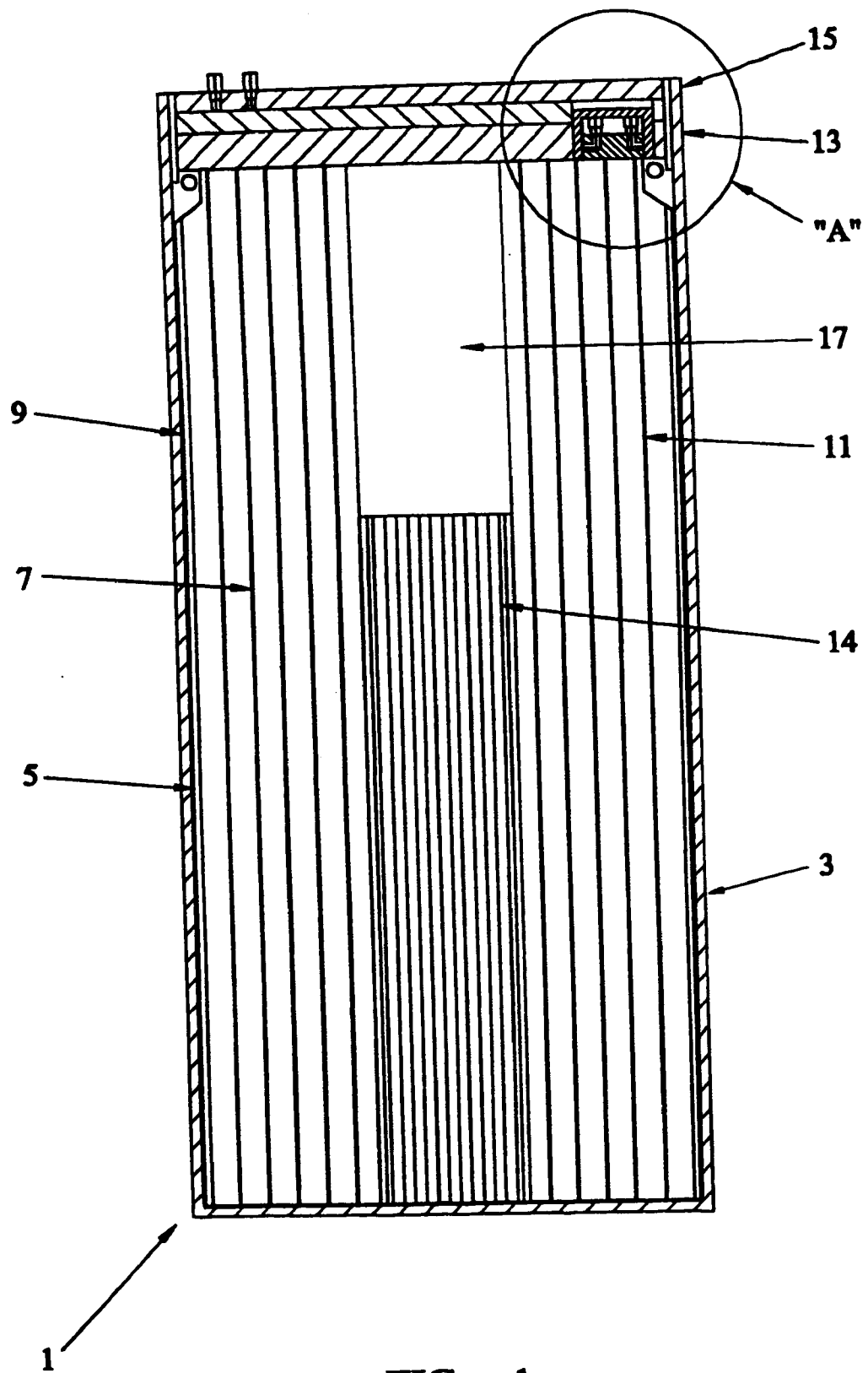
8. Apparatus according to claim 7 wherein said second spacer comprises ceramic material.
9. Apparatus according to any preceding claim wherein the gap between load bearing surfaces of the inner and outer vessels is in the range 0.001 to 0.20 metres.
10. Apparatus according to any preceding claim wherein at least one detector is located in said gap, or adjacent said gap and in fluid connection therewith.
11. Apparatus according to claim 8 wherein a said detector detects radioactivity.
12. Apparatus according to claim 10 or claim 11 wherein said detector detects the pressure of said fluid, or a change in pressure thereof.
13. Apparatus according to any one of claims 10 to 12 wherein a said detector detects fluid composition.
14. Apparatus according to any preceding claim wherein the vessels are substantially cylindrical.
15. Apparatus according to any preceding claim wherein a backfilling valve is connected to the outer vessel for adding said inert fluid to the gap.
16. Apparatus according to claim 15 wherein a said backfilling valve is recessed with the depth of a wall of said outer vessel.
17. Apparatus according to claim 15 or claim 16 wherein said backfilling valve is protected by a plate welded in place after use.
18. Apparatus according to any preceding claim wherein the inner vessel is filled with an inert gas.

