

50-507

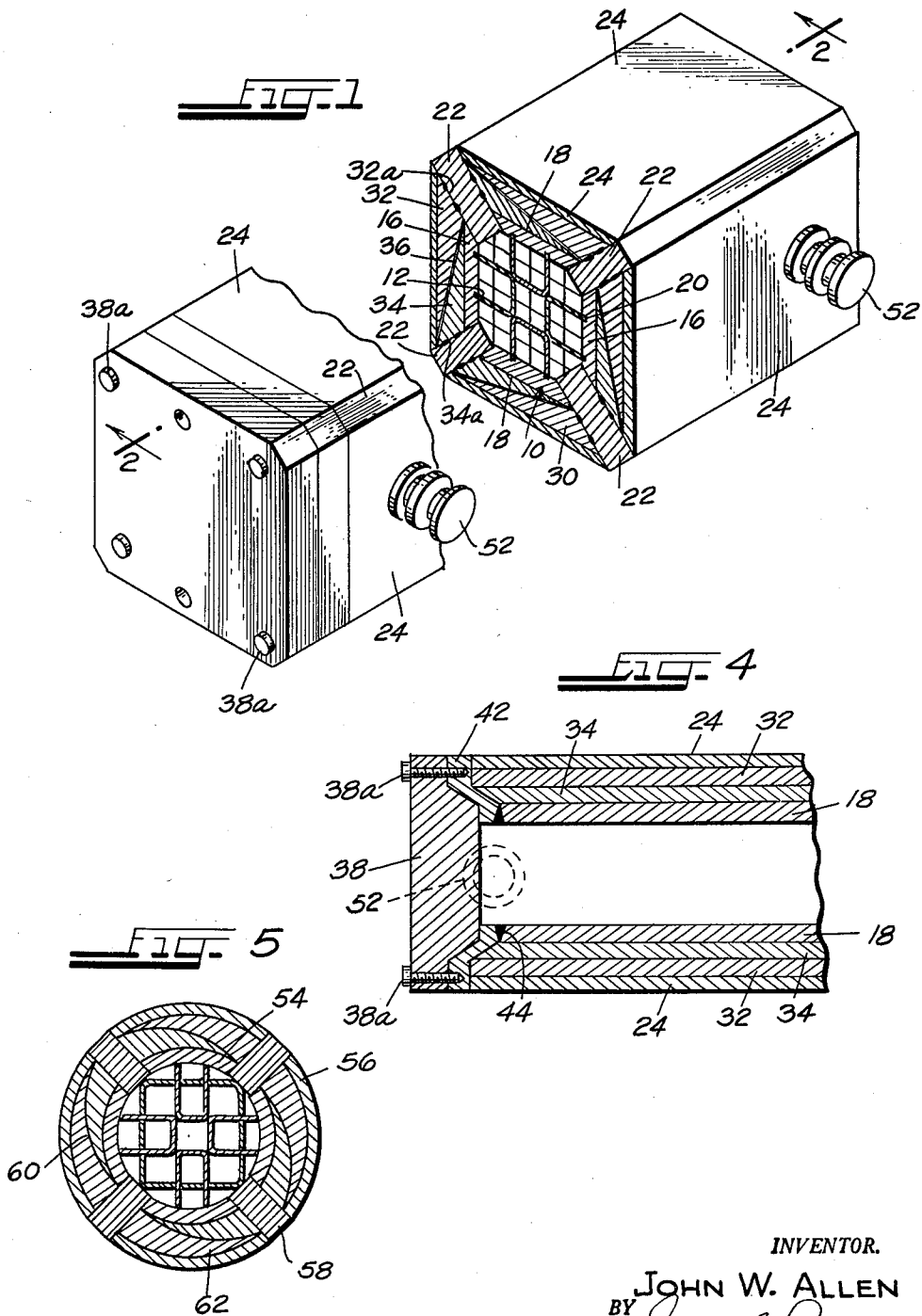
Jan. 28, 1964

J. W. ALLEN
CONTAINER FOR TRANSPORTING THERMALLY
HOT INTENSELY RADIOACTIVE MATERIAL

3,119,933

Filed May 3, 1960

4 Sheets-Sheet 1



INVENTOR.

