

Dec. 9, 1969

C. F. BONILLA ET AL
SHIPPING CONTAINER FOR RADIOACTIVE MATERIALS
HAVING CORNER SHIELDING MEANS

3,483,381

Filed Sept. 9, 1966

5 Sheets-Sheet 1

Fig. 1.

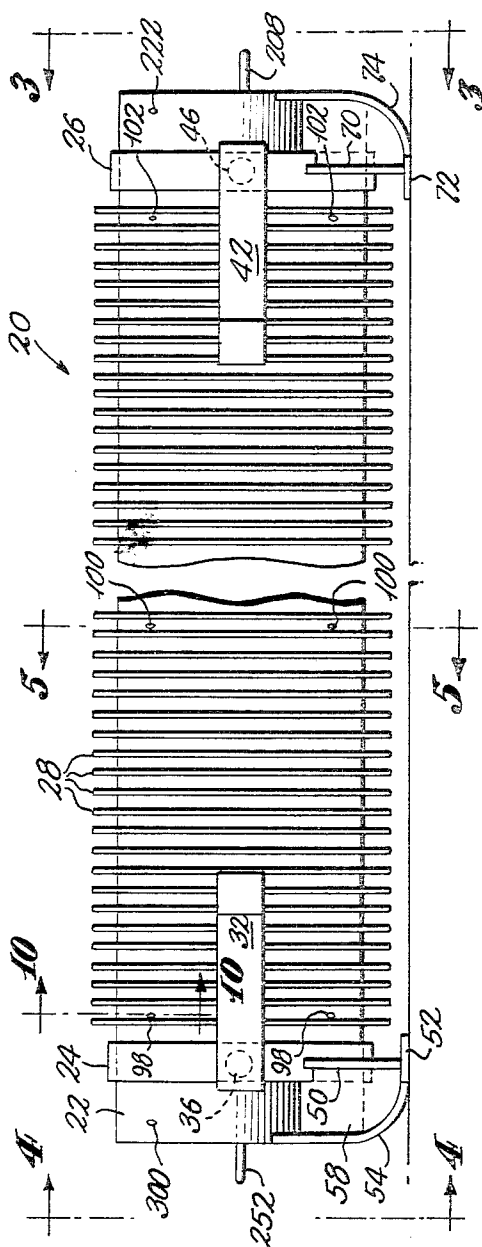
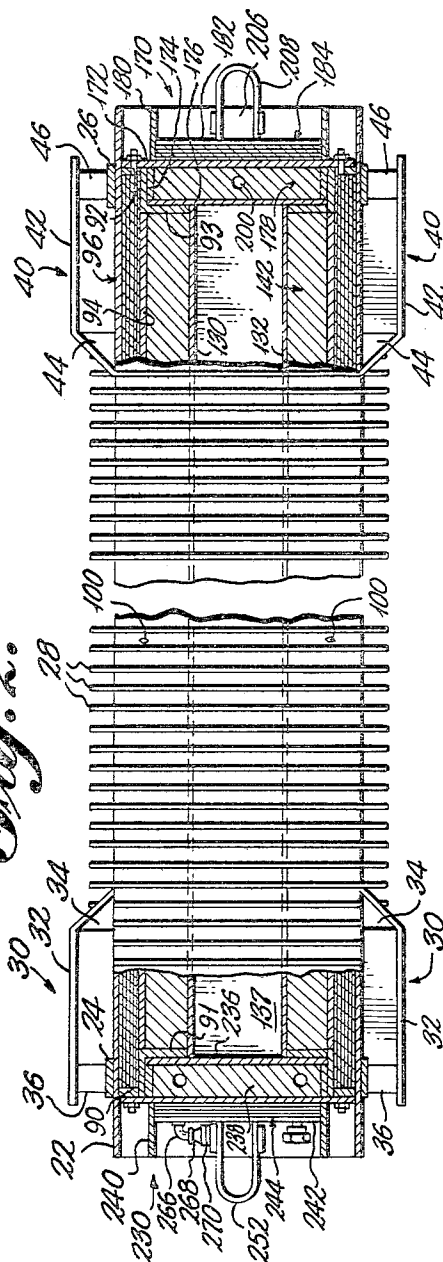


Fig. 2.



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Fig. 3.

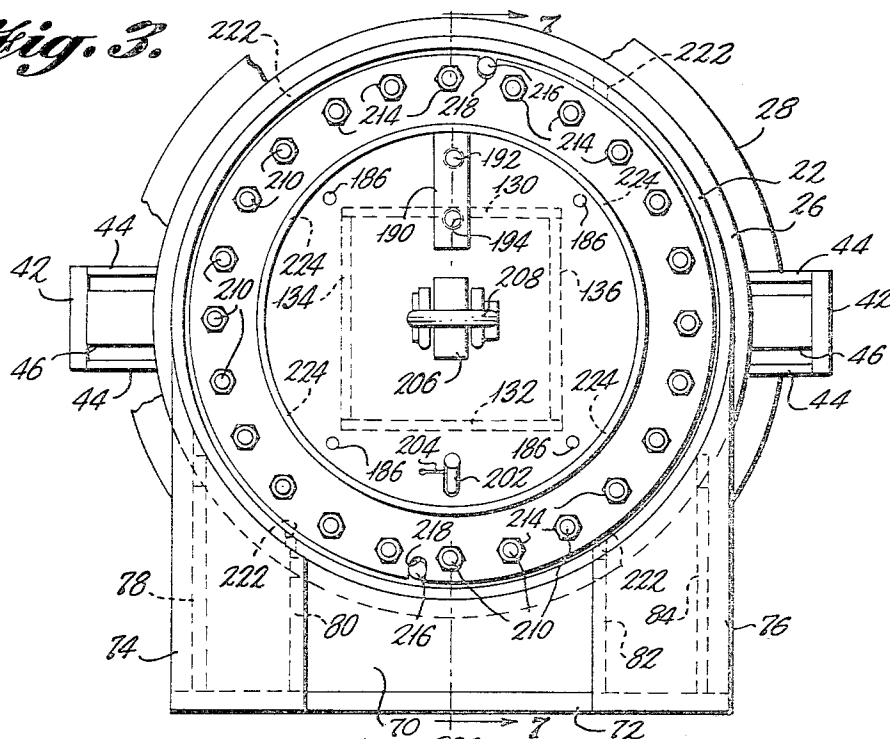
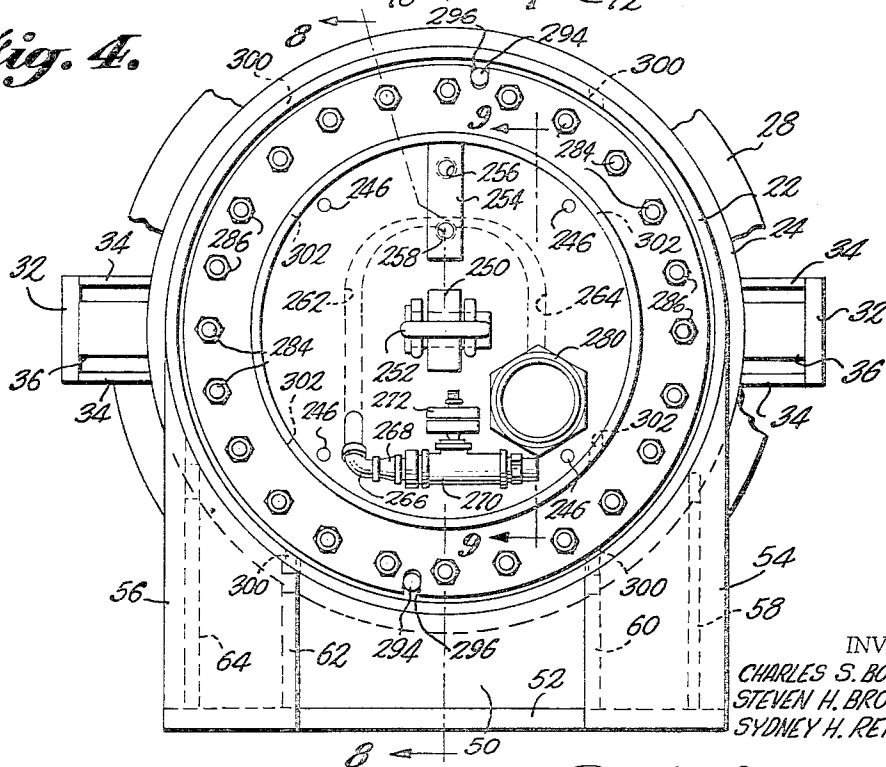


Fig. 4.



