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(54) **Shipping cask for nuclear fuel.**

(57) The shipping cask comprises a vessel (3), and a removable basket assembly (11) within the vessel.

The vessel (3) has heat-conductive ribs (5) projecting from its outer surface, a layer of radiation-absorbing material covering its outer surface between the ribs (5), and flat heat-conductive fins (9) joined to outer edge portions of the ribs and bridging the spaces therebetween so as to form a watertight barrier supportingly and protectively overlying the layer of radiation-absorbing material. The basket assembly (11) includes, at its perimeter, heat-conductive formers (22) arranged so as to provide structural reinforcement, equilibration of mechanical shock forces, and good conductive heat transfer without objectionable impediment to convective and radiative heat transfer between the basket assembly and the vessel.

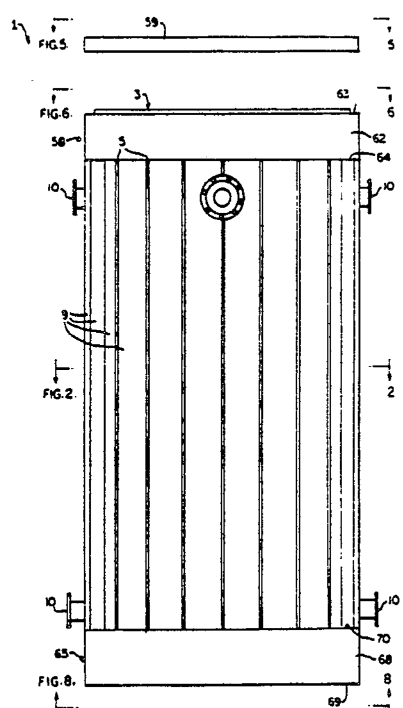

FIG.1.

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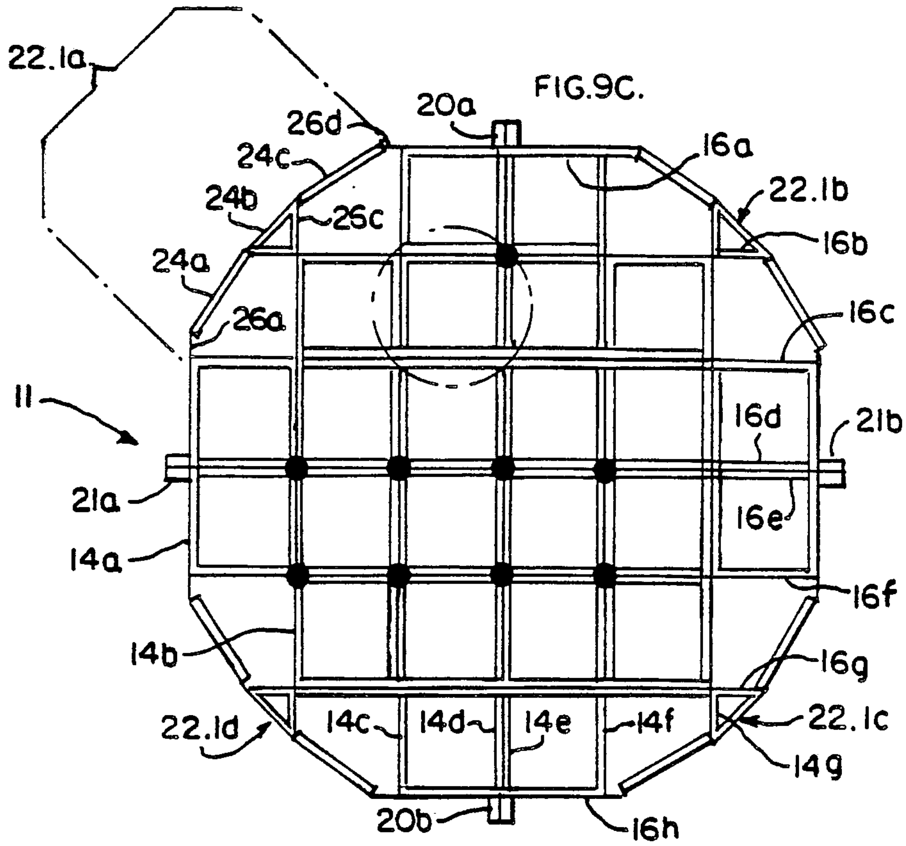
22.1a
FIG.9C.
20a
26d
16a
24c
22.1b
24b
26c
16b
24a
16c
26a
11
16d
21b
21a
16e
14a
16f
14b
16g
22.1d
14c
14d
14e
14f
22.1c
14g
20b
16h

FIG.9B.

SHIPPING CASK FOR NUCLEAR FUEL

This invention relates to a cask for transporting nuclear materials to or from nuclear power plant facilities.

Casks for shipping fuel rods to and from nuclear power plants are known in the prior art. Such casks generally include a transportable steel vessel cylindrical in shape, and a basket structure receivable within the steel vessel and having an array of cells for holding rectangular storage containers each designed to hold either a fuel assembly or a spent-fuel canister with fuel rods consolidated therein in a dense, triangular-pitch arrangement. Such transportable casks are adapted to be mounted on and secured to the trailer of a tractor-trailer, and they are typically used to ship spent fuel rods from a nuclear power plant to a permanent waste isolation site or a reprocessing facility in as safe a manner as possible. At present, relatively few such shipping casks have been manufactured and used since most of the utility companies which own nuclear facilities have been able to store the spent fuel rods in spent-fuel pools initially built into the reactor facilities. However, the availability of such on-site storage space is steadily diminishing as an increasing number of fuel assemblies are being loaded into the spent-fuel pools every day so that there is a growing need for more storage facilities, and eventually for transporting spent fuel assemblies from on-site storage facilities of nuclear power plants to an off-site nuclear waste disposal facility. For this purpose, shipping casks are needed.

In order to be practical, a cask for transporting radioactive material by truck must meet at least five basic requirements. First the cask must have walls capable of effectively shielding both the gamma and neutron radiation emitted by its payload well enough in order for the total amount of radiation emitted from the surface of the cask to be at a level safe for handling, e.g., not more than 200 millirems at any given point of the cask surface, and not more than 10 millirems at a distance of two meters from the vehicle carrying the cask. Second, the cask must be capable of withstanding mechanical shock of a magnitude commensurate with that occurring during a vehicular accident. In this regard, it is not enough that the walls of the cask continue to contain the radioactive material after such a mechanical shock; they must also remain water-tight at all points so that water cannot leak into the interior of the cask and thereby thermalize the neutrons emitted by the spent fuel rods or other material contained in the cask. Third, the basket structure within the cask must be capable, in the event of an accident, of withstanding the forces applied to its perimeter by the inner cask walls without any significant distortion of its individual nuclear waste-containing cells, for if these cells were significantly deformed, the effectiveness of the so-called neutron "traps" installed between them could be impaired which in turn could result in a criticality condition within the cask. Forth, the cask must be immersible in water without any incursion of water into it and, furthermore, must be completely drainable. The reason for this requirement is that casks are often loaded and unloaded in spent-fuel pools of nuclear facilities in order to reduce exposure of the operating personnel to potentially harmful radiation, and the water in such pools typically contains dissolved radionucleides which, if allowed to seep into the crevices in the cask or to deposit themselves into micropores on the cask surface, might prove difficult if not impossible to remove. The deposition of such radionucleides in the crevices and surface pores of casks could well raise the surface radiation of the casks beyond allowable limits, thus preventing the use of such casks. Finally, the cask must be capable of effectively dissipating the heat of decay generated by the radioactive materials within it, for if no effective heat dissipation mechanism existed, the temperature within the cask could become high enough to generate dangerous levels of pressure.