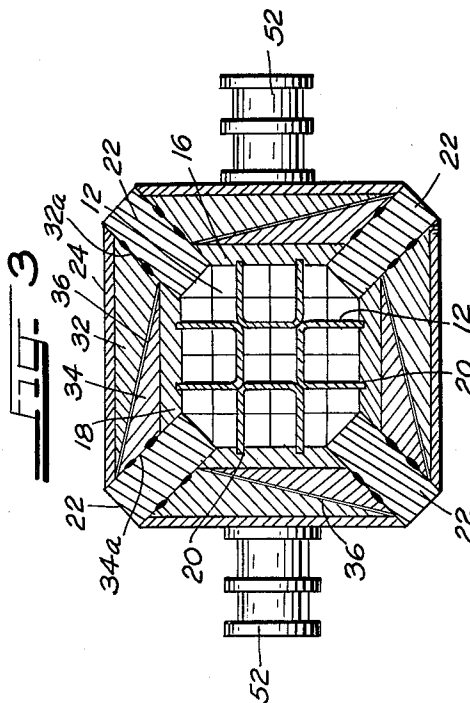
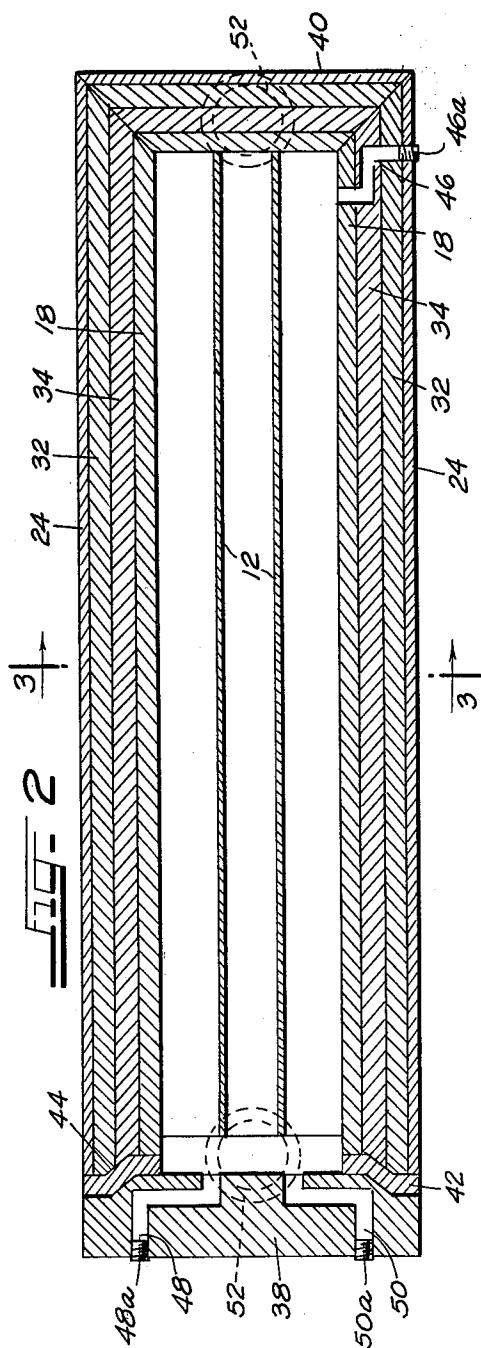
JOHN W. ALLEN

BY *Sabin C. Brown*
ATTORNEY.

Filed May 3, 1960

4 Sheets-Sheet 2

3,119,933



JOHN W. ALLEN
BY *[Signature]*

BY Sabin C. Prosser
M.D.