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Fig. 5.

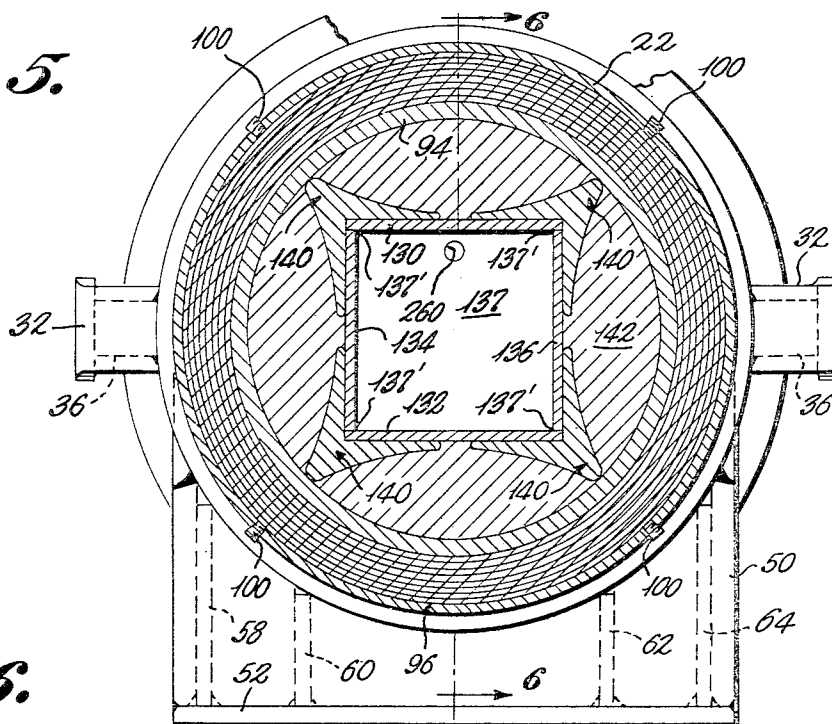
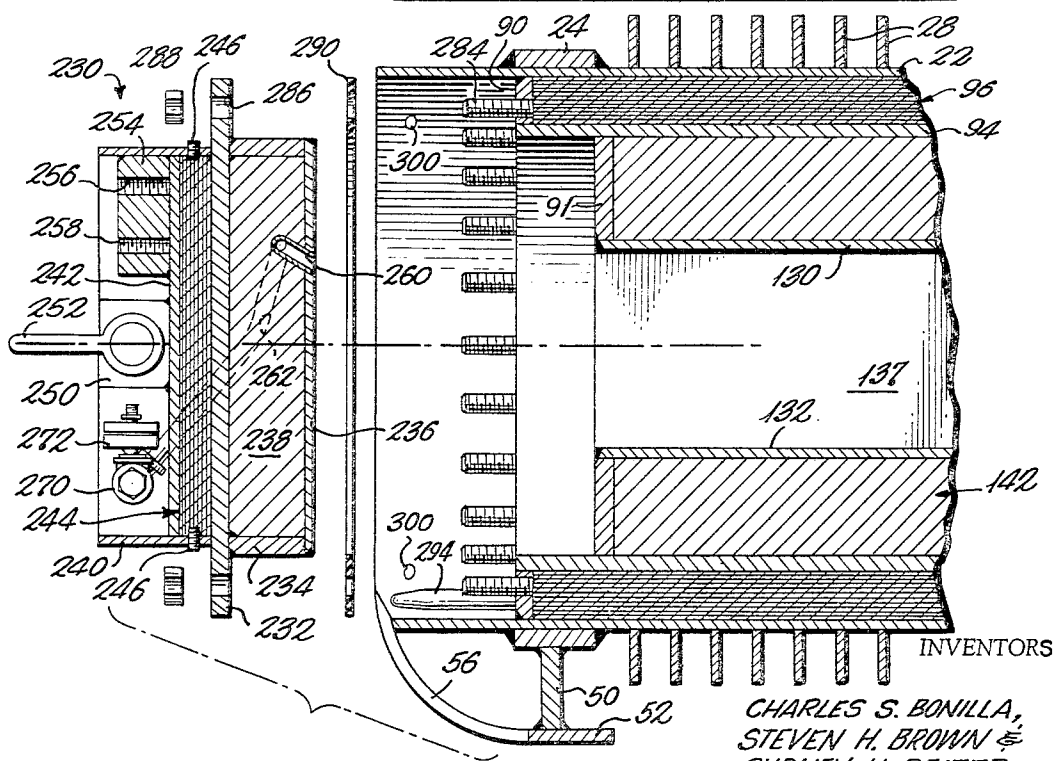


Fig. 6.



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Fig. 9.

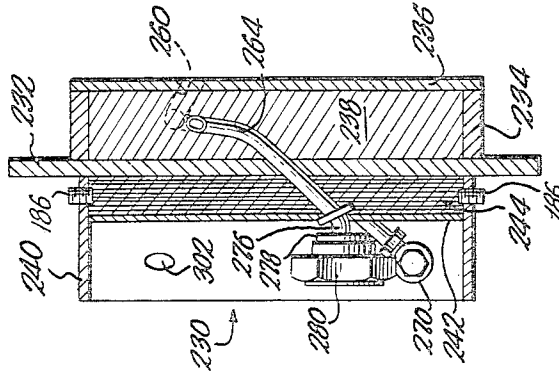


Fig. 8.

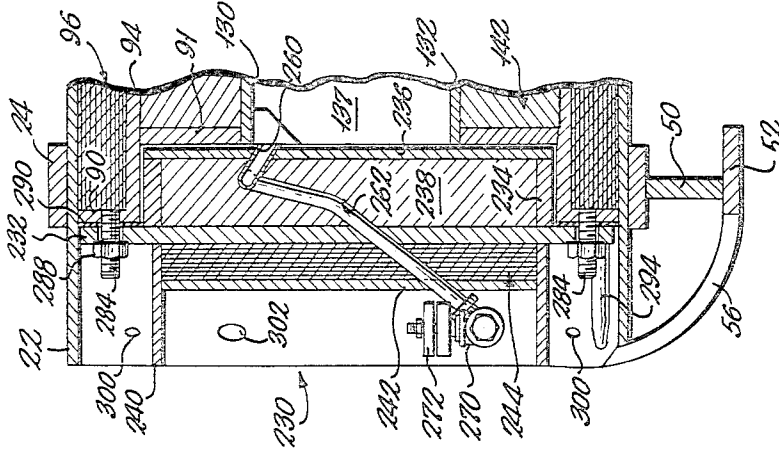
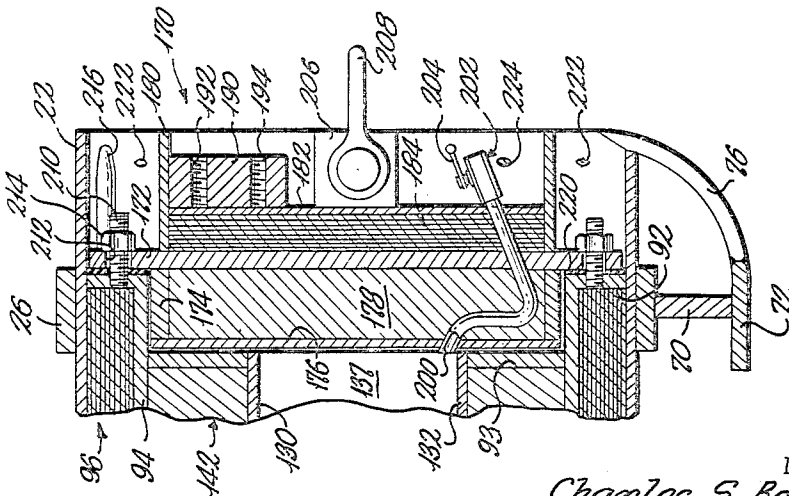


Fig. 7.