Unfortunately, the simultaneous achievement of these five criteria is difficult since the materials and mechanisms for achieving the various criteria are often at cross-purposes with one another. For example, fins radially projecting from the outer cask surface will improve heat dissipation but impair the cask's ability to withstand large mechanical shocks without detriment to its wall integrity. One of the best and most economical neutron shielding materials known is high-hydrogen cement, but it is relatively brittle and likely to break up under the shattering forces of an accident. Lead, depleted uranium, and Boro-silicon^R are also well known as effective gamma shielding materials but none of these materials has sufficient mechanical strength to withstand an accident condition by itself. Moreover, none of these materials is good heat conductor, and none of them is easy to weld, or to join by any other known means, to a structurally strong metal because of the large differences in mechanical and metallurgical properties involved. While stainless steel has good structural and corrosion-resistant properties, it is not a particularly good heat transfer medium and is expensive. It has also been observed that the surface of stainless steel contains micropores which are capable of capturing dissolved radionucleides and radioactive dust. Finally, whilst carbon steel is a good and inexpensive structural material having better heat transfer properties than stainless steel, it is liable to corrode when exposed to water.

It is the principal object of the invention to provide an improved shipping cask which reasonably fulfills the five aforesaid criteria and is relatively easy and inexpensive to fabricate.

The invention accordingly resides in a shipping cask for transporting radioactive material, as defined and characterized in claim 1.

More particularly, the shipping cask embodying the invention comprises an inner vessel having metallic, heat-conducting walls preferably formed from low alloy steel, a plurality of heat-conductive, mutually parallel ribs, preferably formed from carbon steel, each of which has an inside edge joined to the outside surface of the heat-conducting wall of the vessel, a layer of radiation absorbing, cementitious material disposed between the mutually parallel ribs and covering the outer surface of the heat-conducting wall of the inner vessel, and a plurality of flat, circumferentially disposed fin members, preferably also formed from carbon steel, each of which is joined along its longitudinal edges to the outer edges of two adjacent ribs. The circumferentially disposed fin members advantageously function both to dissipate heat generated by radioactive material within the inner vessel, and to form a watertight barrier supporting and protecting the layer of cementitious material.

The shipping cask includes further a removable basket assembly which is insertable into and withdrawable from the inner vessel, and defines an array of cells each capable of receiving a selected volume of radioactive waste. In the preferred embodiment, the cell structure of the basket assembly is formed from two sets of parallel stainless-steel plates which are orthogonally disposed with respect to one another and interfit in "egg-crate" fashion.

The periphery of the basket assembly is defined by the corners of the outer or perimetric cells and by angular formers which protect the cells from deformation under mechanical shock applied to the outside of the cask, and in addition provide enlarged contact surfaces for good heat transfer from the basket assembly to the heat- conductive wall of the vessel. The formers are spaced apart so as not to interfere significantly with the convective and radiative transfer of heat from the radioactive material in the cell structure of the basket to the inner vessel, and the total area of the spaced-apart formers is not more than about 30%, and preferably not more than 20%, of the total area of the outer periphery of the basket assembly. Each of the formers may be formed from several plates arranged in tandem circumferentially of the basket assembly and with the edges of each plate connected to the corners of two adjacent cells.

In order to further increase the resistance of the cell structure of the basket assembly to deformation in the event that the cask is subjected to an intense mechanical shock, the periphery of the basket assembly includes a plurality of uniformly spaced, discrete contact surfaces for uniformly distributing shock forces which may occur between the outer periphery of the basket assembly and the inside surface of the inner vessel. In the preferred embodiment, these discrete contact surfaces conform to the corners of the peripherally located cells of the basket assembly.

Fabricating the inner vessel from low alloy steel and the ribs and fin members from carbon steel allows all of the structural components of the cask to be easily welded together. In order to prevent surface corrosion and the lodgment of dissolved radionucleides or radioactive dust in the pores of the metal forming the circumferential fins, the outer surfaces of the fins preferably are provided with an anti-corrosive coating which may consist of a layer of zinc-containing primer, a layer of epoxy polyamide, and a layer of polyurethane.

A preferred embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a side view of a shipping cask embodying the invention, showing the outer closure lid of the cask raised above its top;

Figure 2 is a cross-sectional view of the cask as taken along the line 2-2 in Fig. 1, and with some of the fins and part of the layer of cement shown broken away for clarity.

Figure 3 is a cross-sectional side view of the cask taken along line 3-3 in Figure 2, and with the basket assembly removed for clarity;

Figure 4A is an enlarged view of the area encircled in Figure 3;

Figure 4B is an enlarged view of the area encircled in Figure 4A which shows layers of a protective coating applied to the exterior of the cask;

Figure 5 is a plan view of the outer lid of the cask as seen when viewed along line 5-5 in Fig. 1;

Figure 6 is a plan view of the upper end of the cask as seen when viewed along line 6-6 in Fig. 1;

Figure 7 is an enlarged view of the area encircled in Figure 6;

Figure 8 is a plan view of the bottom end of the cask as seen when viewed along line 8-8 in Fig. 1;

Figure 9A is a side view of the basket assembly of the cask, with part of the peripheral basket wall broken away to expose some of the canisters disposed within the cells of the basket assembly;

Figure 9B is a plan view of the basket assembly illustrated in Figure 9A;

Figure 9C illustrates the manner in which the two sets of plates from which the basket assembly is formed are interfit with one another; and

Figure 9D is an enlarged view of the cell encircled in Figure 9B.

With particular reference now to Figures 1, 2 and 3, the shipping cask 1 illustrated therein comprises an elongated generally cylindrical inner vessel 3 which has a metallic, heat-conductive wall 4, preferably formed of low alloy steel, and has a plurality of heat-conductive mutually parallel and uniformly spaced and radially oriented longitudinal ribs 5 joined, preferably welded, to its outer surface. A layer of neutron-absorbing cement 7 is applied to and over the outer surface of the vessel 3 between the uniformly spaced ribs 5. Preferably, the layer 7 is formed from a cement having a high percentage content of atomic hydrogen.

As seen best in Figs. 2 and 4A, the exterior of the cask 1 is formed by a plurality of plate-like circumferential fins 9, each of which is joined, preferably welded, along its longitudinal edges to outer edge portions of two mutually adjacent ones of the ribs 5 so as to form a secure and watertight joint between the fin and the ribs 5 associated therewith. Preferably, each of the fins 9 is an elongate, rectangular plate of carbon steel approximately 6.5 mm thick. The fins 9 advantageously perform three functions. First, they provide an effective means for dissipating heat conducted to them through the ribs 5. Second, they provide a strong mechanical barrier which retains, supports and protects the layer 7 of neutron-absorbing cement from fracture, even in the event of an accident. Third, these fins 9 provide a waterproof barrier preventing the layer of cement from absorbing dissolved radionucleides when the cask is lowered into a spent fuel pool. In the preferred mode of fabricating the cask 1, the fins 9 are first welded into position on the ribs 5 and the neutron-absorbing cement 7 is then poured into the spaces between the vessel 3 and the fins 9. Such mode of manufacturing has the advantage of providing a "leak-test" for the welds formed between the fins 9 and the ribs 5, in that any leaking of water and cement occurring on the outer surface of the cask 1 after the neutron-absorbing cement 7 has been poured will serve as an indication telling the manufacturer that the cement needs to be removed in the affected areas, and the affected joints between fins 9 and ribs 5 need to be rewelded to make them watertight.

