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HOT PRESSING TO FORM CANNED URANIUM SLUGS

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Fig. 1

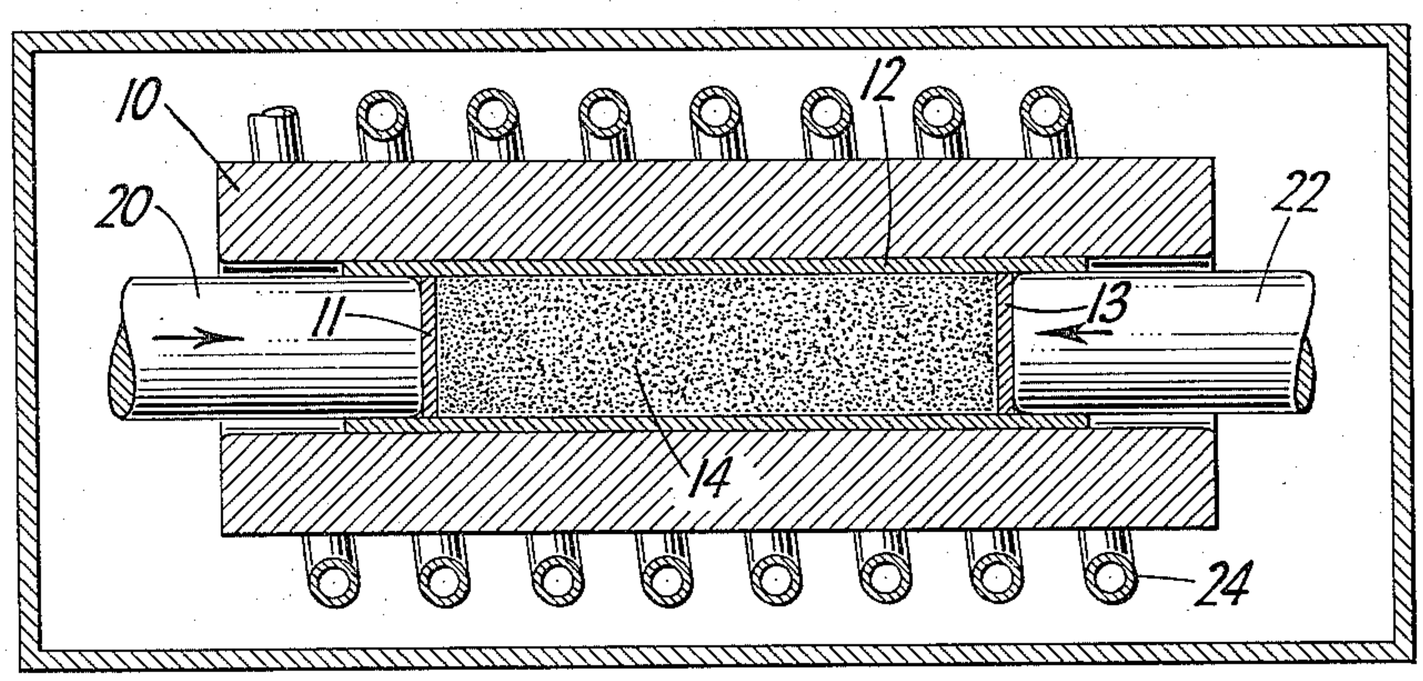


Fig. 2

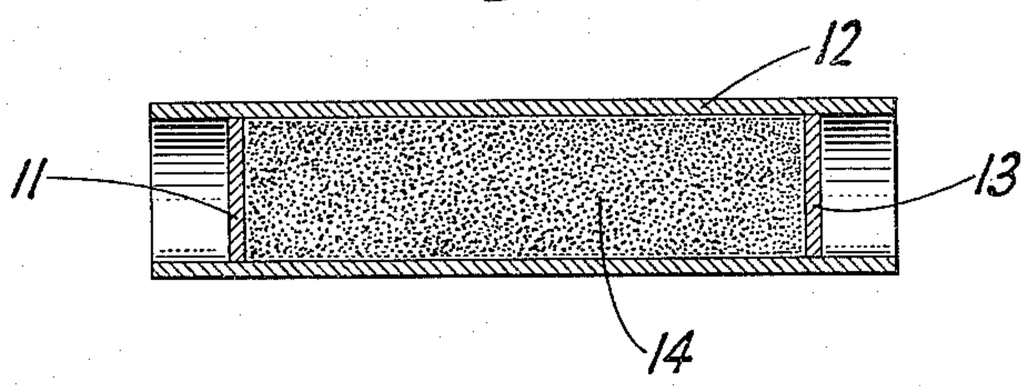
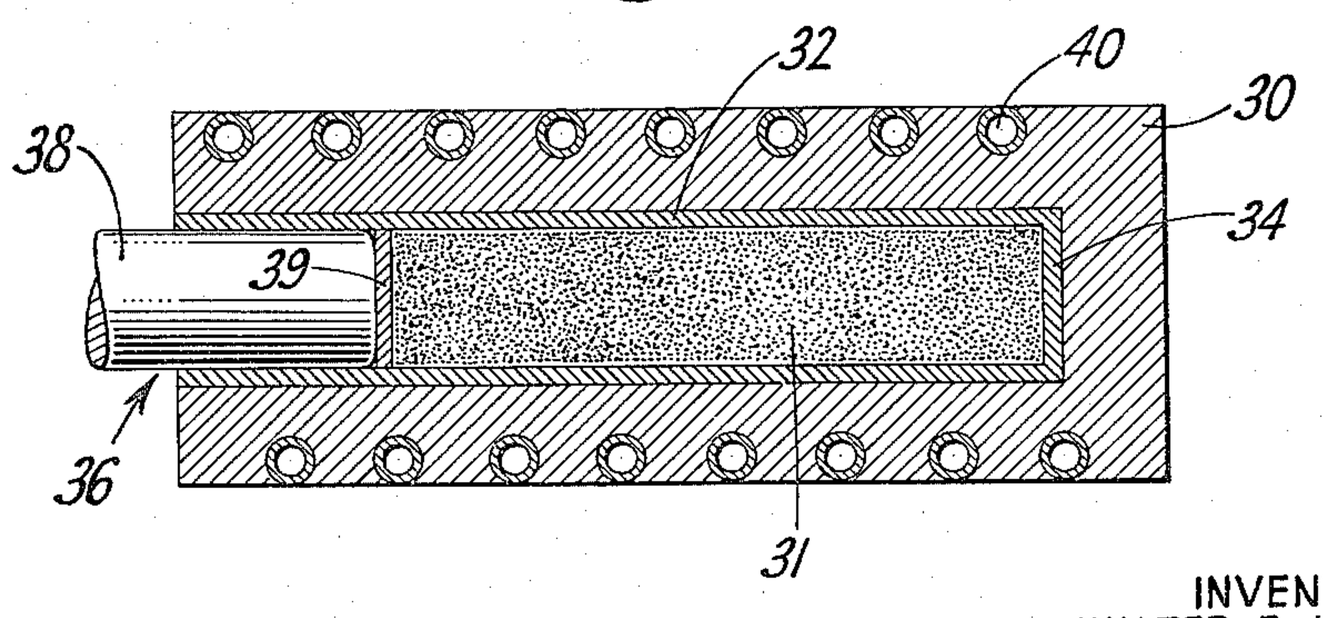


Fig. 3



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HOT PRESSING TO FORM CANNED URANIUM SLUGS

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This invention relates to a method of and apparatus for simultaneously preparing and canning metallic slugs or billets. Mor particularly, it relates to a method and apparatus for preparing canned billets or slugs of metals such as uranium, thorium, protectinium, plutonium, beryllium and zirconium.

In accordance with prior practice, the metal such as uranium which is to be canned is first melted, then cast into ingots which are subsequently hot and cold rolled or extruded to form billets. These billets are then cut up into desired lengths, in preparation for canning. Prior to canning, the cut billets are dipped in a low melting point solder, or alloy whose purpose is to promote good bonding between the uranium slug and the enclosing aluminum can and to prevent rapid diffusion of the uranium through the aluminum can. The billet is then sealed in an aluminum can.

This process as presently practiced, is costly. It also requires involved techniques and becomes complicated because of the rigid controls if satisfactory results are to be obtained. Furthermore, due to the fact that the cast ingots are hot and cold rolled and extruded, the crystalline structure of the material takes on a preferred orientation as well as a tendency toward excessive grain growth. Both of these factors are believed to contribute to dimensional instability when the billets are subjected to certain physical conditions such as thermal cycling, neutron bombardment, etc.