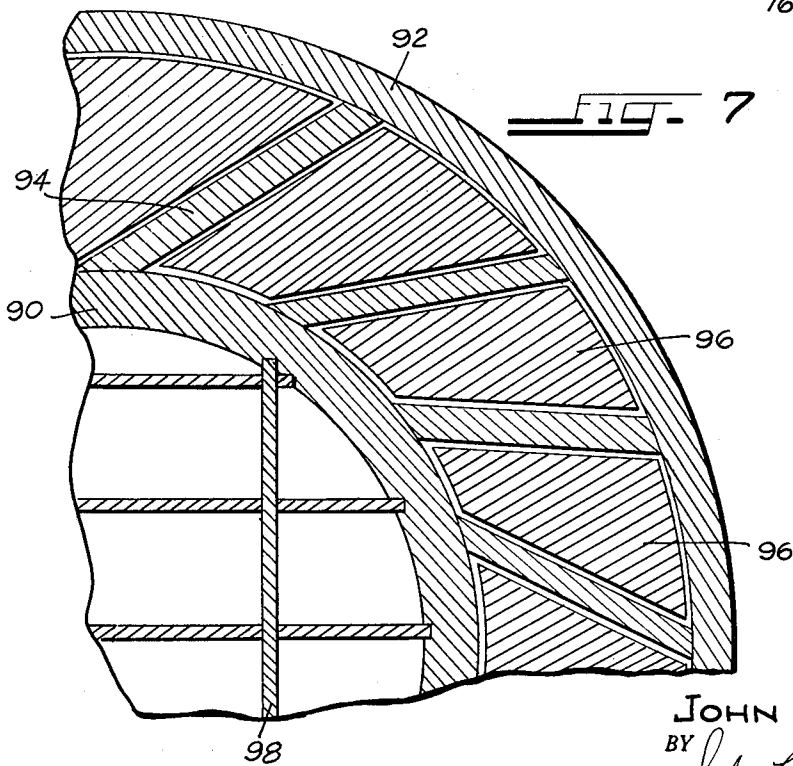
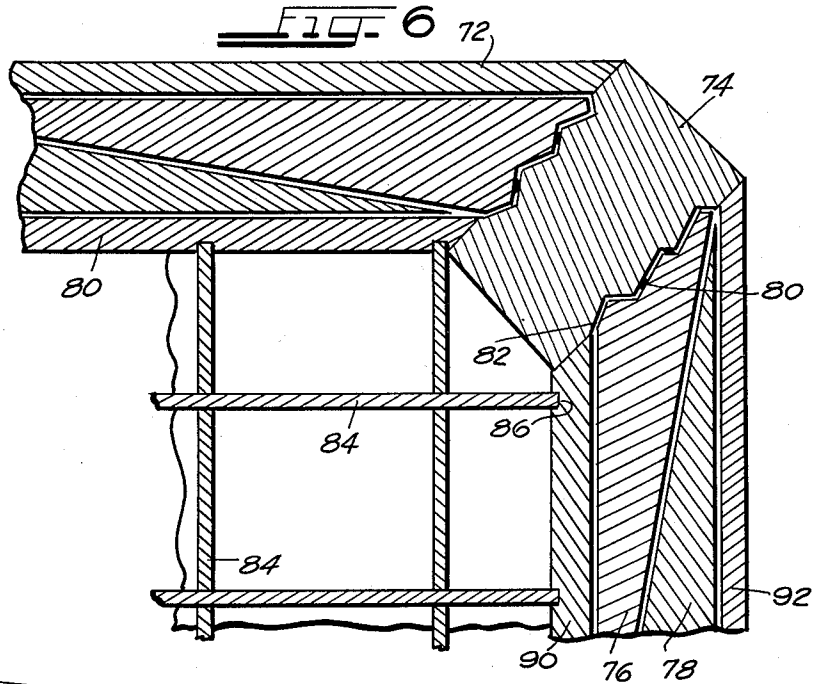
Jan. 28, 1964

J. W. ALLEN
CONTAINER FOR TRANSPORTING THERMALLY
HOT INTENSELY RADIOACTIVE MATERIAL

3,119,933

Filed May 3, 1960

4 Sheets-Sheet 3



INVENTOR.
JOHN W. ALLEN
BY *John C. Prosser*
Att'y.