Referring now to Figures 6, 9A, 9B and 9C, the cask 1 further includes a basket assembly 11 which is freely insertable into and withdrawable from the inner vessel 3. The basket assembly 11 is formed from two sets of parallel plates 14a-14h and 16a-16h. The plates 14a-14h and 16a-16h of the two sets are provided with slots 15 and 17, respectively, which interfit, as seen best from Figure 9C, to form an egg-crate like structure defining square cells 18a-18x. Preferably, the plates 14a-h and 16a-h are formed from a solid sheet of stainless steel approximately 1 cm thick. In addition to being interleaved, the plates 14a-h and 16a-h are secured to one another by means of welds formed along the edges of the respective slots 15 and 17 throughout their entire length. As seen best from Fig. 9B, each set of parallel plates 14a-14h or 16a-16h includes a central pair of closely spaced plates 14d, 14e or 16d, 16e, respectively, which due to their central location within the basket assembly 11 lend extra strength to the latter as a whole. These central pairs of plates terminate in plate-pair ends 20a, 20b, 21a, 21b, respectively, which provide four uniformly spaced contact surfaces between the periphery of the basket assembly 11 and the inner surface of the vessel 3. These contact surfaces will assure not only a uniform heat transfer from the radioactive material within the cells 18a-18x through the walls of the vessel 3 but also a uniform absorption of impact forces between the basket assembly 11 and the inner wall of the vessel 3 in the event the cask 1 is subjected to an accident condition. Additionally, at least one of the plate-pair ends 20a, 20b, 21a, 21b coacts, as further described later herein, with plate retaining means 38 on the inner surface of the vessel 3 in a manner such as to maintain the proper orientation of the basket assembly 11 within the vessel 3 in the event the vessel 3 is subjected to torque.

As seen best from Figures 9A and 9B, the basket assembly 11 is circumscribed by a plurality of angular formers 22.1a-22.5a, 22.1b-22.5b, 22.1c-22.5c and 22.1d-22.5d, each of which is formed from three strut plates 24a, 24b, and 24c arranged in tandem and welded, along their edges, to corners defined by plate overhangs 26a, 26b, 26c and 26d. In the preferred embodiment, each of the strut plates 24 is formed from stainless steel plate material approximately 1 cm thick. Such material is advantageously weld-compatible with the stainless steel plates 14a-14h and 16a-16h used to form the basket assembly 11. As seen best from Figure 9A, the angular formers 22.1a-22.5d are spaced apart, preferably uniformly, along the longitudinal axis of the basket assembly 11. The total area of the angular formers 22.1a-22.5d relative to the total exterior area of the basket assembly 11 preferably is only about 20 percent. The use of such angular formers 22.1a-22.5d in the basket assembly 11 is advantageous in two major respects. First, the multiple, shallow corners which the formers provide over the respective plate overhangs 26a, 26b, 26c and 26d offer four broad areas of contact between the outer surface of the basket assembly 11 and the inner surface of the vessel 3. These multiple areas of contact, together with the contact areas presented by the ends 20a, 20b and 21a, 21b of plate pairs 14d, 14e and 16d, 16e, provide an ample amount of contact surface between the basket assembly 11 and the vessel 3, both for thermal conduction and for the equilibration of any mechanical shock forces applied to the exterior of the cask 1 as the result of an accident. Second, due to the fact that the area of the strut plates 24a, 24b and 24c in these formers 22.1a-22.5d is relatively small (20 percent) as compared to the area of the periphery of the basket assembly 11 as a whole, it interferes very little with the conductive and radiative transfer of heat from the radioactive materials disposed within the basket 11 to the walls of the inner vessel 3.

Referring once more to Figures 1, 2 and 3, the generally cylindrical inner vessel 3 of the cask 1 has an open top end 28 and a closed bottom end 29 and, at its top end 28, has an inner annular shoulder 32 and an outer annular shoulder 34 each with uniformly spaced bolt holes 33 or 35, respectively, therein. The general purpose of these annular shoulders 32, 34 is to support a double-lid closure assembly (not shown), e.g., of the type described in EP-A-0312870.

As mentioned hereinbefore, the vessel 3 has disposed on its inner surface 36 at least one basket retaining means or assembly 38 (Figs. 6 and 7). In the embodiment shown, the basket retaining assembly 38 is formed from a pair of stainless steel dowels 42, 43 measuring preferably about 2.5 cm in diameter. When the basket 11 is to be loaded into the vessel 3, one of its central plate-pair ends 20a, 20b or 21a, 21b is inserted into the guide channel defined between the dowels 42, 43 of the basket retaining assembly 38 so as to slide down therein as the basket is lowered. The purpose of the basket retaining assembly 38 is to prevent the basket assembly 11 from rotating relative to the vessel 3, as mentioned earlier herein.

With particular reference to Figs. 2, 3 and 4, the ribs 5 on the outer surface of the vessel 3 which preferably are made of carbon steel have their inner edges 47 joined to the low-alloy steel walls 4 of the vessel 3 by means of fillet welds 48 formed on both sides of each rib 5. These fillet welds 48 not only provide a strong mechanical joint between the vessel wall 4 and the ribs 5 but also form highly heat-conductive bridges or paths between the vessel wall 4 and the ribs 5 which will facilitate the conduction of heat from the inner surface 36 of the vessel 3 to its outer surface 45.

The high-hydrogen content cement 7 applied to the outer surface 45 of the vessel 3 between the ribs 5 provides, due to its high hydrogen content, a high neutron capture cross-section which renders the layers 7 particularly effective as a neutron-radiation absorbing medium. This is highly advantageous since the low-alloy steel of the wall 4 of the vessel 3 shields effectively against gamma radiation but not so effectively against neutron radiation. Likewise as seen best from Fig. 4A, the peripheral fins 9 are joined to the outer edges 51 of the respective ribs 5 also by means of fillet welds 53 which are applied to the edges 52a, 52b of the fins 9 and preferably are continuous for the full length of the edges 52a, 52b. As mentioned hereinbefore, the peripheral fins 9 and the manner in which they are attached to the outer edges 51 of the ribs 5 offer four distinct advantages. First, during fabrication of the cask 1, the fins 9 may advantageously be used as molds for applying the cementitious material 7 upon the outside surface 45 of the vessel 3. Second, the fins 9, having a thickness in the order of about 6.5 mm, form a strong mechanical barrier covering the relatively brittle layer of cement 7, thereby protecting it from fracturing or shattering in the event of mechanical shock applied to the exterior of cask 1. Third, the fins 9 form a watertight barrier over the layer of cement 7 which renders the cask 1 immersible in a spent-fuel pool without any danger of dissolved radio-nucleides soaking into the porous and water-permeable cement 7. Finally, the peripheral fins 9 provide excellent heat dissipation in a structure which is considerably less fragile than one formed by radially oriented heat dissipating fins alone.