It is, therefore, an object of this invention to improve the technique of preparing canned billets or slugs in such manner as to make the process more economical as well as to improve the product obtained.

It is a further object of this invention to develop a method of preparing canned billets or slugs of metal whose dimensions and metallurgical structure under thermal cycling and radiation will be stable.

It is a further object of this invention to develop a method of preparing billets or slugs of metal approaching theoretical density having small grain size and exhibiting a random orientation of particles.

It has been found that these objects and other advantages can be obtained by compacting and pressing powdered uranium, zirconium, thorium, protactinium, plutonium, beryllium, or their hydrides under controlled temperature conditions.

In the drawings which illustrate a preferred embodiment of apparatus suitable for carrying out the invention,

FIGURE 1 is a schematic drawing of an apparatus showing the die body, the metal from which the can is formed, the powdered material under compression, rams for applying pressure, heating means, and means for maintaining vacuum or other atmosphere around the object.

FIGURE 2 is an elevation of a sintered canned slug as produced with apparatus of the type shown in FIGURE 1 when operating in accordance with this invention.

FIGURE 3 is an elevation partly in section of a modified apparatus in which pressure in brought to bear by means of a single pressure ram.

In the drawings illustrating a suitable apparatus for

carrying out preferred embodiments of this invention in which powdered material can be compressed and heated **10** represents an externally heated die. The die **10** is so designed that a casing or can **12** will form a close fit within the cylindrical aperture of the main body of the die. The powder **14** is shown compacted therein between end caps **11** and **13** of the same material as the casing. The compacted powdered particles **14** are thereby wholly enclosed within the cylindrical casing **12** and the end caps **11** and **13**. Pressure rams **20** and **22** are so designed as to slide snugly within the casing **12** and are adapted for compacting powdered particles within the casing **12** as well as for exerting the necessary pressures on the powdered particles **14** through end caps **11** and **13** at sintering conditions.

A water cooled induction coil **24** surrounding the die **10** is shown in the drawing as a means of supplying heat to both the material being compacted and/or sintered and the enclosing metal casing. Any other heating means designed to provide sufficient heat within the area of the compacted powdered metal to permit sintering of the particles would of course be satisfactory. This means need not necessarily be limited to either electric or electronic means.

In FIGURE 3 of the drawings a modified apparatus is shown in which the die **30** is cup shaped. In this embodiment, the metal casing **32** for the powder, instead of being an open ended cylinder, is provided with a bottom **34** and is only open at one end **36**. A single pressure ram **38** designed to fit snugly within the cylindrical wall of the metal casing **32** is adapted to cooperate with the die member **30** in bringing pressure to bear on powdered particles **31** within casing **32** through cap member **39** which is made of the same metal as casing **32**. A heating means consisting of electrical resistance elements **40** is shown as being imbedded in the die **30**.

In operation, the casing **12** is placed in the main body of the die, and the bottom ram **20** on the top of which is placed cap member **11** is slid into the bottom end of the casing **12**. The proper amount of powder is then poured into the casing **12** within the die and leveled off. The top cap member **13** is then placed on the powder and the top ram **22** slid down inside the casing, making contact with the top cap **13**. In those cases in which atmospheric conditions, other than those normally encountered, are desired, these conditions are established. After this the powdered particles may, if desired, be first compacted by means of pressure exerted, by the cooperative action of the rams **20** and **22** and die **10** and then heated at desired pressures by heating the compacted powdered particles with the aid of the water cooled induction coil **40** or other suitable means while maintaining the powdered metal under the desired pressure by means of pressure rams **20** and **22**. The compacting and heating operation may of course be carried out substantially simultaneously.

During the hot pressing operation or after the completion of the application of pressure, it is possible to fuse the cap ends **11** and **13** to the casing material **12** and thus form a clug of compressed canned sintered material, such as shown in FIGURE 2 of the drawings.

The hot pressing method herein above described has broad application in the production of many compressed powdered materials, as for example in the production of multilayer billets which can be drawn into coated or Dumet type wires. It is particularly advantageous for the production of canned uranium, thorium, plutonium, zirconium, protactinium, or beryllium billets and slugs.