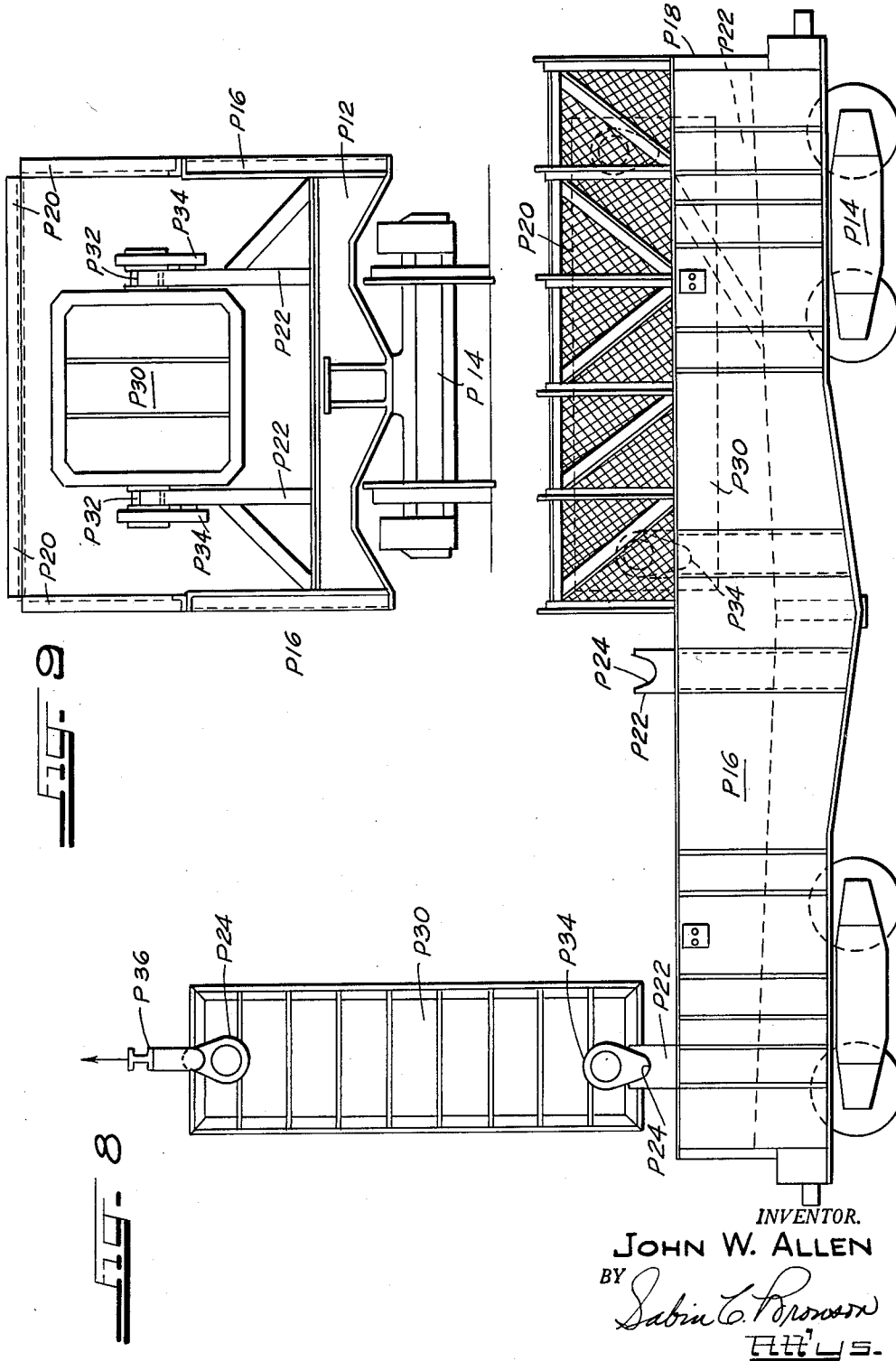
Jan. 28, 1964

J. W. ALLEN
CONTAINER FOR TRANSPORTING THERMALLY
HOT INTENSELY RADIOACTIVE MATERIAL

3,119,933

Filed May 3, 1960

4 Sheets-Sheet 4



1

3,119,933

CONTAINER FOR TRANSPORTING THERMALLY HOT INTENSELY RADIOACTIVE MATERIAL**John W. Allen, La Grange, Ill., assignor to Stanray Corporation, Chicago, Ill., a corporation of Delaware****Filed May 3, 1960, Ser. No. 26,468****6 Claims. (Cl. 250-108)**

This invention relates to containers for transporting radioactive materials, more particularly, it relates to containers of minimal dimensions and weight yet having high strength for transporting intensely radioactive materials which are exothermal and which may encounter temperatures from heat generated internally of several hundred degrees Fahrenheit during transport.

This application is a continuation in part of my co-pending United States patent application, Serial Number 783,474, filed December 29, 1958, titled "Container for Radioactive Material," John W. Allen, inventor, now abandoned.

As disclosed in the aforesaid patent application there is need for containers suitable for the shipment of intensely radioactive materials which may be exothermal and even under favorable cooling conditions may reach temperatures of several hundred degrees Fahrenheit. Such materials are, for instance, encountered as waste products in the form of spent nuclear reactor fuel elements.

It is necessary to transport intensely radio-active and highly exothermal nuclear reactor waste products over common carrier transportation lines such as truck and rail routes. These materials are carried into and through populated areas and are not infrequently left standing on sidings and in traffic where the general public could, as they pass nearby, be exposed to the hazards of radiation and thermal heat burns excepting for the protection afforded by the container in which the dangerous radioactive material is being carried. The weight and dimensions of suitable containers for transporting radio-active materials are limited by economic considerations as well as the awkwardness of manipulating and conveying immense heavy radiation shield structures. In addition to the cost and physical difficulty of conveying radio-active materials in a shielded container, the problem of the integrity of the container and the integrity of the radiation shield under the stress of differential heating of the various parts of the container and the mechanical shock attendant in loading, unloading and high speed travel across the country must be solved. The more dense, and therefore, better gamma ray radiation attenuating materials, such as lead and metal loaded concrete are generally deficient in strength and in heat conductivity; the stronger materials, such as carbon steel, aluminum alloy and copper are generally good heat conductors but not necessarily superior gamma ray radiation attenuators and are subject to severe dimensional disturbances due to large coefficients of heat expansion. Hence, a composite structure is required which will incorporate the best features of various materials for the construction of a suitable radiation shielding container, achieve a minimal weight configuration, and provide design which assures complete radiation shielding under all circumstances of stress.