19. Apparatus according to claim 18 wherein a backfilling valve connected to the inner vessel for filling it with said inert gas.
20. Apparatus according to claim 19 wherein said backfilling valve is protected by
5 a plate welded in place after use.
21. A method of storing a radioactive object or material, wherein said object or material is sealed within an inner vessel and said inner vessel is sealed within an outer vessel with a gap between the inner and outer vessels, wherein said gap is filled with
10 an inert fluid and wherein said method includes the step of allowing said inert fluid to circulate by natural convection alone.
22. A method of storing a radioactive object or material, wherein said object or material is sealed within an inner vessel and said inner vessel is sealed within an outer
15 vessel with a gap between the inner and outer vessels, wherein said gap is filled with an inert fluid and wherein said outer vessel is substantially self contained.
23. A method according to claim 21 or claim 22 wherein said inert fluid is a gas.
- 20 24. A method according to any one of claims 21 to 23 wherein said gap is filled by means of a backfilling valve in said outer vessel
25. A method according to any one of claims 21 to 24 wherein said backfilling valve is protected by the welding of a plate after said gap is filled.
25
26. A method according to any one of claims 21 to 25 and including the step of monitoring said inert fluid for at least one property selected from the group consisting of radioactivity; pressure; change of pressure; and composition.

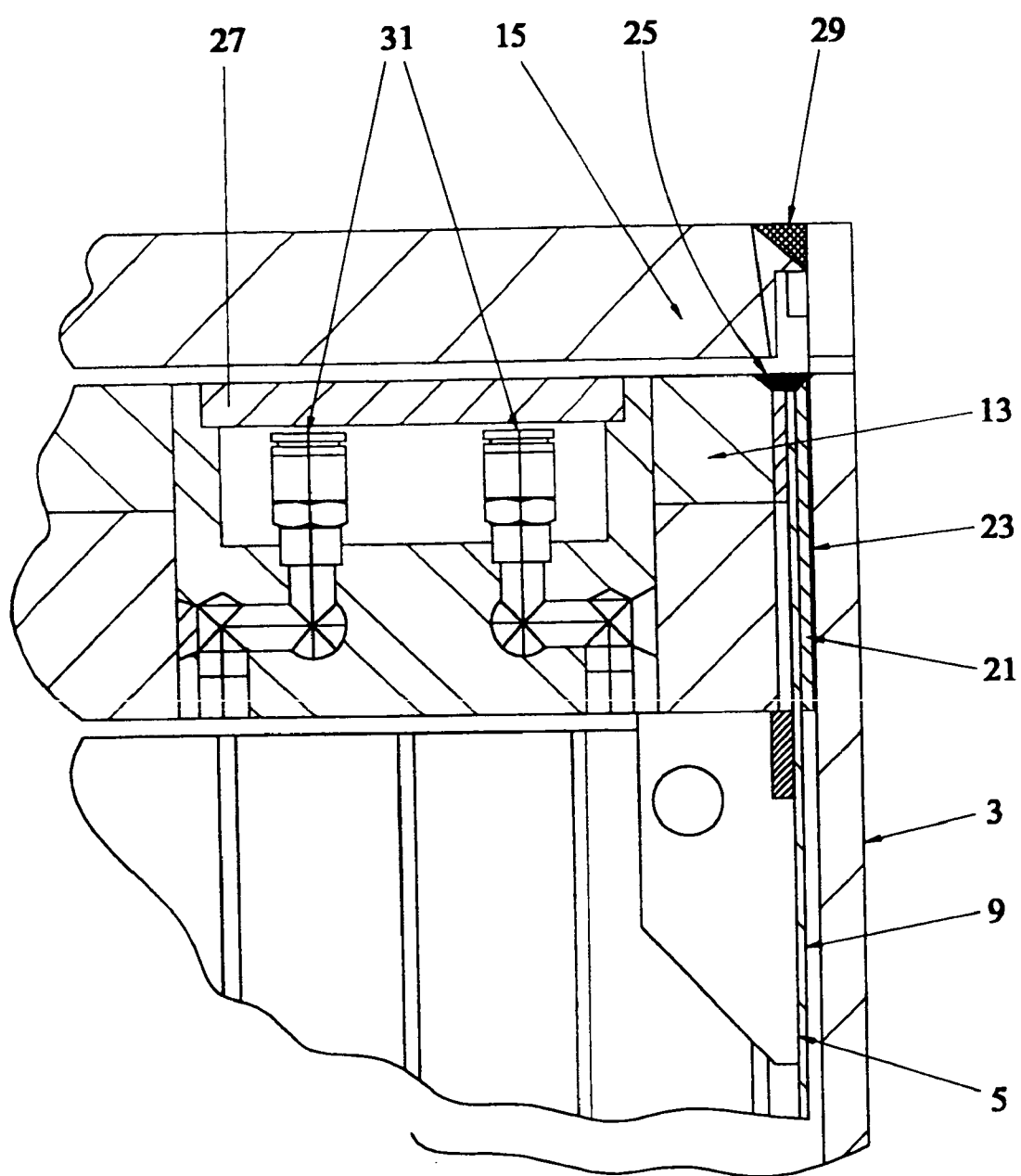
27. A method according to any one of claims 21 to 24 and including the step of monitoring said inert fluid via said backfilling valve for at least one property selected from the group consisting of radioactivity; pressure; change of pressure; and composition.