As shown in Figure 4B, the exterior surfaces of the fins 9 preferably are covered with a coating 54 rendering the fins 9 corrosion-resistant and sealing the micropores normally existing in the surface of carbon steel, thereby preventing radioactive dust or dissolved radionucleides from lodging in surface pores of the fins 9. In the preferred embodiment illustrated, the coating 54 consists of a base layer 55 of a zinc-containing primer, an intermediate layer 56 of an epoxy polyamide, and top layer 56 of polyester polyurethane. Preferably, the primer is Carbo Zinc -8 manufactured by the Carboline Company located in St. Louis, Missouri, and the top and intermediate layers 56 and 57 are a Series 66 High-Build Epoxoline and a Series 70 and 71 Endura-Shield, both manufactured by Tnemec Company, Inc., located in St. Louis, Missouri.

The cask 1 includes also a lid assembly 58 comprising a lid 59 with stud-and-nut assemblies 60 (Fig. 5) for fastening it to the vessel 3 at the open end 28 thereof, and an upper ring 62 (Fig. 3) which extends around an upper end portion of the cask 1 and has its lower edge 64 welded (not shown) to the upper edges of the fins 9 so as to create a strong mechanical and watertight joint therebetween. The outer edge of the lid 59 abuts the upper edge 63 of the ring 62 when the lid is secured in place upon the cask.

As seen from Figs. 1, 3 and 8, the cask 1 also includes a floor assembly 65 comprising a disk 66, a spoke assembly 67 provided over the ground-engaging surface of the disk 66 to help in evening out the load applied by the cask 1 upon the disk 66 when standing upright on the ground, and a lower ring 68 which is similar to the upper ring 62 but circumscribes the cask 1 at the very bottom thereof. The ring 68 has its bottom edge 69 welded all around to the peripheral edge of the bottom disk 66 so as to form a strong, watertight connection therebetween, and has its upper edge welded to the lower edges of the fins 9 so as to form a strong mechanical and watertight joint therebetween.

With reference now to Figures 9A, 9B and 9D, each of the cells 18a-18x of the basket assembly 11 has disposed therein a container 74 for spent fuel rods. As seen best from Figure 9A, each of the containers 74 has a lead-in flange 75 disposed thereabout at the upper end thereof in order to facilitate the insertion of fuel rods therein, and has each of its four walls lined on its outer surface, as indicated in Fig. 9D, with a sheet 76a-76d of Boral® or some other material having a high neutron capture cross-section. The provision of such high neutron-absorbing sheets 76a-76d, or "poison plates" as they are known in the art, creates neutron-flux traps between adjacent cells 18a-8x which greatly attenuate the transmission of thermal neutrons among the various cells 18a-18x of the basket assembly 11. Finally, each of the cells 18a-18x has disposed therein corner brackets 78a-78d for securing the container 74 therein in place. Preferably, the containers 74 are made of anti-corrosive stainless-steel sheet material.

Claims

1. A shipping cask (1) for transporting radioactive material, comprising a vessel (3) having a metallic heat-conductive wall (4), a plurality of substantially parallel spaced, heat-conductive ribs (5) disposed on and projecting from the outer surface of said heat-conductive wall, a layer (7) of radiation-absorbing material covering the outer surface of the heat-conductive wall between the ribs, and a removable basket assembly (11) disposed in said vessel and adapted to receive radioactive material, characterized in that said vessel (3) includes a plurality of circumferentially disposed, flat, heat-conductive fin members (9) joined along opposite edges thereof to outer edge portions (51) of the respective ribs (5) and bridging the spaces between the latter so as to form a watertight barrier supportingly and protectively overlying said layer (7) of radiation-absorbing material; and said basket assembly (11) includes a plurality of heat-conductive formers (22) joined to the basket assembly so as to structurally reinforce same, said formers (22) being located at the perimeter of the basket assembly and arrayed in spaced relationship with respect to each other in a manner such as to enable the formers to conduct heat from the basket assembly (11) to said heat-conductive wall (4) of the vessel (3) without objectionably impeding the convective and radiative transfer of heat therebetween.

2. A shipping cask according to claim 1, characterized in that said ribs (5) are welded to the metallic heat-conductive wall (4) of said vessel (3).

3. A shipping cask according to claim 1 or 2, characterized in that said ribs (5) and said fin members (9) are made of a metal of substantially the same type, and the fin members are welded to the ribs.

4. A shipping cask according to claim 1, 2 or 3, characterized in that the metallic heat-conductive wall (4) of said vessel (3) consists of low alloy steel, and said ribs (5) consist of carbon alloy steel.

5. A shipping cask according to claim 1, 2, 3 or 4, characterized in that said flat, heat-conductive fin members (9) have disposed on their outer surfaces an anti-corrosion and pore-sealing coating (54).

6. A shipping cask according to claim 5, characterized in that said coating (54) is composed of a layer (55) of zinc-containing primer, a layer (56) of epoxy polyamide, and a layer of polyester polyurethane.

7. A shipping cask according to any one of the preceding claims, characterized in that said formers (22) are spaced apart substantially uniformly.

8. A shipping cask according to any one of the preceding claims, characterized in that said formers (22) cover substantially not more than 30% of the perimetric area of the basket assembly (11).

9. A shipping cask according to any one of the preceding claims, characterized in that said basket assembly (11) has a perimetric outline defining several corners (26), and each of said formers (22) is composed of strut plates (24) each connected to the basket assembly at two mutually adjacent ones of said corners.

10. A shipping cask according to any one of the preceding claims, characterized in that said basket assembly (11) has portions (20,21) located at its perimeter and presenting discrete contact surfaces adapted to coact with inner surface portions of the heat-conductive wall of said vessel (3) to transfer heat from the basket assembly to said heat-conductive wall and to absorb impact forces if and when acting therebetween.

11. A shipping cask according to claim 10, characterized in that the contact-surface presenting portions (20,21) of the basket assembly (11) are spaced apart substantially uniformly about the perimeter of the basket assembly.

12. A shipping cask according to claim 10 or 11, characterized in that said basket assembly (11) comprises a cell structure (18a-18x) composed of substantially orthogonically interleaved plates (14,16), said contact-surface presenting portions (20,21) of the basket assembly being formed by opposite edge portions of central ones (14e-f, 16e-4) of said plates, and said vessel (3) including at least one plate retaining means (38) for receiving and retaining at least one (20a) of said contact-surface presenting portions (20,21).

13. A shipping cask according to claim 12, characterized in that said or each plate retaining means (38) comprises a pair of dowels (42,43) disposed on the inner surface (36) of said heat-conductive wall (4) of the vessel (3), and projecting therefrom in substantially parallel spaced relationship with respect to each other so as to receive said or the respective contact-surface presenting portion (20a) of the basket assembly (11) slidably therebetween.

14. A shipping cask according to any one of the preceding claims, characterized in that said vessel (3) has an open top end (28), and the shipping cask includes a closure assembly (58) for sealingly closing said top end (28) of the vessel, said closure assembly (58) including a lower edge (64) adapted to be sealingly connected to upper edges of said fin members (9).

15. A shipping cask according to claim 14, characterized in that said closure assembly (58) includes a ring (62) having thereon said lower edge (64), and a lid (59) which is sealingly and detachably connected to an upper edge (63) of said ring (62).

16. A shipping cask according to any one of the preceding claims, characterized in that said vessel (3) has a closed bottom end (29), and the shipping cask includes a floor assembly (65) disposed at the bottom end of the vessel and having an upper edge (70) which is sealingly connected to bottom edges of said fin members (9).