Radioactive waste products resulting from the fission of uranium 235 such as are found in spent nuclear reactor fuel rods contain, for instance, over two hundred fission fragments nearly all of which are radioactive and emit beta rays, neutrons and gamma rays. A large portion of these fission fragments emit both beta and gamma rays as delayed fission gamma radiation. The proportion of neutrons emitted by these delayed fission reactions is a very small percentage of the entire radiation. Neutrons are readily captured in most environments, hence in small

2

concentrations do not constitute a penetration radiation, although their capture will in some isotopes give rise to (N, γ) reactions from which the resultant gamma radiation is highly penetrating. The energy of most of the gamma radiation from delayed fission reactions is less than 2 mev., however, a small but significant percentage is of much higher energy and therefore creates extremely penetrating radiation. The resulting beta radiation falls between 1.2 and 3 mev. Beta rays are light particles which are easily scattered and hence do not form penetrating rays; they carry considerable energy and constitute ionizing radiation which form ion pairs that in themselves are not a radiation hazard. Accordingly, shielding structures for radioactive waste such as spent nuclear reactor fuel rods need only assure absorption of the gamma rays present; the neutrons and beta particles will be substantially totally shielded by any suitable gamma shield structure. A satisfactory gamma ray shield must absorb the gamma photons from the primary source as well as inelastically scattered gamma and gamma photons emitted by nuclei in the shield as a result of interaction with neutrons in (N, γ) reactions.

The absorption of gamma ray radiation in shielding material is accomplished by photoelectric interaction, Compton effect, and by pair production. All of these mechanisms are energy dependent. The individual linear absorption coefficients of each absorption mechanism vary considerably with the energy of the incident rays; accordingly, the sum of these three absorption coefficients varies in non-linear relationship with the energy of the incident radiation. The least absorption of gamma rays in most shielding materials occurs in the vicinity of 4 mev. energy incident radiation. The various absorber materials such as might be utilized in a radiation shield each possesses a characteristic gamma ray absorption coefficient curve which is energy dependent.

Because of the considerable complexity of the many parameters which must be considered in computing the thickness of an appropriate radiation shield certain simplifying assumptions may be made to aid the designer. One of these is the relaxation length of a material; that is the approximate linear length or thickness of a shielding material required to reduce the intensity of the incident radiation (assumed to be about 4 mev. energy photons) by a factor of $1/e$ or $1/2.72$. The decrease in radiation intensity through a shield is exponential, hence no simple formula will relate the shield effectiveness to the strength of the radiation source and the dimensions and character of the shield material. The linear absorption coefficient N given in cm.^{-1} units relates the thickness, x , of a shield, for any particular energy of gamma radiation to the intensity of the radiation I_0 and the intensity of radiation I_x at x cm. through the shield by the relationship: $I_x = I_0 e^{-Nx}$. The above information and additional data relating to specific shield materials is published in numerous places in the literature, particular reference is made to "Principles of Nuclear Reactor Engineering," Samuel Glasstone, New York, 1955.

Much thermal energy is given off by radioactive material and considerable thermal heat is generated by the capture of nuclear radiation in a shield material. One specific example of the high exothermal character of radioactive waste in spent reactor fuel rods is indicated by the fact that approximately 100,000 B.t.u. per hour are emitted by a bundle of only thirty-two such fuel rods. A container in which to carry these rods must therefore dissipate this much thermal energy to maintain temperature equilibrium. Such an amount of heat compares with the heat capacity of a household furnace. Failure to dissipate the evolved thermal energy will cause an abrupt rise in temperature of the container and its contents and ultimately failure of the radiation shielding container.

3

It is therefore an object of this invention to provide a minimal dimension safe container for storing and transporting intensely radioactive and highly exothermal radioactive waste products.

It is also an object of this invention to provide a minimal weight container adapted to dissipate sizeable quantities of thermal heat and simultaneously provide radiation shielding without risk of openings in the radiation shielding structure due to thermal stresses induced by differential heating of various parts of the container.

It is still another object of this invention to provide a container which is extremely rugged, suitable for transporting intensely radioactive materials which will assure safe biological radiation levels about its exterior during all predictable circumstances while the container is in transport.

This and other objects and advantages of my invention will be apparent from the following description, specifications, drawings and claims.

My invention comprises, briefly, a minimum dimension container adapted for transporting intensely radioactive, highly exothermic material comprising an inner and an outer shell in spaced relationship, webbed sections therebetween, the shells and web being made of high strength material with high coefficient of heat conductivity, high density radiation shielding material positioned in the voids between the shells, whereby the radiation shielding integrity of the container is preserved regardless of the temperature of the component parts of the container, the heat being removed from the interior of the inner shell by conduction through the webs to the outer surface of the outer shell where it is dissipated, and the radiation being attenuated by passing transversely through the high density shielding material members or longitudinally through the web sections.