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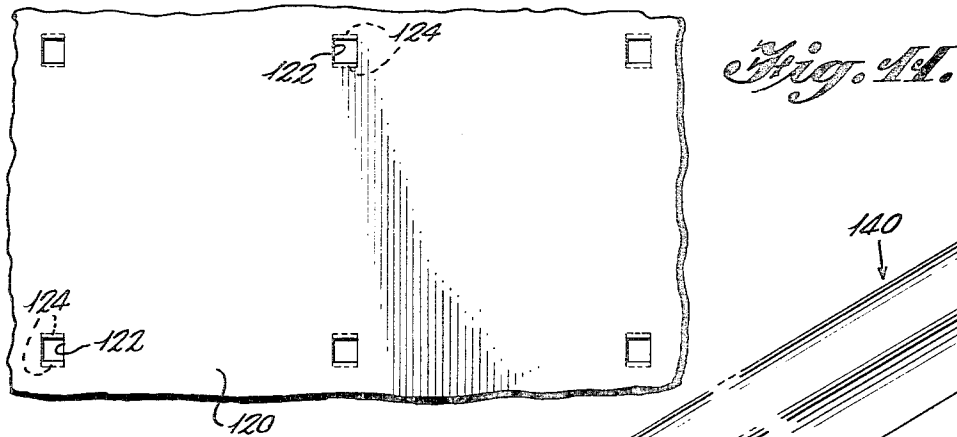
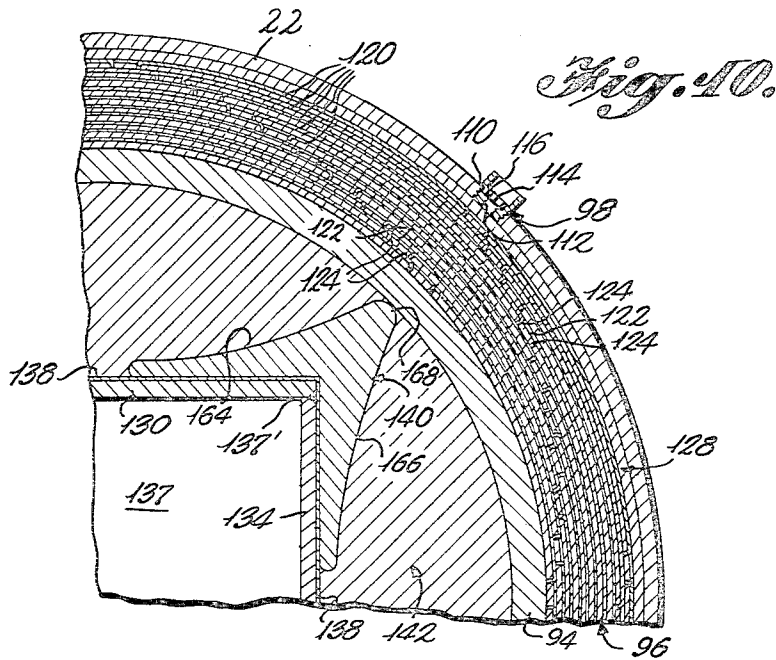
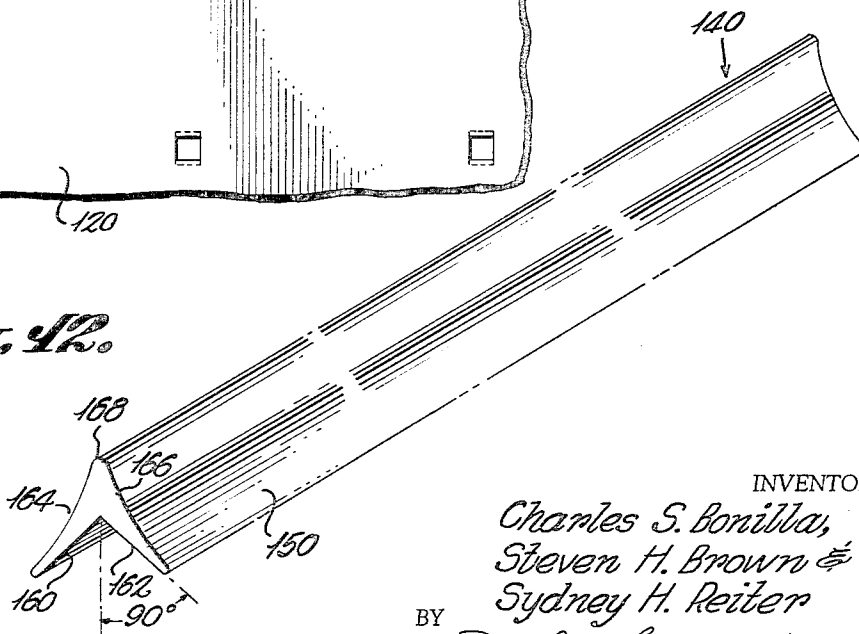


Fig. 42.



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3,483,381

SHIPPING CONTAINER FOR RADIOACTIVE MATERIALS HAVING CORNER SHIELDING MEANS

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U.S. Cl. 250—108

17 Claims

ABSTRACT OF THE DISCLOSURE

A shipping container for radioactive materials in which the container cavity is of generally rectangular cross sectional configuration, there being an outer shell of the container of generally cylindrical configuration, which is spaced apart from the cavity, the intervening space being filled with radiation shielding material. At the corners of the cavity there are cast uranium inserts which are more dense than the lead which is employed as the primary shielding material.

The present invention relates to shipping containers for radioactive materials, and more particularly to shipping containers for shipping irradiated fuel elements or the like such as used in nuclear reactors.

The present invention is particularly directed to shipping containers utilized for shipping highly radioactive material emanating strong gamma radiation. It is of course apparent that when shipping this type of material a principal consideration is to provide adequate radiation protection for personnel in the area. In addition, it is important to provide good physical protection for the shipped material, and accordingly the shipping container should be of a strong and rugged construction.

In addition, it is further important to provide a fire shielding means to provide built-in protection against accidental exposure to fire so as to minimize melting of the primary radiation shielding material and to prevent overheating of the inner cavity and radioactive contents of the container.

The shipping container includes a central cavity for containing the radioactive material, and this cavity is usually desirably of a rectangular or square shape for maximum efficiency. At the same time, it is desirable that the outer shell portions of the container which provide the principal strength of the container be of a cylindrical configuration.

Prior art containers for a similar purpose have generally been of an all steel construction or a combination of steel along with lead shielding for radiation protection as well as a crash shield and a fire shield in addition thereto. These prior art constructions have proved to be excessively bulky and quite heavy in construction. A particular advantage of the present invention is the fact that a substantial reduction in weight is provided while at the same time affording the necessary characteristics as described above.

In the present invention, the inner wall means defines a central cavity of generally rectangular configuration, whereas the inner and outer shell means disposed in surrounding spaced relationship thereto are of generally cylindrical configuration. It is evident that the space between the inner wall means and the inner shell means will not be of uniform thickness, but of reduced dimension directly outwardly of the corner portions of the cavity.