When this process is applied to the manufacture of canned uranium slugs, powdered uranium or uranium hydride powder or alloy powders of uranium (to which may be added if desired other elements or compounds

such as the grain growth inhibitors, thorium oxide, zirconium oxide, aluminum oxide, beryllium oxide, or silicon dioxide) are introduced into the main body of the die and into the casing 12 in a desired amount, whereupon the powder is leveled off and a cap is placed thereover. After the top plunger has slid down inside the casing to make contact with the top cap, the pressing operation is carried out simultaneously with a heating operation. It should be understood that during this operation the die may be maintained at an optimum temperature or heat may be applied during the pressing and sintering operation. This operation may be carried out in a vacuum or a protective atmosphere of argon, helium, or other gas, and this atmosphere may be established prior to or during the pressing operation by enclosing the die body within a chamber in which the desired atmospheric conditions are maintained. The canned powder is heated to the proper temperature either by the high frequency means illustrated or by other conventional methods suitable for accomplishing a similar purpose. After or during the attainment of the optimum temperature of operation, the correct pressure and time relationship is established to give the optimum density and other physical properties such as grain size, orientation, etc., and to achieve adequate sealing of the end caps to the casing as well as the desired bonding between the body and the casing. While pressures of the order of 100 t.s.i. may be used densities approaching theoretical have been obtained at pressures of the order of 30 t.s.i. for about one minute.

To achieve random orientation and small grain size of particles which will give dimensional stability under irradiation to the product, it is essential to carry out the hot pressing operation at a temperature within the alpha phase of the uranium particles, advantageously at a temperature of 450° to 660° C., preferably at about 600° C. At these temperatures, the fine grain size and optimum degree of randomness of grain orientation can be maintained; strain hardening is avoided and density approaching theoretical density can be reached. Since the sintering and hot pressing are done at temperatures above that at which strain hardening can take place in the alpha phase, there will be no cold working and thus there will be no major internal stresses which would tend to deform the shapes during use. The original randomness of orientation of the metal or alloy particles will be retained by the grains formed from these particles during sintering in the alpha phase.

In the case of plutonium, in order to achieve high density with random orientation and small grain size of particles, it is essential to carry out this operation at a temperature within the alpha phase of the plutonium particles, that is, at a temperature of about 75° C. to about 114° C., preferably at about 110° C.

It is of course understandable that the canning process herein described may be used in carrying out operations requiring higher temperatures when it may be desirable, for example, to hot press the particles in either the beta or gamma phase.

When canning slugs of thorium, beryllium, and zirconium it is practical to hot press and can at temperatures of at least 1000° C., and with protactinium, at about 300° C. or above. Useful materials for the casing to envelop these metals may be selected from a variety of metals and alloys such as, for example, aluminum, copper, brass, titanium, beryllium and zirconium. The casing metal will be selected so that it does not melt under the conditions used, and is different from the metal of the slug.

The casing or can in which the metallic particles are to be enclosed may be made of any suitable metal which will achieve the results desired. In those cases in which the method of this invention is to be used for canning uranium it has been found preferable to make use of a metal or alloy having high corrosion resistance and/or good bonding properties such as aluminum, zirconium, or beryllium. In the preferred embodiment of this invention described herein, aluminum is referred to as the casing material. When aluminum is so used in forming the canned sintered slug of uranium it has been found that a certain alloying takes place between the aluminum casing and the uranium sintered body which gives a tenacious alloy type bond with good thermal conductive properties. This eliminates the need for any bonding agents and furthermore assures for the most effective use of the space within the can and the maximum amount of the sintered uranium body. The aluminum end caps are likewise alloyed to the uranium body and also to the aluminum casing, thereby forming the protective covering desired. If such an alloy bond is not deemed to be adequate or desirable, it is, of course, understood that the casing and end caps can be coated with special materials or alloys on the inside in order to achieve maximum protection. Thus, it would be possible to lead coat the inside of the aluminum casing and end caps or use other methods of furnishing additional protection.