My invention is described and illustrated by the following drawings and specifications:

FIGURE 1 is a partly cut-away perspective view of a preferred embodiment of my invention;

FIGURE 2 is a transverse cross sectional view of the embodiment shown in FIGURE 1;

FIGURE 3 is a longitudinal cross sectional view of the embodiment shown in FIGURES 1 and 2;

FIGURE 4 is a fragmentary view showing certain structural details of the embodiment illustrated in FIGURE 1;

FIGURE 5 is a perspective cut-away view of a second embodiment of my invention;

FIGURE 6 is a fragmentary cross sectional view of a specific embodiment of my invention very similar to that illustrated in FIGURES 1, 2 and 3;

FIGURE 7 is a fragmentary cross sectional view of another specific embodiment of my invention;

FIGURES 8 and 9 are drawings copied in detail from the original parent patent application, Serial No. 783,474, now abandoned, therein designated FIGURES 1 and 2, which illustrate the suspension means for loading and hauling a typical container in a railway car such as is illustrated in FIGURE 1 of this application. The reference numerals have been changed by the addition of the prefix P to avoid confusion with the reference numerals in the present application.

Referring now to the drawings, an inner shell 10 made of a rigid material having a high coefficient of thermal conductivity such as iron or aluminum, is fitted internally with a cellular structure 12 comprised of support bars 14. The support bars 14 may be conveniently made of any good thermal conductive metal such as copper. Radioactive material may be placed within the openings between the support bars; such a structure is particularly convenient when radioactive fuel rods are being shipped wherein each assembly of fuel rods may be inserted within a cell 12. The support bars 14 conduct thermal heat to the sides 16, 18 of the shell 10, and in turn the support

4

bars 14 are mounted in slots 20 provided on the inner surfaces of the side walls 16 and 18.

The inner shell 10 is supported by a plurality of heavy webs 22 designed to provide both mechanical support and to conduct thermal energy from the side walls 16 and 18 outward toward the outer shell 24. The outer shell is comprised of a strong metallic material preferably carbon steel clad with stainless steel having good structural properties and high coefficient of heat conductivity and emissivity so that thermal energy may be dissipated by radiation into the surrounding air. The thickness of the sides 26, 28 of the outer shell need not be nearly so large from the standpoint of thermal heat transfer as the walls of the inner shell sides 16 and 18 or the webs 22.

The webs 22, as shown in the embodiment illustrated in FIGURES 1 through 4, are positioned diagonally on the edges of the rectangular inner and outer shells 10 and 24 respectively. The various sections of the inner and outer shells and the webs may be joined by heavy weldments; it is important that the junctions of the various structural members be smoothly juxtaposed and preferably metallurgically bonded to obtain the maximum heat transfer efficiency.

Between the inner and outer shells there are openings 30 into which radiation shielding material such as lead blocks 32, 34 may be inserted. These blocks are tapered and cut diagonally at 36 to provide complementary halves as shown in the drawings so that when the steel or rigid shell structures expand due to thermal heating there will be no openings created in the radiation shielding. The blocks 32, 34 are fastened at their thicker ends 32a and 34a to the webs 22. Upon expansion due to heating the lead blocks move with respect to one another along the diagonal cut 36, thus assuring that no radiation leakage path may be inadvertently opened between the steel shells and webs and the lead absorber blocks.

The relative proportions of the webs, the inner shell wall thicknesses, the outer shell wall thicknesses and the spacing between the shells must be determined in each instance to satisfy simultaneously the thermal heat transfer conditions and the radiation attenuation conditions. The radiation attenuation longitudinally through the web section must be sufficient to prevent excessive radiation leakage, and therefore, for any given material selected for the web and thermal heat transfer medium a minimum length of the web is determined. A wide variety of materials having different properties are available with which various combinations permit designs of reasonable weight and dimensions. Table I below tabulates the parameters for some preferred materials.

Table I

Material	Gamma Absorption Coefficient for Shielding Design (cm. ⁻¹) for 1.4 mev. Gammas	Coefficient of Thermal Conductivity, B.t.u./hr. ft. °F. at 400° F.	Density, cm. ³ /g.
Iron.....	.39	26	7.8
Stainless Steel 18-8.....	.39	10.0	7.8
Lead.....	.63	18	11.3
Concrete.....	.12	0.5	2.3
Tungsten.....	0.96	83	19.3
Aluminum.....	0.12	124	2.7
Water.....	0.06	0.4	1.00
Copper.....	0.42	215	8.9

Openings must be provided in the container to drain any moisture which collects therein and to provide a means for ventilating. It is convenient to charge the loaded container with helium gas which provides a much better heat transfer medium than air between the radioactive material and the walls 16 and 18 of the inner shell 10. These openings 46 for the drain, and 48 and 50 for purging with helium must be circuitous so that no direct

unobstructed radiation path is provided in the container. Threaded removable plugs 46a, 48a and 50a are positioned in the respective openings.

The ends of the container are sealed by a removable cover 38 on one end and a fixed end 40 at the other end. If the end enclosures 38 and 40 are made of the same material as the webs they may conveniently be made as thick as the length of the web sections. The removable cover 38 must be provided with a recessed seating surface 42 and carefully fitted contour 44 so that the closure of the cover on the container will be tight and not permit openings for the leakage of dangerous radiation. The cover may be secured by means of bolts 38a.