While this instant invention is particularly applicable to a shipping container having a square or generally rectangular cavity for holding radioactive material therein, it is to be recognized that the invention is generally

useful when the cavity is of any configuration other than circular. Whenever the surrounding shell portions of the container are of cylindrical configuration, as is contemplated herein, it will be apparent that should the cavity for holding the radioactive material be other than circular, the radiation shielding surrounding same will not be of uniform thickness and thus, in the absence of the construction contemplated herein the external radiation dose rate would not be uniform in all directions. By insertion of the corner shielding means as hereinafter described in greater detail it is possible to establish uniform shielding conditions throughout the entire structure. While the invention is described in the specification and in the drawings primarily with respect to a generally rectangular configuration of the cavity it should be apparent to those skilled in this art that the invention may be more broadly utilized as before indicated.

In order to provide the necessary radiation shielding, corner shielding means is provided at the corner portions of the cavity, this corner means in the present case being of cast uranium which is more dense than the lead employed as the primary radiation shielding material. In this manner, a substantially uniform radiation shielding means is provided so that the external radiation dose rate is uniform around the container. The cast uranium corner shielding means are of a maximum thickness directly outwardly of the corner portions of the cavity and taper to a smaller dimension in a direction toward the central parts of the associated inner wall means. While we have specifically referred to the use of cast uranium, this concept embraces the use of any denser shielding material than the primary shield material for service as the corner shielding means.

In addition, the corner shielding means are of a unique construction in that the outer surfaces thereof are curved to provide a curved interface between the corner shielding means and the body of lead comprising the primary radiation shield. These curved surfaces are necessary to avoid beaming of gamma radiation from the radioactive material within the central cavity along the interface of the lead and the uranium in case the lead is not bonded to the uranium and provision must be made for a small gap or void along such interface which is not filled with any shielding material. The curvature of the outer surfaces of insulator means which is made concave is most efficient, since any beaming possible would then have to pass through the more dense uranium than the less dense lead. It is possible, according to this invention, to use serrated or broken flat surfaces instead of curved ones, but they are less desirable on account of strength, cost, or other factors.

The construction of the present invention is quite rugged and provides good physical protection for the contents of the container. The cylindrical inner shell means is of heavy-duty construction and of maximum strength, and the outer shell means disposed in surrounding relationship to the inner shell means is also of cylindrical configuration. The safety shield means disposed between the inner shell means and the outer shell means is filled with a shielding substance which not only serves as a thermal safety shield means, but also normally assists in reducing the radiation hazard as well as providing additional strength to the over-all shipping container.

The safety shield means disposed about the body means and in both of the closure means at opposite ends of the cavity within the body means is of such a construction that it is adapted to melt or vaporize before the body of material comprising the primary radiation shielding means and thereby minimize melting of the primary shielding material and prevent overheating of the inner cavity and the radioactive contents thereof. The safety shield means is of such a construction that when sub-

jected to heat, it develops an increased resistance to the heat.

The safety shield means preferably employed is a lead alloy as hereinafter described in greater detail. However, other shielding substances may be utilized within the scope of this invention, for example, various salt compositions having appropriate melting and freezing points may be employed, likewise liquid systems, aqueous, inorganic, and organic may be selected. Water itself can be used. The general principles and construction are recited herein may be easily adapted to permit the use of the aforementioned materials, for example, substitution of a simple relief valve for one of the relief plugs will permit the use of water or other fluids systems which are capable of boiling away when conditions of overheating occur. Likewise, the space between the inner shell and the outer shell means may be somewhat less than completely filled with appropriate materials thus permitting expansion of the materials in the presence of substantial amounts of heat without the relief valve or plugs needing to operate.

The construction of the present invention substantially reduces the weight of the shielding required by employing a compound shield of lead, steel and uranium. The desirable rectangular or square central cavity configuration is retained while at the same time employing cylindrical shell portions for maximum strength or minimum weight. Special corner shielding means of a particular configuration enables this construction. Furthermore, as mentioned above, this corner shielding means is of a unique construction to prevent beaming of gamma radiation at the corner portions of the cavity.

An object of the present invention is to provide a new and novel shipping container for radioactive materials.

Another object of the invention is to provide a shipping container for radioactive materials which provides effective radiation protection to personnel in the general area of the container.

Still another object of the invention is the provision of a shipping container for radioactive materials of such a construction to provide maximum physical protection for the contents thereof.

Still another object of the invention is to provide a shipping container which provides built-in protection against accidental exposure to fire and which minimizes melting of the primary shielding material and prevents overheating of the inner cavity and radioactive contents thereof.

Still a further object of the invention is the provision of a shipping container including safety shield means which when subjected to heat develops an increased resistance to the heat.

Yet another object of the invention is the provision of a shipping container which substantially reduces the weight of the shielding material required.

Still a further object of the invention is to provide a shipping container which has a generally rectangular or other than circular cavity for holding radioactive material therewithin and wherein the surrounding shell portions of the container are of cylindrical configuration.

Another object of the invention is the provision of a shipping container including a unique construction to prevent beaming of gamma radiation at the corner portions of the cavity therewithin.

Yet another object of the invention is to provide a shipping container which is quite simple and inexpensive in construction, and yet at the same time which is quite efficient and reliable in use.

Other objects and many attendant advantages of the invention will become more apparent when considered in connection with the specification and accompanying drawings, wherein:

FIG. 1 is a side view of the shipping container according to the present invention;

FIG. 2 is a top view of the shipping container shown in FIG. 1 with certain parts broken away and in section;

FIG. 3 is an end view of the container taken along lines 3—3 of FIG. 1 looking in the direction of the arrows and on an enlarged scale;

FIG. 4 is an end view of the opposite end of the container taken along line 4—4 of FIG. 1 looking in the direction of the arrows and on an enlarged scale;

FIG. 5 is a sectional view taken substantially along lines 5—5 of FIG. 1 looking in the direction of the arrows and on an enlarged scale.

FIG. 6 is a sectional view taken substantially along line 6—6 of FIG. 5 looking in the direction of the arrows and with certain of the components shown in an exploded array for the sake of clarity;

FIG. 7 is a sectional view taken substantially along line 7—7 of FIG. 3 looking in the direction of the arrows;

FIG. 8 is a sectional view taken substantially along line 8—8 of FIG. 4 looking in the direction of the arrows;

FIG. 9 is a sectional view taken substantially along line 9—9 of FIG. 4 looking in the direction of the arrows;

FIG. 10 is an enlarged sectional view taken substantially along line 10—10 of FIG. 1 looking in the direction of the arrows;

FIG. 11 is an enlarged view illustrating a portion of the safety shield means construction; and

FIG. 12 is a top perspective view of one of the cast uranium corner shielding means of the present invention.

Referring now to the drawings wherein like reference characters designate corresponding parts throughout the several views, and as seen most particularly in FIGS. 1-6 inclusive, the shipping container of the present invention is indicated generally by reference numeral 20 and includes an outer shell means 22 which may be formed of a suitable material such as stainless steel or the like, and in a typical example may have a wall thickness of approximately ½ inch with an inner diameter of 32½ inches and a length of approximately 156 inches. A pair of ring members 24 and 26 are secured as by welding to the outer surface of the outer shell means 22, these ring members also being formed of stainless steel and may have a wall thickness of approximately 1 inch in order to provide a reinforcing means for securing the supporting means in operative position as hereinafter described.

A plurality of cooling fins 28 of generally annular configuration are suitably fixed as by welding to the outer surface of the outer shell means 22, the fins 28 lying in planes extending perpendicular to the longitudinal axis of the outer shell means and being spaced longitudinal along the container. These cooling fins may be formed of steel to provide suitable conduction of heat away from the container.