When preparing canned uranium slugs in accordance with this invention, such slugs will be found to have good dimensional stability, excellent protective coating, fine grain size, and optimum randomness of grain orientation. Furthermore, it is believed that this method will be considerably more economical than any process involving casting of uranium, hot rolling, annealing, grinding, canning, etc., as is now commonly done in the preparation of fuel elements for nuclear reactors. Detailed information concerning the operation of nuclear reactors is given in an application of Fermi and Szilard, Serial Number 568,904 now United States Letters Patent No. 2,708,656, issued December 19, 1944.

When preparing canned slugs or shapes in accordance with this invention, it will be found that there will be a saving of metal, sometimes precious, since this invention assures virtually 100% usage of the metal. It will also be found that the material has been formed into the exact configuration desired. This is in contrast to other methods of forming these slugs or shapes which involve the steps of semi-precision casting of ingots, with melting and cropping losses; subsequent extrusion or rolling, with cropping losses; and subsequent machining to size, with inherent machining losses. The prior methods of forming the slugs and shapes are also limited in the economical production of unusual configurations.

When preparing canned slugs in accordance with this invention, it will be found that an excellent heat transfer interface has been readily formed between the case and the core, eliminating the necessity for special bonding materials and laborious bonding procedures which are currently used to ensure the existence of a good heat transfer interface. This new method jackets and forms a good interface in one operation, without the use of added materials, whereas other methods require extra materials and steps to form a bond between the core and the jacket.

It is to be understood that if it is desirable to obtain a slug of uranium or plutonium without the protective metallic can, it will be possible to make such slug by the same technique, thus obtaining all the advantages outlined above which are not in part attributable to the protective metallic coating. In this case, the powder would be pressed in the main body of the die under controlled temperature conditions so that a fine grain size and optimum degree of randomness of grain orientation is obtained. The technique used is one of hot pressing which is advantageously done at a temperature above that at which strain hardening can take place in the alpha phase, the preferred temperature for uranium, as indicated previously, being in the neighborhood of 600° C. and for plutonium being about 110° C.

While the above description and drawings submitted herewith disclose preferred and practical embodiments of the method and apparatus of this invention it will

be understood that the specific details of construction and arrangement of parts as shown and described are by way of illustration and are not to be construed as limiting the scope of the invention.

What is claimed is:

1. In the method of preparing uranium slugs having a density approaching theoretical density, small grain size and random orientation of particles, the steps comprising introducing powdered uranium into a die and subjecting the powdered material to pressures of 30 to 100 t.s.i. while maintaining the material at a temperature within the range of 450° to 660° C.

2. In the method of preparing uranium slugs having a density approaching theoretical density, small grain size and random orientation of particles, the steps comprising introducing powdered uranium into a die and subjecting the powdered material to a pressure of the order of 30 t.s.i. while maintaining the materials at a temperature within the range of 450° to 660° C. for a period of approximately 1 minute.

3. In the method of preparing canned uranium slugs the steps comprising introducing an open ended can into a snugly fitting die, introducing a measured quantity of powdered uranium material into said can, placing a metallic disc thereupon, and subjecting the powdered particles to a pressure above 30 t.s.i. while maintaining the material at a temperature of 450° to 660° C.

4. In the method of preparing canned uranium slugs the steps comprising introducing a metal sleeve into a die, inserting a disc of metal which snugly fits into said sleeve, and resting on a ram projecting into said sleeve,

introducing a measured quantity of powdered uranium material into said sleeve, placing a metallic disc thereover, and subjecting the powdered particles to a pressure above 30 t.s.i. while maintaining the material at a temperature of 450° to 660° C.

5. In the method of preparing canned uranium slugs the steps comprising introducing a zirconium sleeve into a die, inserting a disc of zirconium which snugly fits into said sleeve and rests on a ram projecting into said sleeve, introducing powdered uranium material into said sleeve, placing a zirconium disc thereover, and subjecting the powdered particles to a pressure above 30 t.s.i. while maintaining the material at a temperature of 450° to 660° C.

6. In the method of preparing canned uranium slugs the steps comprising introducing a metal sleeve into a die inserting a disc of metal which snugly fits into said sleeve, and rests on a ram projecting into said sleeve, introducing powdered uranium material into said sleeve, placing a metallic disc thereover, and subjecting the powdered particles to a pressure about 30 t.s.i. while maintaining the material at a temperature of about 600° C. for a period of approximately 1 minute.

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