The container is provided with trunnions 52, two on either side, to facilitate positioning on a frame or cradle which may be mounted on a railway car. It is necessary to suspend the loaded container so that air freely passes about all outer surfaces of the container to conduct away the considerable quantity of heat emitted by the radioactive contents.

FIGURES 8 and 9 illustrate the cradle and positioning within a railway car appropriate to carry the container disclosed herein. A suitable railway car is shown at P10. It is of the gondola car type with a drop center floor structure P12 consisting of longitudinal stringers and cross members as usual, but much heavier due to the unusual load requirements. The car is supported upon wheel axle truck assemblies indicated at P14 for operation upon railroad track. Car sides and ends are indicated at P16 and P18 respectively. Extending upwardly and over the car is a two section removable guard screen P20, but one of such sections being shown for convenience of illustration. This guard screen surrounds the containers when in the car and protects the public and railroad personnel from the heat being dissipated therefrom. Rising from the floor of the car are four pairs of frame-like saddles P22; two pairs being located adjacent the ends of the car, and the other two pairs adjacent the transverse center of the car. Said saddles are spaced transversely of the car a distance approximating the width of the containers as clearly seen in FIGURE 9. The upper extremities of each pair of saddles are formed into upwardly facing semi-circular cradle seats P24 which are axially aligned transversely of the car. The saddles at one end of the container are pivotally mounted to allow for temperature expansion of the containers.

The containers themselves are indicated generally at P30, and as before stated are substantially square in cross section and in length about half the length of the car P10, so that two such containers may be conveniently carried thereon. At opposite sides of each container, near each end, is provided a laterally extending trunnion having two journal portions, the inner portions P32 for seating within the cradles P24. Upon the outer journal portion of each trunnion P32 is pivotally mounted a lift and tie-down lug P34 by means of which the containers may be secured to the car or lifted therefrom by means of a crane lift indicated at P36.

A second preferred embodiment of my invention is illustrated in FIGURE 5 which shows a cut-away perspective view of a circular cylindrical container comprising a circular cylindrical inner shell 54, an outer cylindrical shell 56 and a plurality of webs 58 mounted to suspend the inner shell within the outer shell. By providing a greater number of webs a greater heat transfer between the inner shell and outer shell is achieved however less radiation attenuation shielding may be obtained through the webs than through the radiation shielding blocks 62 positioned in the space 60 between the shells 54 and 56. By the use, for the webs 58, of a metal containing a high percentage of tungsten which has a large coefficient of gamma ray absorption the size of the cylindrical container may be made small and serve its purpose of providing both radiation attenuation and means for thermal cooling.

A specific design is described below:

FIGURES 6 and 7 illustrate specific embodiments which have successfully utilized the broader concept of my invention. Twelve assemblies of a particular nuclear reactor fuel rod, removed after extensive use within the reactor, emit both gamma and beta radiation which produces an intensity of 4.15×10^5 roentgens per hour on the inside surface of the container. At the same time the twelve assemblies produce 73,000 B.t.u. per hour which must be dissipated through the outer shell of the container. The fuel rods are 11 feet 2 inches long, the interior of the container 12 feet 2 inches long.

Referring now to FIGURE 6, the inner shell 70, the outer shell 72 and the web 74 are made of carbon steel. The web has mean transverse dimensions of 18 cm. and as shown in the cross sectional view is 44 cm. long. Both the inner and outer shells are $4\frac{1}{2}$ cm. thick. The two shells are separated by a distance of $21\frac{1}{2}$ cm. into which tapered lead blocks 76 and 78 have been inserted. The thicker portion of the lead block 76 is fastened at 80 to a corrugated surface 82 of the web 74. Copper support bars 84 are mounted in slots 86 which have been provided within the inner shell 70. The center lines of the copper bars are positioned 16 cm. apart on both sides of the squares wherein the fuel assemblies, each comprising twenty five fuel rods, are conveniently positioned. The dimensions of the outer shell between the inner section thereof with the web and the center line of the container is 47 cm. By use of the materials in the configuration described the temperature along the center line between the inner wall of the inner shell and the outer surface of the outer shell is approximately 250° F. The maximum radiation intensity about any point on the surface of the outer shell is 5.5 milliroentgens per hour.

FIGURE 7 illustrates a cylindrical cask which utilizes the principle of my invention. It is adapted to hold twelve assemblies of twenty five fuel rods each having the heat and radiation properties as specified above in connection with the charge for which the embodiment of FIGURE 6 was designed. The inner shell 90, the outer shell 92 and the webs 94 are made of carbon steel. The inner shell radius is $30\frac{1}{2}$ cm. Both the inner and outer shell thicknesses are 4 cm.; and the separation between the inner shell and outer shell is 25 cm. The webs 94 are $2\frac{1}{2}$ cm. thick, extend longitudinally the full length of the cask and are 38 cm. long. There are twelve webs positioned between the inner and outer shell through which thermal energy is conducted from the inner shell to the outer shell. These webs are positioned at approximately a 45° angle to the radius. Lead absorber blocks 96 are positioned between the inner and outer shells and between each of the webs. The positioning of the webs in non-radial orientation assures that the radiation must pass through a substantial portion of one or more of the lead blocks before it reaches the outer shell, and thus attenuation is assured. Copper support bars 98 are positioned to form squares 16 cm. on the side within the inner shell.