As seen particularly in FIGS. 1, 2 and 4, a first pair of trunnion assemblies indicated generally by reference numerals 30 and of substantially identical construction are disposed at diametrically opposite portions of the container and extend outwardly of the outer shell means 22. Each of these trunnion assemblies includes a support member 32 welded at one end thereof to the outer surface of shell means 22, and a pair of gusset plates 34 are secured between the outer surface of the shell means 22 and the inner surface of support members 32. Trunnions 36 are secured as by welding between the inner surfaces of support members 32 and the outer surface of ring member 24. Each of the members of the trunnion assemblies may be formed of a suitable material such as stainless steel.

A second pair of trunnion assemblies 40 of substantially identical construction are disposed at the opposite end of the container and extend outwardly from diametrically opposite sides of the outer shell means 22. Each of trunnion assemblies 40 includes a support member 42 fixed at one end thereof to the outer surface of shell means 22 as by welding or the like, a pair of gusset plates 44 being fixed between the outer surface of the shell means

and the inner surface of each of the support members 42. Trunnion members 46 are secured between the inner surfaces of support members 42 and the outer surface of the ring member 26, each of the components of these trunnion assemblies also being formed for example of stainless steel.

A support means at one end of the container includes a flat cradle plate 50 secured as by welding to ring member 24 and having a base plate 52 fixed to the lower edge thereof. A pair of curved leg members 54 and 56 extend forwardly and upwardly from the base plate 52 and are secured to the outer shell means 22 at the upper ends thereof. A first pair of gusset plates 58 and 60 extend between the cradle plate 50 and leg member 54, and a similar pair of gusset plates 62 and 64 extend between cradle plate 50 and leg member 56. All of these members are suitably fixed to one another as by welding or the like, and the various components of the support means may be formed for example of stainless steel.

A similar support means is provided at the opposite end of the container and includes a cradle plate 70 secured to ring member 26 and having a base plate 72 fixed to the lower edge thereof. A pair of spaced upwardly curved leg members 74 and 76 are fixed to the forward edge of base plate 72 and extend upwardly and are secured to the outer surface of the shell means 22. A first pair of gusset plates 78 and 80 are fixed between cradle plate 70 and leg member 74, and a second pair of gusset plates 82 and 84 are fixed between cradle plate 70 and leg member 76. All of these components of the support means may be suitably secured to one another as by welding and may include elements formed for example of stainless steel.

A pair of end plates 90 and 92 are secured to the inner periphery of the outer shell means 22 adjacent the opposite ends thereof. A substantially cylindrical inner shell means 94 is fixed between the end plates 90 and 92 and adjoining plates 91 and 93, all of these various elements being suitably secured in place as by welding, the inner shell means 94 being concentric with the outer substantially cylindrical shell means 22. The space between the inner shell means 94 and the outer shell means 22 is occupied by safety shield means, the details of which are described hereinafter. Inner shell means 94 is designed to provide a substantial degree of strength and rigidity to the body means and may comprise stainless steel and have a wall thickness of approximately 1 inch.

The safety shield means 96 will be seen to extend throughout the length of the body means between the end plates 90 and 92 and between the inner and outer shell means. This safety shield means includes suitable discharge means for a purpose hereinafter described. The discharge means includes a first plurality of relief plug means 98 which may be four in number and equally angularly spaced about the outer periphery of the outer shell means 22. A similar plurality of relief plug means 100 are disposed about a central portion of the outer shell means, and a further plurality of relief plug means 102 are disposed about the outer periphery of the outer shell means adjacent the opposite end thereof. It will be noted that these relief plug means are spaced peripherally about the body means and are spaced longitudinally thereof so as to provide a plurality of spaced portions through which the shielding substance may be discharged as hereinafter explained.

Referring now particularly to FIG. 10, the details of the safety shield means may be more clearly understood. The relief plug means 98 is typical of the construction of each of the relief plug means and includes a stainless steel pipe plug 110 which is threaded into a suitable threaded opening provided in the outer shell means 22. Member 110 is provided with a bore 112 in communication with the space between the inner and outer shell means, and member 110 is counterbored to provide a seat which receives a thin membrane of wafer 114 of a suitable ma-

terial such as polyethylene plastic which is adapted to yield at a predetermined temperature so as to permit discharge of the material between the inner and outer shell means when the container is exposed to a fire or the like whereupon the safety shield means becomes operative as hereinafter explained. The thin member 114 is held in place by means of a retainer ring 116 suitably fixed within the counterbored portion of member 110. It should be understood that member 114 may also be so designed as to yield at a predetermined pressure. These relief plug means also permit filling of the enclosed space between the inner and outer shell means with a suitable shield substance by temporarily utilizing a solid plug in each hole not required for pouring or venting while pouring the lead alloy or otherwise introducing the shielding substance.

A plurality of members or layers of material 120 are provided, these layers being shown as ten in number in the illustrated example. The layers of material are formed of a material such as steel which has good heat conducting characteristics for normal operation when it is desired to transfer the decay heat outward with the minimum temperature drop and which preferably has a shiny surface to enhance its operation as a thermal insulating means for emergency operation when it is desired to minimize heat flow into the container from an external fire.

As seen particularly in FIG. 11, one of the sheets of material 120 is illustrated in a flat form, and each sheet 120 is provided with a plurality of holes 122 which may be formed by punching portions 124 out of the plane of the sheet of material so as to form integral offset portions. As seen in FIG. 10, when members 120 are wrapped around the inner shell means 94, the integral offset portions 124 serve to maintain the sheets of material 120 in spaced relationship from one another, and the holes 122 provide communication between the spaces defined by adjacent sheets of material 120.

When assembling members 120, the various sheets of material are rotated with respect to one another so that the inner shell means cannot be seen through any group of holes provided by the different sheets of material. In this manner, there is no direct radial path from the inner shell means to the outer shell means through a series of holes in the members 120. It is evident that the totality of the members 120 may also be assembled from one or more long strips of sheet metal of adequate width, spirally wrapped about the inner shell means.

The remaining space between the inner and outer shell means is completely filled with a shield substance indicated by the reference numeral 128. The shield substance is of such composition as to be capable of flowing out of the enclosed space between the inner and outer shell means at high temperatures. The shield substance is preferably a low melting alloy which is solid at all normal operating conditions as up to approximately 150° C. but which will melt at higher temperatures. The alloy should preferably be an alloy of lead so as to present a substantial radiation shielding characteristic.

The shield material employed in the present invention is preferably 94% lead and 6% antimony so as to have a melting point well below the melting point of the pure lead used as the primary radiation shielding material as hereinafter described. This provides the desired result of enabling the shield substance of the safety shield means to melt and run out of the enclosed spaces between the inner and outer shell means before the primary lead shielding material melts. Other suitable alloying metals may be employed with lead such as lithium, sodium, tin, etc. A particular advantage of these lead alloys which may be employed in the safety shield means is that they are stronger than the usual shielding lead thereby adding deformation and penetration resistance to the container. It will be understood that if the thin membranes 114 of the various relief plug means have been opened so as to

allow the shield substance to be discharged from the safety shield means, the lower holes may be temporarily plugged and the safety shield substance can then be again introduced into the space between the inner and outer shell means and the diaphragms of the various relief plug means may be then replaced. Alternatively, it may be possible to replace the safety shield substance temporarily with another shield substance, such as water, as may be more readily available at the time.

As seen most clearly in FIGS. 5 and 10, inner wall means is provided in the form of a pair of generally horizontally extending plates 130 and 132 which are spaced from one another and parallel with one another and which are interconnected by a pair of spaced generally vertically extending plates 134 and 136, these various plates being rigidly interconnected to one another as by welding. All of these plates may be formed of a suitable substance such as stainless steel or the like, these inner wall members being fixed at their opposite ends to the end plates 91 and 93. This inner wall means defines a central elongated cavity 137 open at both ends and which is of rectangular cross sectional configuration and in fact of generally square cross sectional configuration to define four corner portions indicated by reference numerals 137'.