17. A shipping cask according to claim 16, characterized in that said floor assembly (65) includes a bottom plate (66), and said layer (7) of radiation-absorbing material extends between said bottom plate (66) and the closed bottom end (29) of the vessel (3).

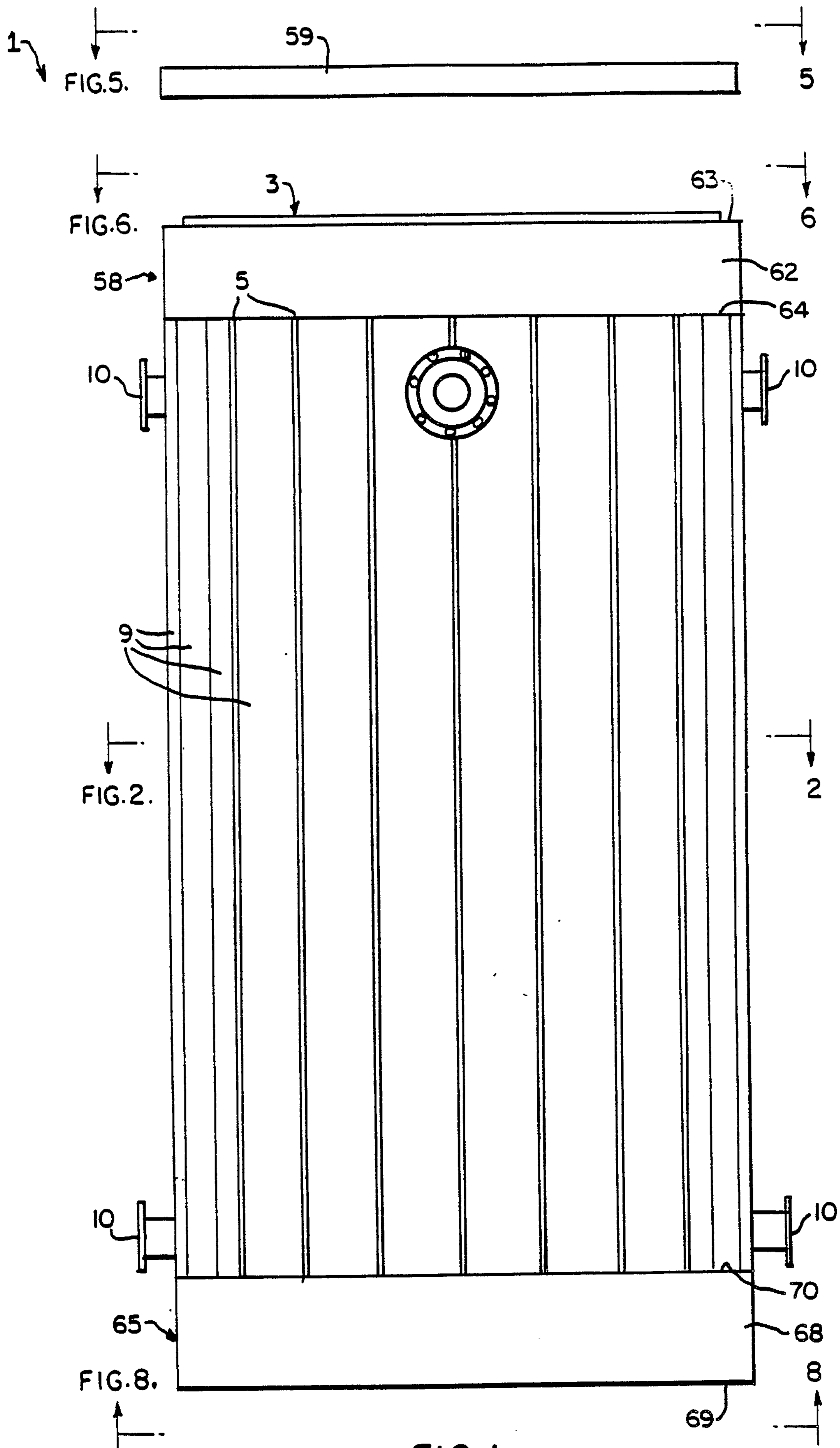
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FIG.5.
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FIG.6.
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FIG.2.
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FIG.8.
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FIG.1.

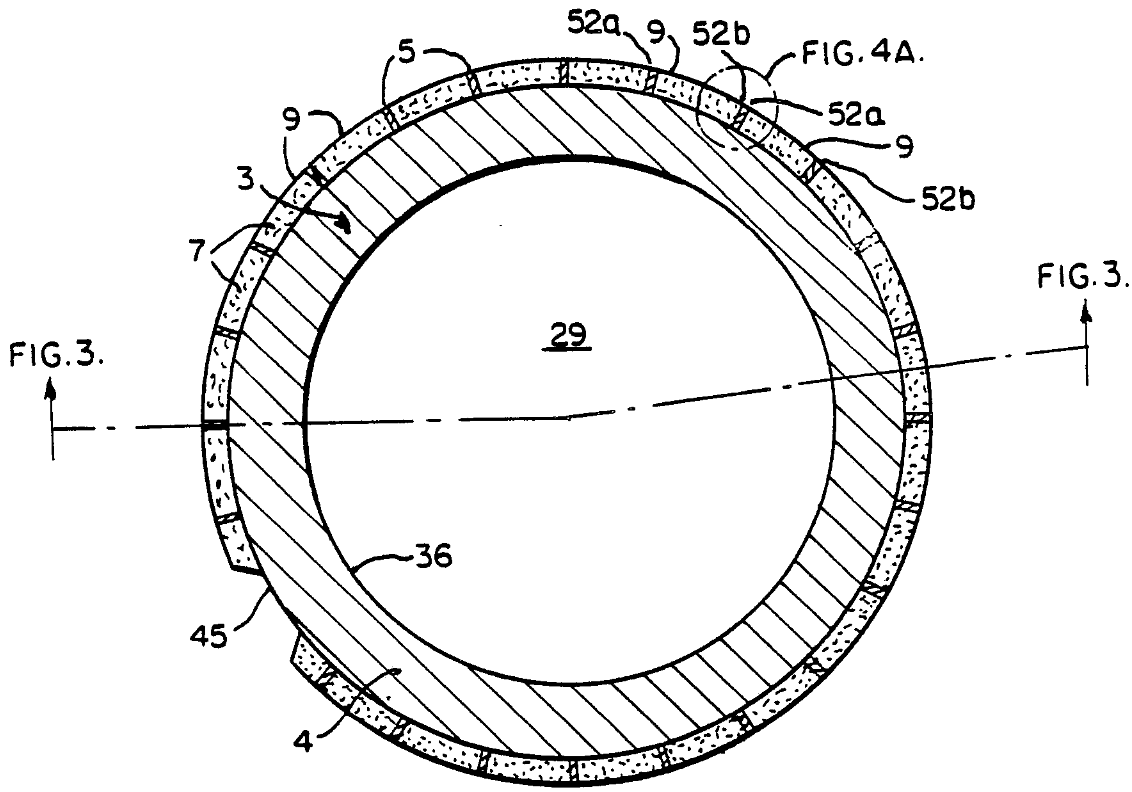


FIG. 2.