The radiation dosage rate at the outer surface of the outer shell does not exceed 5.5 milliroentgens per hour. The temperature difference between the inner shell and the outer surface of the outer shell along any radius will not exceed 46° F.

The foregoing description, specifications and drawings are merely illustrative of my invention, the scope of which is limited only by the following claims.

I claim:

1. A minimum dimension container for transporting intensely radioactive highly exothermic material comprising an inner and an outer shell in spaced relationship, spaced diagonally disposed web sections therebetween, the shells and web sections being made of high strength material having high coefficient of heat conductivity and lesser nuclear radiation absorption coefficient, material having high nuclear radiation absorption coefficient positioned within the voids between the shells and between

adjacent web sections, the width of the webs being related inversely to the radiation absorption coefficient of the web material such that the radiation attenuation through the shells and interconnecting webs is equal to that through the shells and the absorber material whereby heat is removed from radioactive material positioned within the inner shell by conduction through the webs and radiation is attenuated by the radiation absorber material in the space between the shells.

2. A minimum dimension container for transporting thermally hot high intensity radioactive material comprising an inner shell of a high modulus of elasticity and high coefficient of thermal conductivity material with intermediate gamma ray capture cross section, an outer shell of material similar in properties to the inner shell in spaced relationship thereto, spaced diagonally disposed web sections positioned between the inner and outer shells, the concentric shells in combination with the web sections comprising a means for conductively transporting thermal heat from the interior of the inner shell to the exterior of the outer shell, complementary tapered sections of high coefficient of gamma ray capture cross section material positioned in the voids between the inner and outer shells and between adjacent web sections mounted to the web sections at the thicker ends of the taper sections whereby heat is removed from the inner shell and transported to the outer shell for dissipation through the web sections, nuclear radiations are mainly absorbed by the high density material in the void between the shells, and by passage longitudinally through the web sections, and whereby thermal expansion of the shells and the resulting relative movement of the webs slides the dense shielding sections with respect to one another transversely of the direct radiation path thereby assuring integrity of the radiation shield regardless of the thermal temperature of the various parts of the container.

3. A minimum dimension container for transporting intensely radioactive, highly exothermic material comprising an inner and outer shell in spaced relationship, radial web sections therebetween, the shells and web being made of high strength material with high coefficient of heat conductivity, complementary tapered members of high density nuclear radiation shielding material positioned in the voids between the shells, the tapered surfaces being juxtaposed and the thicker ends of the high density members attached to the web sections, whereby the radiation shielding integrity of the container is preserved regardless

of temperature of the component parts of the container, heat is removed from the interior of the inner shell by conduction through the webs to the outer surface of the outer shell where it is dissipated, and the radiation is attenuated by passing through the high density shielding material or longitudinally through the web sections.

4. A container for transporting intensely radioactive highly exothermic material comprising an inner and outer shell in spaced relationship, spaced diagonally disposed web sections therebetween, the shells and web sections being made of high strength material having high coefficient of heat conductivity and lesser nuclear radiation absorption coefficient, material having high nuclear radiation absorption coefficient positioned within the voids between the shells and between adjacent web sections, the webs being substantially wider than the radial distance of spacing between the shells such that the webs are positioned at an angle to the radial plane between the shells whereby heat is removed from the radioactive material positioned within the inner shell by conduction through the webs and nuclear radiation is attenuated by the radiation absorber material in the space between the shells.

5. A container for radioactive material comprising a metallic inside shell and a metallic outside shell spaced from said inside shell, solid metallic webs connecting said inside and outside shells, the webs being substantially wider than the distance between the shells, blocks of a more dense material than that of the shells filling the space between the shells and between adjacent webs, said blocks being diagonally cut to provide complementary halves so that upon expansion, due to heating, said blocks move with respect to one another along the diagonal cut, thus maintaining radiation shielding.

6. A container as in claim 5 with four trunnions located on opposite sides near the ends for supporting the container in endless and permanent rotating lugs on the trunnions to act as lifting lugs and also as hold-down lugs when resting on the support saddles.

References Cited in the file of this patent

UNITED STATES PATENTS

2,419,346	Ellis	Apr. 22, 1947
2,580,249	Seeley	Dec. 25, 1951
2,684,447	Gilks	July 20, 1954
2,843,754	Costello	July 15, 1958
3,005,105	Lusk	Oct. 17, 1960