A relatively thin layer of lead 138 is disposed about the outer surface of the inner wall means, or some equivalent method of obtaining good thermal contact between the corner shield means and the inner wall means is provided.

It will be noted that the inner wall means defines a rectangular cavity in the central portion of the body means and that the inner wall means is disposed centrally within the inner shell means 94. It is accordingly evident that the corner portions 137' of the cavity are disposed closer to the inner shell means than the remaining portions of the cavity. In order to provide adequate shielding outwardly of the corner portions 137', suitable corner shield means indicated generally by reference numeral 140 are provided. These corner shield means in the present example are illustrated as being four in number and each one of the corner shield means is disposed about one of the corner portions of the cavity. The remaining space between the lead sheet means 138 and the inner shell means 94 is substantially filled with a body of radiation shielding material indicated by reference numeral 142 and which may comprise lead.

Referring particularly to FIG. 12, the construction of the corner shielding means is illustrated. Each of the corner shielding means is of substantially identical construction, and accordingly a description of one of these corner shielding means will suffice for all. The corner shielding means are preferably formed of cast uranium so as to provide a shielding material which is more dense than the lead shielding material employed as the primary radiation shielding means. It should be understood that the corner shielding means can as well be formed of a single integral cast body of uranium 150 if desired. On the other hand, it may be made in sections, if preferred, with joints suitably shaped to prevent streaming.

Each of the corner shielding means defines a pair of inner surfaces 160 and 162 which extend at substantially 90° to one another so as to fit snugly about one of the corners of the inner wall means. The two side surfaces 164 and 166 of the corner shielding means are of arcuate configuration and are joined by an apex portion 168 which is also of rounded shape so as not to damage the inner shell means in an accidental fall.

Referring now to FIG. 10, one of the corner shielding means is disposed in operative position about a corner portion of the cavity, and in this position, it will be noted that the curved surfaces 164 and 166 provide a curved interface between the corner shielding means and the primary radiation shielding material 142, and as described previously, this arcuate interface prevents beaming of gamma radiation along the interface of the lead and

uranium. However, a serrated or other broken surface could be utilized instead.

It will be noted as seen in FIG. 10 that the corner shielding means has a maximum thickness in a radial direction directly outwardly of the associated corner of the cavity in a direction away from the center of the cavity. The corner shielding means tapers to a smaller thickness toward the central portions of the associated inner wall means. With this over-all arrangement, the desired radiation shielding may be obtained. In addition, the uranium corner shielding means may be decreased in thickness and width towards the ends of the container to maintain the dose rate uniform outside of the container.

Referring now particularly to FIG. 7, the construction of the closure means at one end of the container is illustrated. This closure means is indicated generally by reference numeral 170 and includes a flat disc-like flange plate 172. A ring member 174 is rigidly secured to plate 172 and extends therefrom, an inner plate 176 being secured to ring 174. The space enclosed between members 172, 174, and 176 is filled with a suitable radiation shielding material such as lead.

A ring member 180 is also secured to plate 172 and extends in a direction opposite to ring 174. An outer plate 182 is fixed to the inner periphery of ring member 180 and the space defined between members 172, 180 and 182 is provided with a safety shield means of a construction similar to the safety shield means 96 previously described. In other words, a plurality of layers of material similar to members 120 is provided in the space defined between members 172, 180 and 182, the remainder of the space being filled with a suitable shield material such as a lead antimony alloy, and a plurality of discharge means are provided in the form of relief plug means 186 which as seen in FIG. 3 and in FIG. 7 may be four or more in number and spaced about the outer plate 182 and ring member 180, these fusible plug means being of a construction similar to that previously described.

A shackle block 190 is suitably secured as by welding to members 180 and 182 and is provided with a pair of threaded openings 192 and 194 to receive suitable correspondingly threaded members for handling the closure means.

A vent pipe 200 opens at one end to the interior of cavity 137, the vent pipe extending completely through the closure means 170 and the opposite end of the vent pipe being closed by a valve 202 which includes a manually operable lever 204 for selectively operating the valve so that the interior of the cavity can be vented when desired.

A shackle block 206 is suitably secured as by welding to the outer plate 182, and a shackle 208 is swingably mounted on the shackle block in a conventional manner, the shackle being provided for facilitating handling of closure means 170.

A plurality of threaded studs 210 are suitably secured to the end plate 92 as being screwed and welded into the plate, these threaded studs extending through a corresponding number of holes 212 provided in flange plate 172. Nuts 214 are threaded onto studs 210 for holding the closure means in the operative position shown, and an annular gasket 220 is adapted to be compressed between plate 172 and the end plate 92 to provide an effective seal therewith. The gasket may be of a suitable material such as neoprene rubber or the like.

A pair of locating pins 216 extend longitudinally from end plate 92, these locating pins being adapted to fit within cutout portions 218 provided at approximately opposite sides of flange plate 172. The interengagement between the locating pins and the cutout portions in the flange plate serves to ensure that closure means 170 will be properly oriented when mounted in operative position on the container,

As seen particularly in FIG. 3, the outer shell means 22 is provided with four spaced holes 222 formed there-through, a pair of holes at either side of the longitudinal axis of the body means being vertically aligned with one another. The ring member 180 of closure means 170 is provided with four spaced holes 224, a pair of holes 224 on either side of the longitudinal axis of the closure means also being vertically aligned with one another. As seen in FIG. 3, it is apparent that a first pair of holes 222 in the outer shell means is vertically aligned with a first pair of holes 224 in the closure means, and in a similar manner second pairs of holes in the respective portions are also aligned with one another. These aligned holes are adapted to receive a suitable retaining pin. These retaining pins are used to hold the closure means in position after horizontal loading of the container and before the nuts 214 are screwed into plate. The retaining pins then simply function to carry the seal wire after the nuts are screwed on.

The closure means 170 is at the drain end of the container and conduit 200 is normally employed as a drain line for draining water after loading the container.

A second closure means indicated generally by reference numeral 230 is provided for closing off the opposite open end of the central cavity within the body means. Closure means 230 includes a flange plate 232 having a ring member 234 extending therefrom, an inner plate 236 being secured to the outer end of ring member 234. The space defined between members 232, 234 and 236 is filled with a suitable radiation shielding material such as a body of lead indicated by reference numeral 238.

A ring member 240 extends from the opposite side of flange plate 232, and an outer plate 242 is rigidly secured to the inner periphery of ring member 240. The space defined between members 232, 240 and 242 is provided with a safety shield means of a construction similar to those previously described. A plurality of layers of material similar to members 120 previously described are provided, the space being filled with a safety shield substance as previously discussed. A plurality of discharge means are provided, these discharge means comprising relief plug means 246 as seen most clearly in FIG. 4 and FIG. 6 which may be four or more in number and disposed about the outer plate 242 and ring member 240. This safety shield means operates in a manner similar to that previously described.

A shackle block 250 is rigidly affixed to outer plate 242, and a shackle 252 is swingably mounted on the shackle block in a conventional manner.

A shackle block 254 is also provided to permit removal of the closure means when the container is in the horizontal position, this shackle block being suitably secured to members 240 and 242, the shackle block having a pair of threaded openings 256 and 258 formed therein.

The closure means 230 is provided with vent means including a first vent conduit portion 260 which is in communication with the interior of cavity 137. Conduit portion 260 is in turn in communication with a pair of conduit portions 262 and 264. Conduit portion 262 is connected with an elbow member 266 which in turn is connected with a reducing coupling 268 which is connected to a relief valve 270. This relief valve may be of a conventional construction and in a typical example may be set to relieve at 5 p.s.i. A filter means 272 is connected with the output of relief valve 270, the filter means being of a conventional construction.