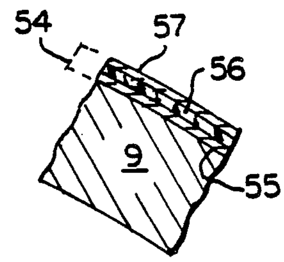


FIG.4B.

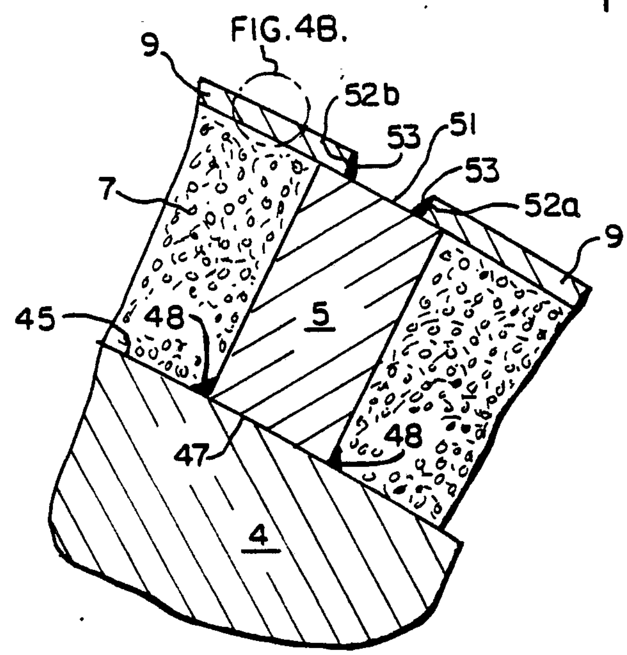
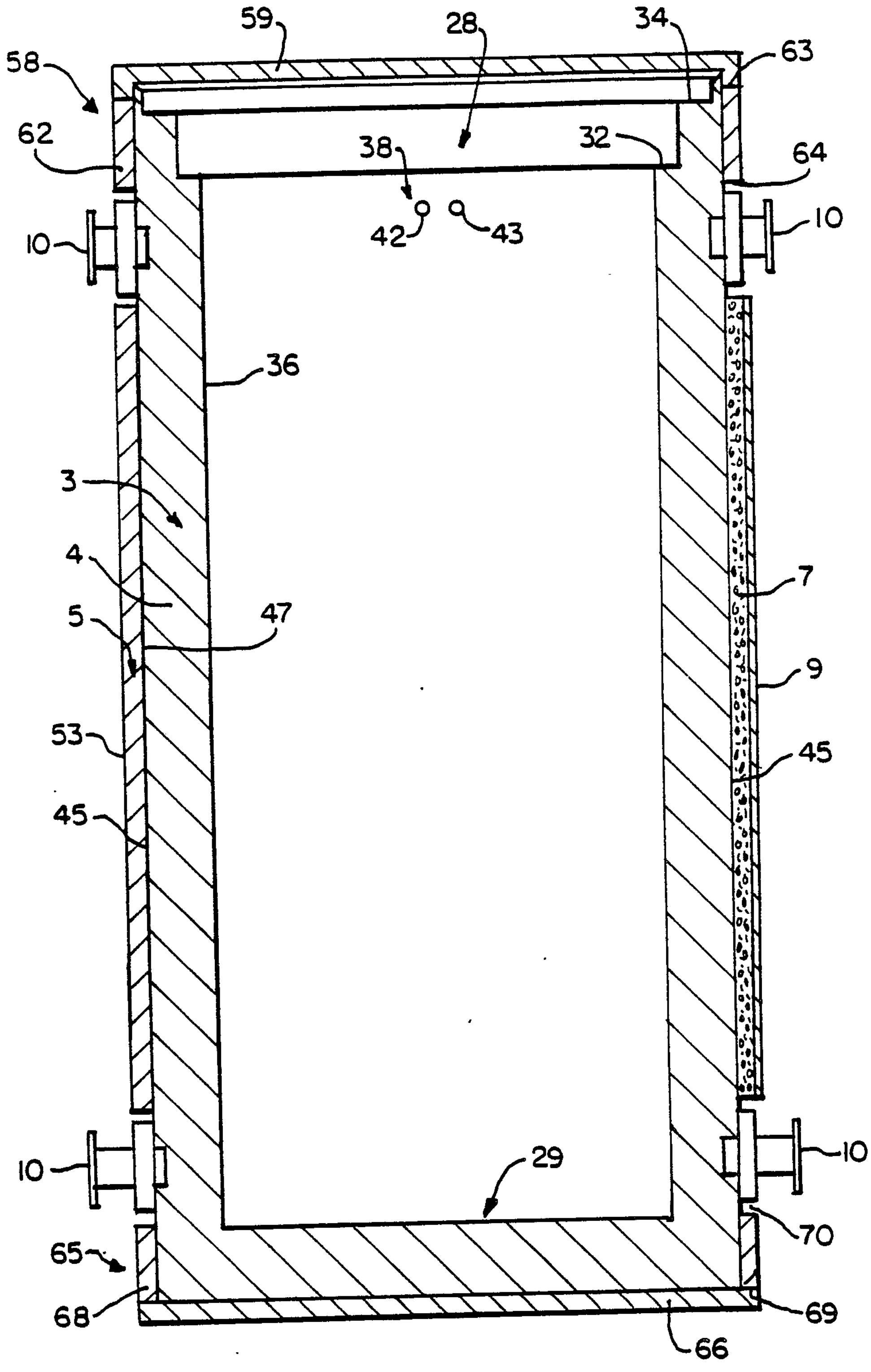


FIG. 4A.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66

FIG. 3.

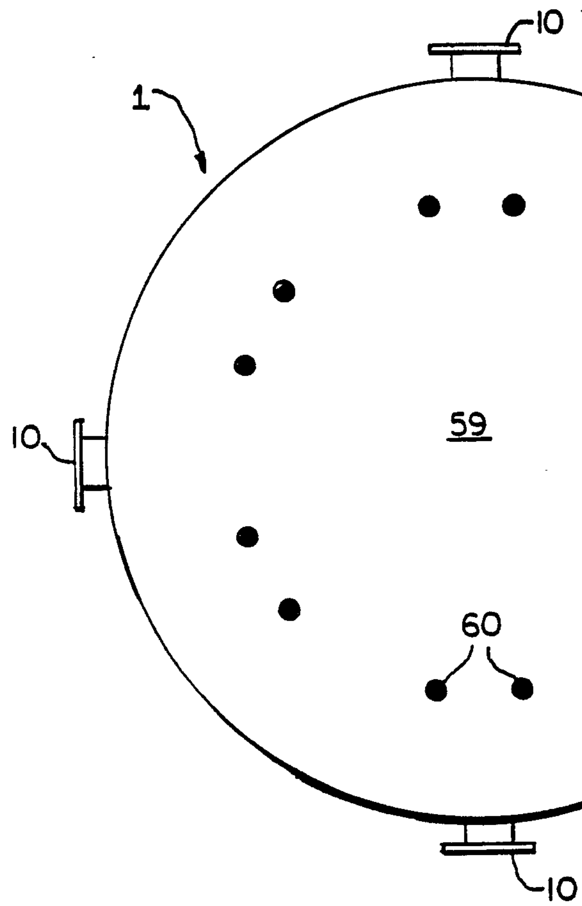
10
1
59
60
10
10
10

FIG. 5.