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FIG. 1

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FIG. 2

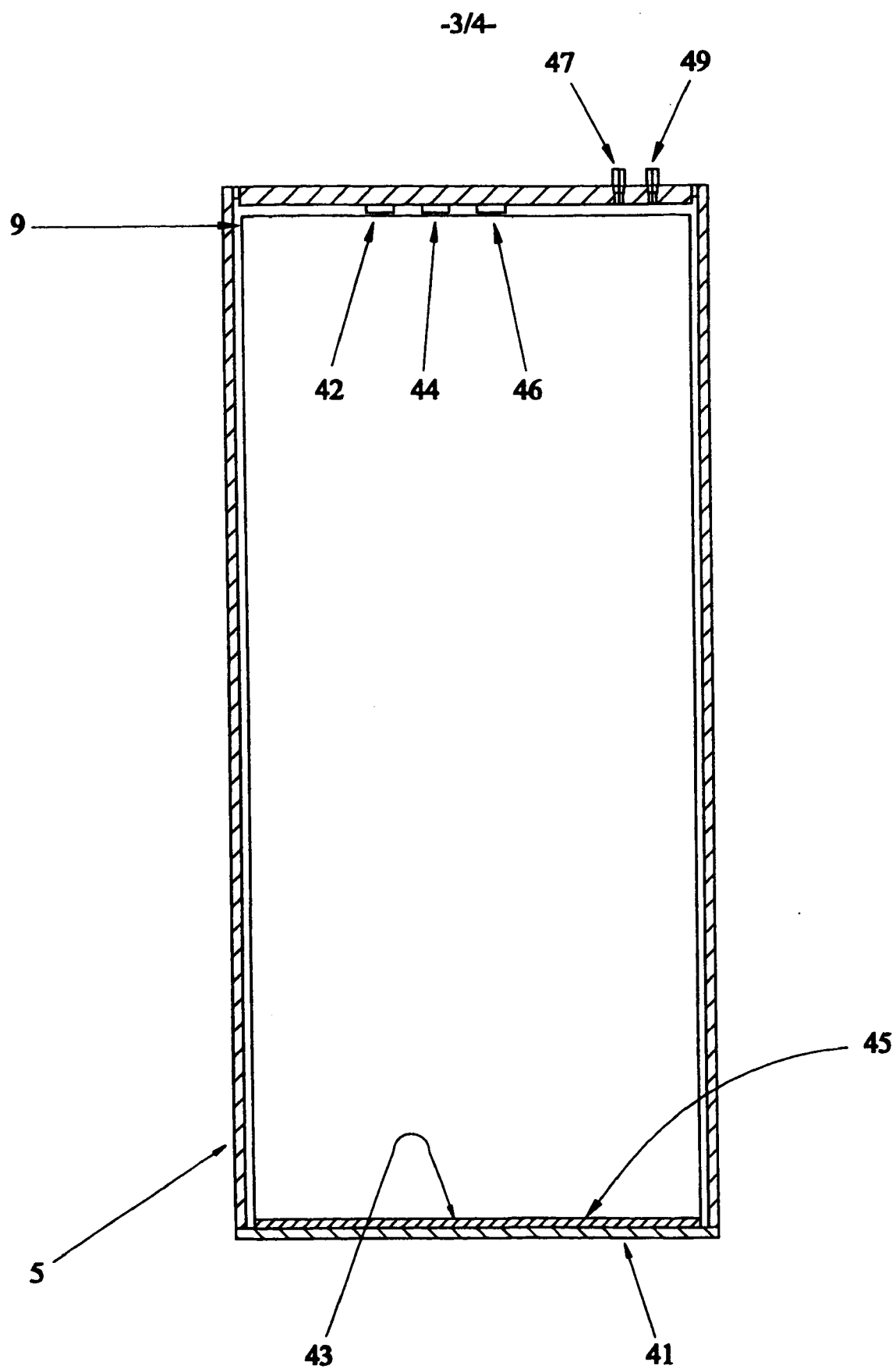
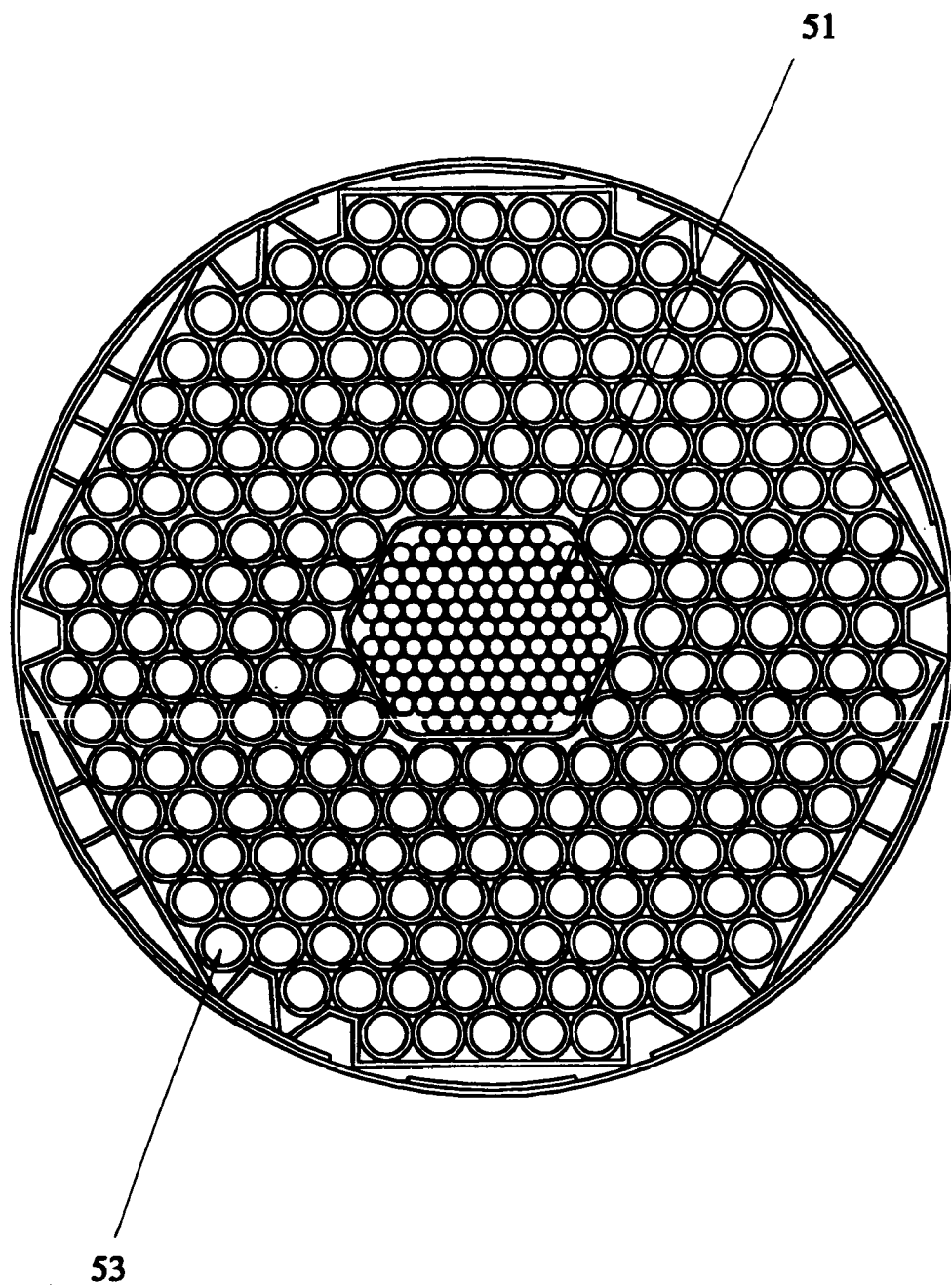


FIG. 3

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