The other conduit portion 264 is connected by an elbow 276 with a bushing 278 which in turn is connected to a safety head 280. This safety head is provided with a rupture disc which is adapted to burst at approximately 15 p.s.i. in a typical example.

As seen most clearly in FIG. 6, a plurality of threaded studs 284 are suitably secured as being screwed and welded into the end plate 90, these threaded studs extend-

ing through a plurality of holes 286 provided in flange plate 232. Nuts 288 are threaded on studs 284 for securing the closure means 230 in operative position. A suitable gasket 290 of annular configuration and formed of a material such as neoprene rubber or the like is adapted to be compressed between the flange plate 232 and end plate 90 when the closure means 230 is in operative position.

A pair of approximately oppositely disposed locating pins 294 extend outwardly from end casting 90, these locating pins being adapted to be received in cutout portions 296 provided in flange plate 232 for properly orienting the closure means 230 when it is mounted in operative position.

As seen most clearly in FIG. 4, the outer shell means 22 is provided with a first pair of vertically aligned holes 300 disposed at one side of the longitudinal axis of the body means, and a second pair of vertically aligned holes 300 provided at the opposite side of the longitudinal axis. In a similar manner, the ring member 240 of closure means 230 is provided with a first pair of vertically aligned holes 302 at one side of the longitudinal axis thereof and a second pair of vertically aligned holes 302 at the other side of the longitudinal axis thereof. As described previously, these vertically aligned holes formed in the outer shell means and the closure means are adapted to receive retaining pins for holding the closure means in position after horizontal loading and before the nuts are screwed into place.

It is apparent from the foregoing that there is provided according to the present invention a new and novel shipping container which is adapted to ship radioactive materials such as nuclear fuel elements and the like. The construction of the present invention is such as to provide an effective degree of radiation protection to personnel in the general area of the container, and also to provide good physical protection for the fuel elements by providing a strong and rugged container. The container includes built-in protection against accidental exposure to fire and minimizes melting of the primary shielding material and prevents overheating of the inner cavity and the radioactive contents of the container. The safety shield when subjected to heat develops an increased resistance to heat due to the fact that the shield material melts and runs out of the safety shield space so as to provide a more effective thermal barrier to an outside source of heat. The weight of the shielding required to prevent excessive radiation is substantially reduced in the present invention by providing a compound shield of lead, steel and uranium. The over-all construction is such as to retain the desired rectangular cross section of the cavity for receiving the radioactive material while at the same time employing generally cylindrical shell portions for maximum strength. The inner cylindrical shield may be constructed by stainless steel or less expensive stainless clad carbon steel, and made thick to provide most of the necessary strength. The outer cylindrical shield is made of stainless steel to resist corrosion but can be made thin according to this design. This arrangement is enabled due to the provision of special corner shielding means of a unique shape. These corner shielding means also employ the unusual shape thereof to prevent beaming of gamma radiation at the interface between the corner shielding means and the primary radiation shielding material. The over-all construction is quite simple and less expensive, and yet at the same time is quite efficient and reliable in operation.

As this invention may be embodied in several forms without departing from the spirit or essential characteristics thereof, the present embodiment is therefore illustrative and not restrictive, and since the scope of the invention is defined by the appended claims, all changes that fall within the metes and bounds of the claims or that form their functional as well as conjointly cooperative equivalents are therefore intended to be embraced by those claims.

What we claim is:

1. A shipping container for radioactive materials comprising body means defining a centrally located cavity formed therewithin, said cavity having a cross sectional configuration defining a plurality of corner portions, shell means disposed in spaced surrounding relationship to said cavity, said shell means being of generally cylindrical configuration, the space between said shell means and said cavity being filled with radiation shielding material, and corner shielding means disposed adjacent the corner portions of said cavity, said corner shielding means being formed of a further radiation shielding material more dense than said first-mentioned shielding material.

2. A shipping container according to claim 1 wherein said cavity has a generally rectangular cross sectional configuration.

3. A shipping container for radioactive materials comprising body means, including inner wall means defining a central cavity within said body means defining a plurality of corner portions, said cavity being open at at least one end portion of said body means, closure means for closing off said open end of the cavity, said body means including shell means of generally cylindrical configuration disposed in spaced surrounding relationship to said inner wall means, a first radiation shielding material disposed between said inner wall means and said shell means, and corner shielding means, said corner shielding means being disposed at each of said corner portions, said corner shield means being formed of a second radiation shielding material more dense than said first radiation shielding material.

4. A shipping container according to claim 3 wherein said inner wall means defines a central cavity within said body means of rectangular cross sectional configuration.

5. Apparatus as defined in claim 3 wherein said corner shielding means includes a plurality of cast uranium members each of which extends around one of said corner portions throughout the length of said inner wall means, each of said corner shielding means having a maximum thickness disposed directly outwardly of the associated corner portion in a direction away from the center of said cavity.

6. A shipping container for radioactive materials comprising body means, said body means including inner wall means defining a central cavity of configuration defining a plurality of corner portions, said body means including shell means disposed in spaced surrounding relationship to said inner wall means and being of generally cylindrical configuration, a first radiation shielding material disposed between said inner wall means and said shell means, said cavity being open at at least one end thereof, closure means for closing off and cavity, and corner shielding means disposed at each corner portion of said cavity and being positioned between said inner wall means and said shell means, said corner shielding means comprising a radiation shielding material more dense than said first-mentioned radiation shielding material, the outer surface of said corner shielding means being curved to define a curved interface between said corner shielding means and said first radiation shielding material whereby said first and second mentioned radiation shielding material substantially fill the space between said inner wall means and said shell means and an effective radiation shield is provided.

7. A shipping container for radioactive materials comprising body means, support means for supporting said body means on a suitable supporting surface, said body means including inner wall means defining an elongated central cavity of generally rectangular configuration and having four corner portions, said cavity being open at opposite ends thereof, a plurality of closure means, each of said closure means being adapted to close off one end of said cavity to provide a sealed cavity within said body means, shell means disposed in spaced surrounding relationship to said inner wall means, a first body of radiation shielding material disposed within the space between said inner wall means and said shell means, corner shielding means disposed within said space between said inner wall means and said shell means, said corner shield means being disposed about each corner portion of said cavity and extending throughout the length of said cavity, said corner shielding means being formed of a second radiation shielding material which is more dense than said first-mentioned radiation shielding material, said first and second radiation shielding materials substantially filling the space between said inner wall means and said shell means, said shell means being generally cylindrical in configuration, said corner shielding means having a maximum thickness directly outwardly of an associated corner portion of the cavity in a direction extending away from the center of the cavity, said corner shielding means tapering from said points of maximum thickness to a lesser thickness in a direction toward the central portions of the associated inner wall means, the outer surfaces of said corner shielding means being curved to define a curved interface between said corner shielding means and said first body of radiation shielding material so as to provide an effective radiation shielding means about said cavity.

8. Apparatus as defined in claim 7 wherein said first body of radiation shielding material is formed of lead, and said corner shielding means is formed of cast uranium.

9. A shipping container for radioactive materials comprising body means, said body means including inner wall means defining a central elongated cavity within said body means of configuration including a plurality of corner portions, said cavity being open at at least one end thereof, closure means for closing off said open end of the cavity, said body means including inner shell means of generally cylindrical configuration and disposed in spaced surrounding relationship to said inner wall means, a body of radiation shielding material disposed within the space between said inner wall means and said inner shell means, corner shielding means disposed within the space between said inner wall means and said inner shell means and along with said first-mentioned radiation shielding material substantially filling said space, said corner shielding means being formed of a radiation shielding material more dense than said first-mentioned radiation shielding material, said corner shielding means being disposed about each corner portion of the cavity, outer shell means disposed in spaced surrounding relationship to said inner shell means, and safety shield means disposed within the space between said inner shell means and outer shell means.