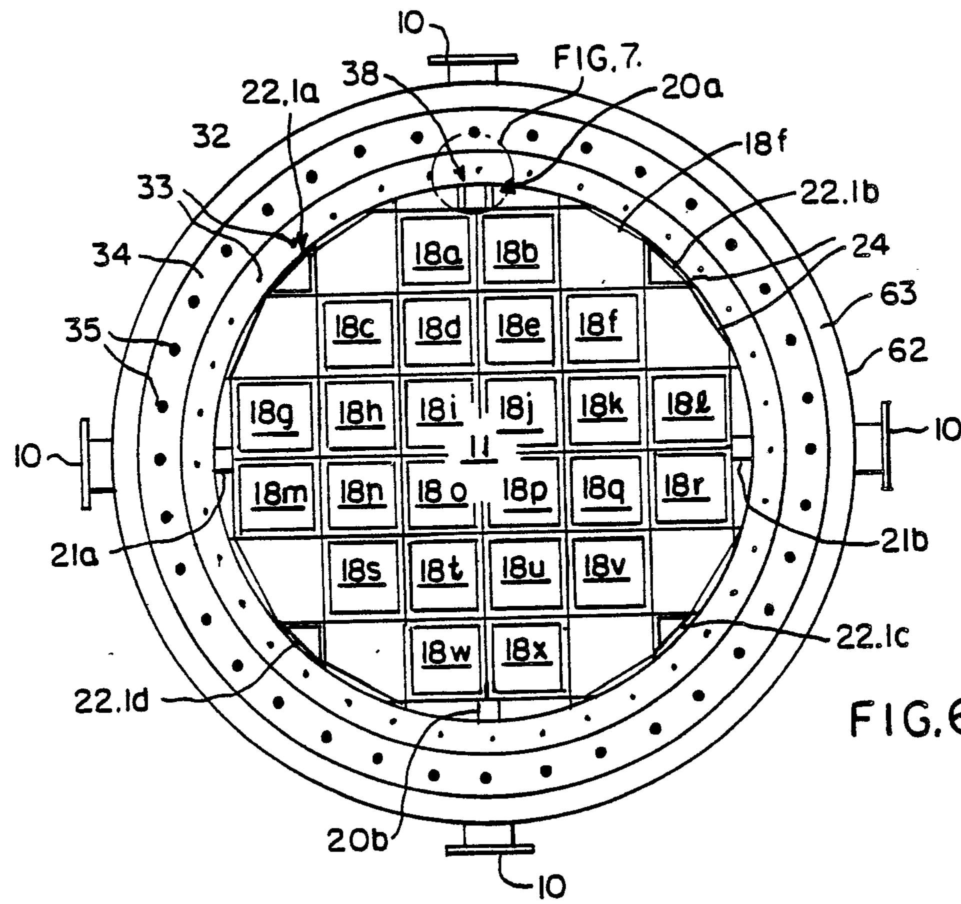
10
FIG.7.
38
20a
22.1a
32
18f
33
22.1b
24
34
63
35
62
18a
18b
18c
18d
18e
18f
18g
18h
18i
18j
18k
18ℓ
11
18m
18n
18o
18p
18q
18r
18s
18t
18u
18v
18w
18x
10
10
21a
21b
22.1c
22.1d
20b
10

FIG.6.

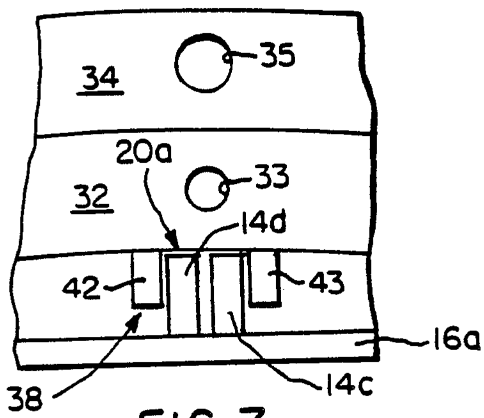

FIG. 7.

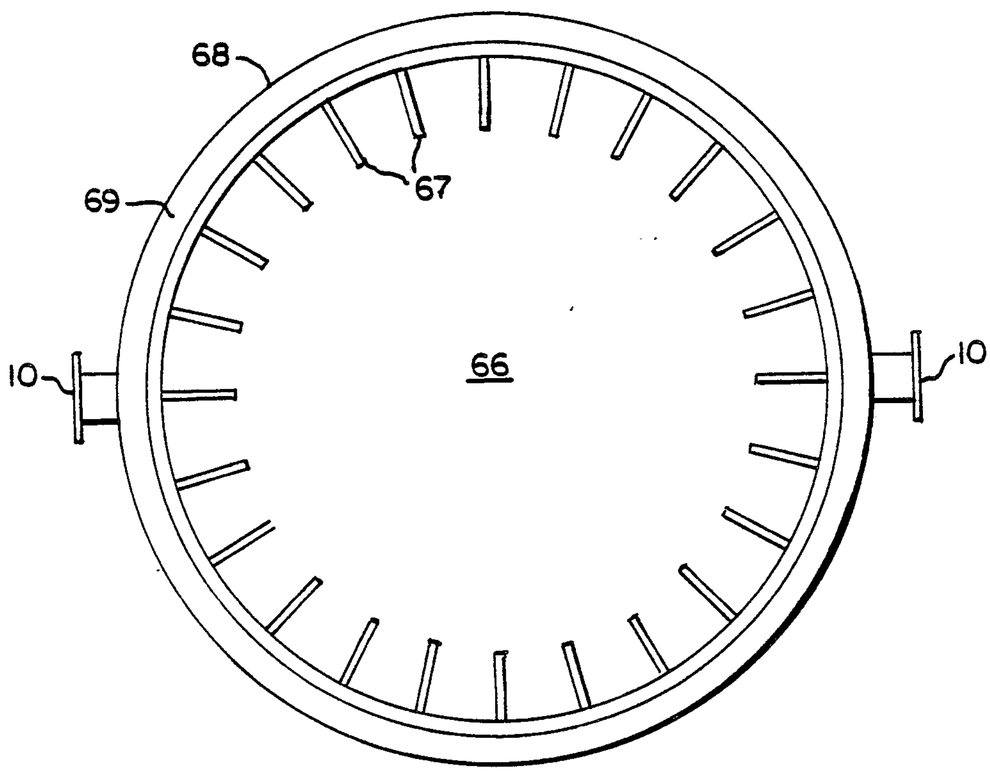

FIG. 8.