10. Apparatus as defined in claim 9 wherein said safety shield means includes a shield substance of lower melting point than said first-mentioned body of radiation shielding material, discharge means for discharging such shield substance from said safety shield means as a fluid, and means for normally preventing discharge through said discharge means.

11. Apparatus as defined in claim 9 wherein said safety shield means includes a plurality of layers of material of good heat conducting characteristics, but opaque to radiant heat, disposed peripherally about said inner shell means, said layers of material being spaced from one another and having holes formed therethrough, a shield substance disposed between said layers of material and having a lower melting point than said first body of radiation shielding material, discharge means for discharging said shield substance from said safety shield means, and plug means for normally preventing discharge of said safety shield substance.

12. A shipping container for radioactive materials comprising body means, said body means including inner wall means defining an elongated central cavity within said body means and being open at opposite ends thereof, said cavity being of generally rectangular cross sectional configuration and defining four corner portions, said body means including inner shell means disposed in spaced surrounding relationship to said inner wall means, a first body of radiation shielding material disposed within the space between said inner wall means and said shell means, corner shielding means disposed within said space between said inner wall means and said shell means, said corner shield means being disposed about each corner portion of said cavity and extending throughout the length of said cavity, said corner shielding means being formed of a second radiation shielding material which is more dense than said first-mentioned radiation shielding material, said first and second radiation shielding materials substantially filling the space between said inner wall means and said shell means, said shell means being generally cylindrical in configuration, said corner shielding means having a maximum thickness directly outwardly of an associated corner portion of the cavity in a direction extending away from the center of the cavity, said corner shielding means tapering from said points of maximum thickness to a lesser thickness in a direction toward the central portions of the associated inner wall means, the outer surfaces of said corner shielding means being curved to define a curved interface between said corner shielding means and said first body of radiation shielding material so as to provide an effective radiation shielding means about said cavity.

13. Apparatus as defined in claim 12 wherein said first body of radiation shielding material is formed of lead, and said corner shielding means is formed of cast uranium.

14. A shipping container for radioactive materials comprising body means, said body means including inner wall means defining an elongated central cavity within said body means and being open at opposite ends thereof, said cavity being of generally rectangular cross sectional configuration and defining four corner portions, said body means including inner shell means disposed in spaced surrounding relationship to said inner wall means, a first body of radiation shielding material disposed within the space between said inner wall means and said shell means, corner shielding means disposed within said space between said inner wall means and said shell means, said corner shield means being disposed about each corner portion of said cavity and extending throughout the length of said cavity, said corner shielding means being formed of a second radiation shielding material which is more dense than said first-mentioned radiation shielding material, said first and second radiation shielding materials substantially filling the space between said inner wall means and said shell means, said shell means being generally cylindrical in configuration, said corner shielding means having a maximum thickness directly outwardly of an associated corner portion of the cavity in a direction extending away from the center of the cavity, said corner shielding means tapering from said points of maximum thickness to a lesser thickness in a direction toward the central portions of the associated inner wall means, the outer surfaces of said corner shielding means being curved to define a curved interface between said corner shielding means and said first body of radiation shielding material so as to provide an effective radiation shielding means about said cavity.

rounding relationship to said inner wall means, a body of first radiation shielding material disposed within the space between said inner wall means and said inner shell means, said inner shell means being substantially cylindrical in configuration, corner shielding means disposed within the space between said inner wall means and said inner shell means and along with said body of first radiation shielding material substantially filling said space, said corner shielding means including a plurality of portions each of which is disposed about one of said corner portions, said corner shielding means being formed of a second radiation shielding material which is more dense than said first-mentioned radiation shielding material, outer shell means disposed in spaced surrounding relationship to said inner shell means, safety shield means disposed between said inner shell means and said outer shell means, and including a shielding substance, said outer shell means having discharge means therein for discharging said shielding substance from said safety shield means, means for normally preventing discharge of said shielding substance through said discharge means, a plurality of closure means each of which is adapted to close off one end of said cavity, each of said closure means including spaced wall portions having safety shield means disposed therebetween, each of said safety shield means of said closure means also including a shielding substance and each of said closure means also including discharge means for discharging the associated shielding substance, and means for normally preventing discharge of said shielding substance through said last-mentioned discharge means.

13. Apparatus as defined in claim 12 wherein said corner shielding means includes four separate cast corner shield means each of which is disposed about one of said corner portions, each of said separate corner shield means having a maximum thickness in a direction extending directly outwardly from the associated corner portion in a direction away from the center of said cavity, each of said separate corner shield means tapering to a smaller thickness in a direction toward the center of the associated inner wall means, each of said separate corner shield means having a curved outer surface to define a curved interface with said body of first radiation shielding material to provide an effective radiation shield.

14. Apparatus as defined in claim 12 wherein each of the safety shield means disposed between said inner shell means and said outer shell means as well as between spaced wall portions of each of said closure means includes a plurality of layers of material of good heat conducting characteristics but opaque to radiant heat, said layers of material being spaced from one another and having holes formed therein such that the associated shielding substance is adapted to be disposed between said layers of material and to flow outwardly thereof upon melting.

15. Apparatus as defined in claim 12 wherein one of said closure means includes relief valve means in communication with said cavity, filter means operatively connected with said relief valve means, and safety head means also in communication with said cavity, said relief valve means being adapted to vent said cavity at a predetermined pressure, said safety head means being adapted to vent said cavity at a higher pressure than said relief valve means.

16. Apparatus as defined in claim 12 wherein one of said closure means includes vent means in communication with said cavity, and manually operable valve means for closing off said vent means.

17. A shipping container for radioactive materials comprising body means, support means for supporting said body means on a suitable supporting surface, said body means including inner wall means defining a central elongated cavity within said body means of rectangular

cross sectional configuration defining four corner portions, said cavity being open at opposite ends thereof, inner shell means disposed in spaced surrounding relationship to said inner wall means and being of generally cylindrical configuration, a body of lead disposed in the space between said inner wall means and said inner shell means, a plurality of corner shield means each of which is formed of cast uranium which is more dense than said first-mentioned body of lead, said cast uranium corner shield means and said body of lead substantially filling said space, each of said cast uranium corner shield means being disposed about a corner portion of said cavity outwardly of said inner wall means, each of said corner shield means having a maximum thickness at a central portion thereof and tapering to a smaller thickness toward opposite ends thereof, whereby the corner shield means when in assembled position define a maximum thickness directly outwardly of one of said corner portions in a direction away from the center of said cavity, each of said corner shield means having curved outer surfaces to define a curved interface with said body of lead to provide an effective radiation shield, outer shell means disposed in spaced surrounding relationship to said inner shell means, said inner shell means being substantially thicker and stronger than each of said inner wall means and said outer shell means, safety shield means disposed between said inner shell means and said outer shell means, said safety shield means including a plurality of layers of material of good heat conducting characteristics, but opaque to radiant heat, spaced from one another and having holes formed therein, a shielding substance disposed between said layers of material, discharge means formed in said outer shell means for discharging said shielding substance upon melting thereof, said shielding substance having a melting point substantially lower than said body of lead, means for normally preventing discharge of shielding substance through said discharge means, a plurality of closure means, each of said closure means including spaced wall portions having safety shield means disposed therebetween, the safety shield means of each of said closure means including a plurality of layers of material of good heat conducting characteristics, but opaque to radiant heat, spaced from one another and having holes formed therein, the safety shield means of each of said closure means including a shielding substance disposed between said layers of material and having a melting point lower than said body of lead, each of said closure means including discharge means for discharging shielding substance therefrom, and means for normally closing off said last-mentioned discharge means, one of said closure means including relief valve means and safety head means each of which is in communication with said cavity and each of which is adapted to open at a predetermined pressure, said safety head means being adapted to open at a higher pressure than said relief valve means, filter means operatively connected with said relief valve means, the other of said closure means having vent means therein in communication with said cavity, and manually operable valve means for selectively closing and opening said vent means.

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