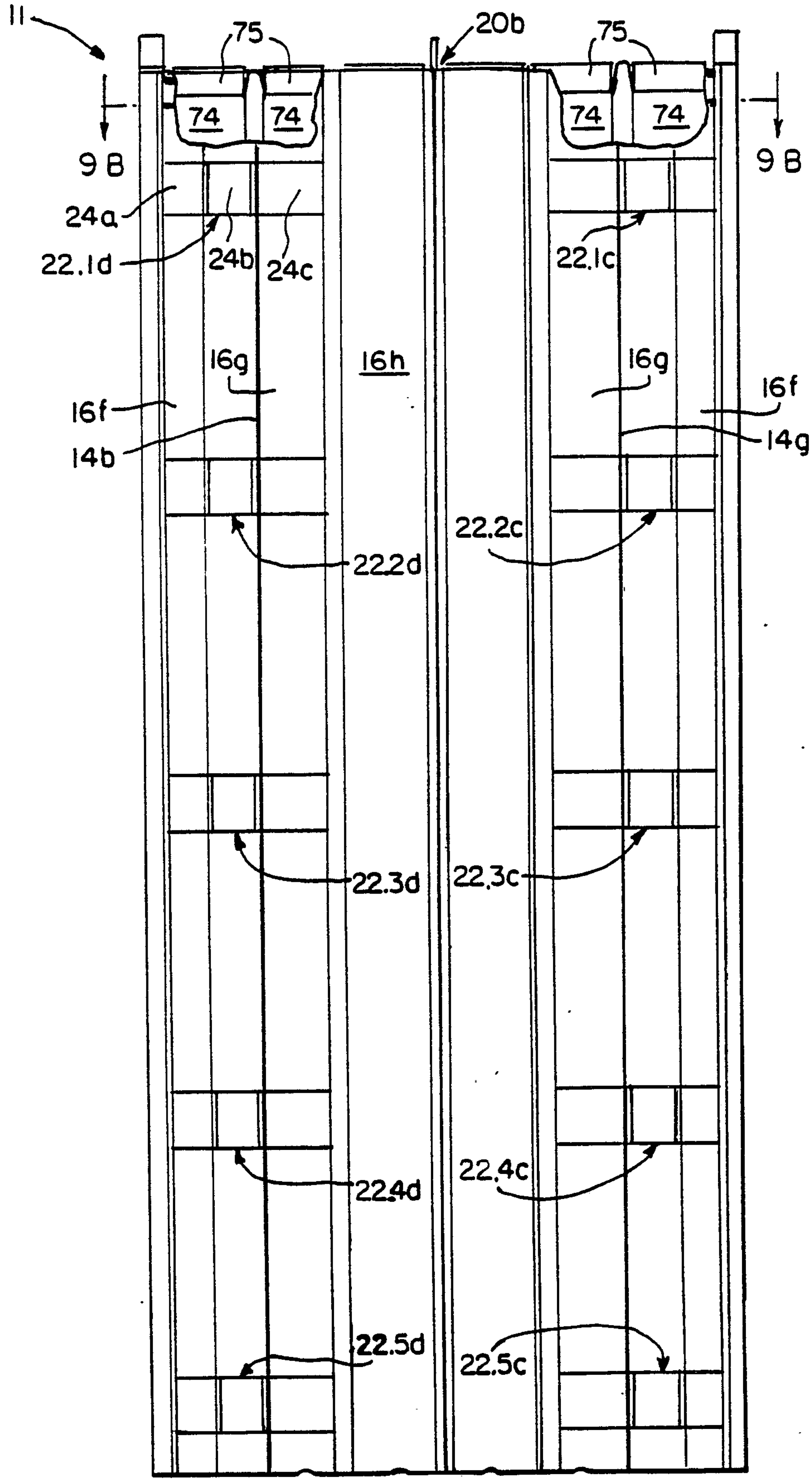
11
75
20b
75
74
74
74
74
9 B
9 B
24a
22.1d
24b
24c
22.1c
16g
16h
16g
16f
16f
14b
14g
22.2c
22.2d
22.3d
22.3c
22.4c
22.4d
22.5d
22.5c

FIG. 9A.

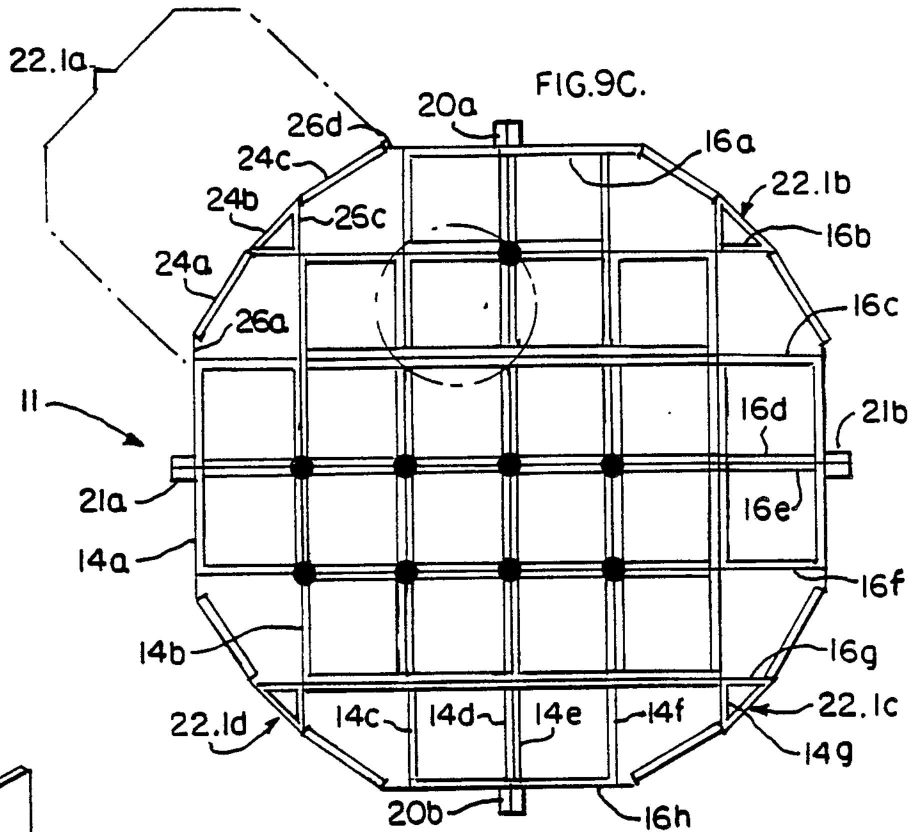

FIG.9B.

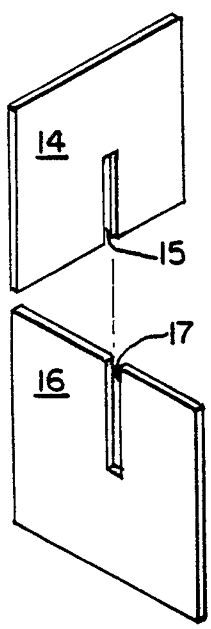

FIG.9C.

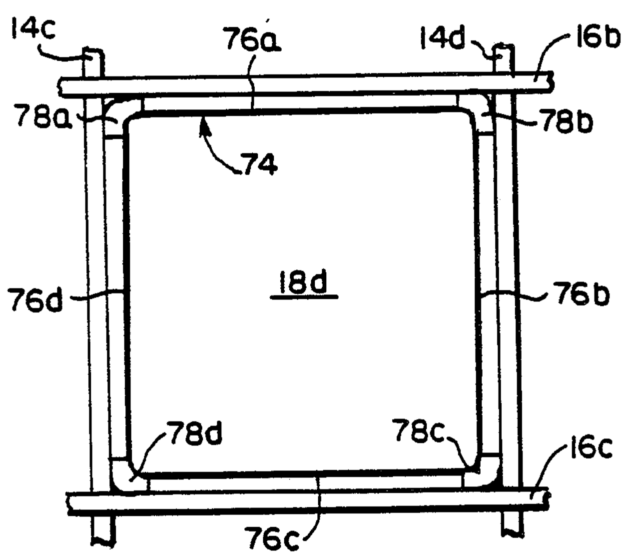

FIG.9D.