May 5, 1959 H. F. LARSON 2,885,287

METHOD OF FORMING ELONGATED COMPACTS

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FIG. 1.

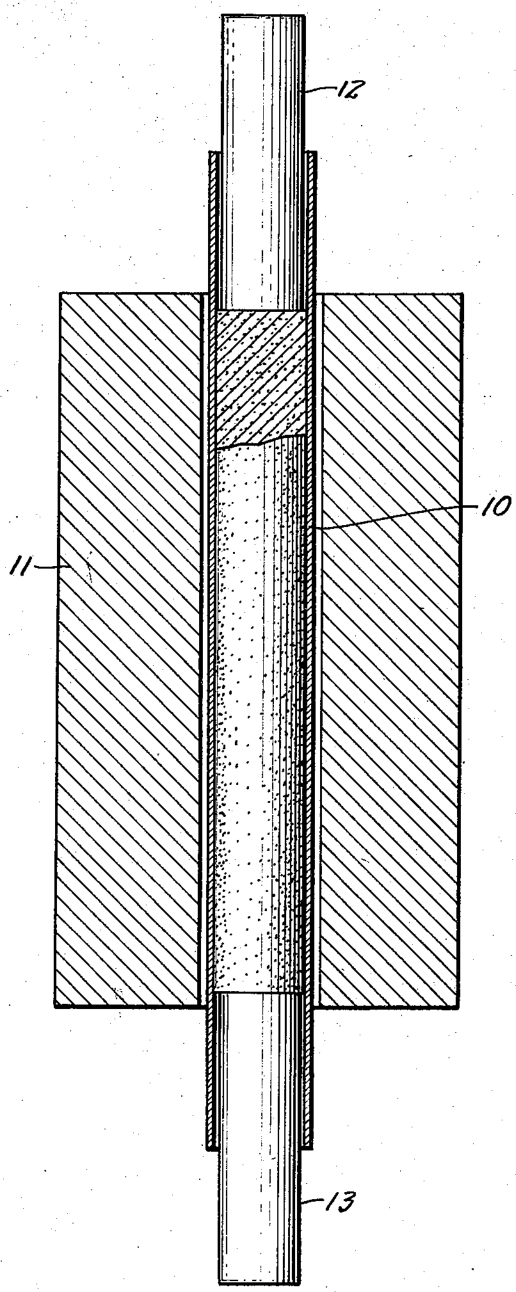

FIG. 2.

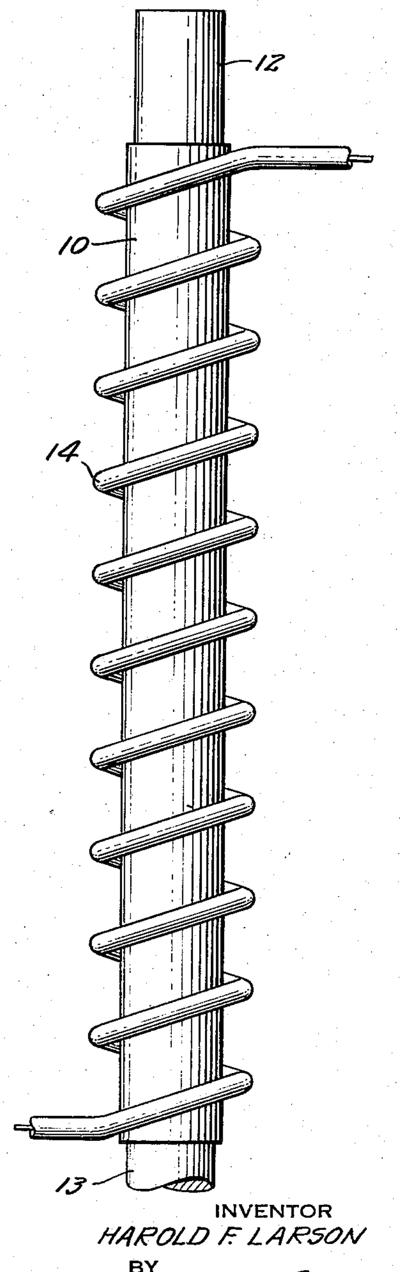

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FIG. 6.

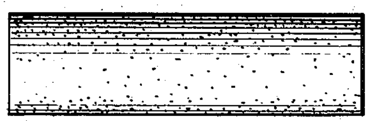

FIG. 5.

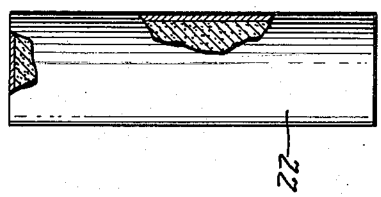

FIG. 4.

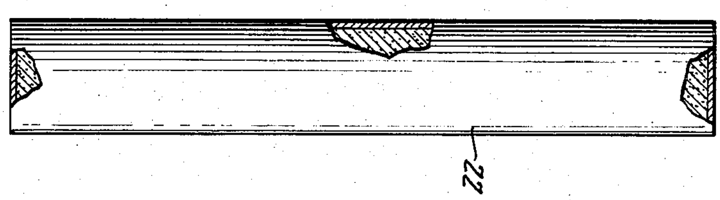

FIG. 3.

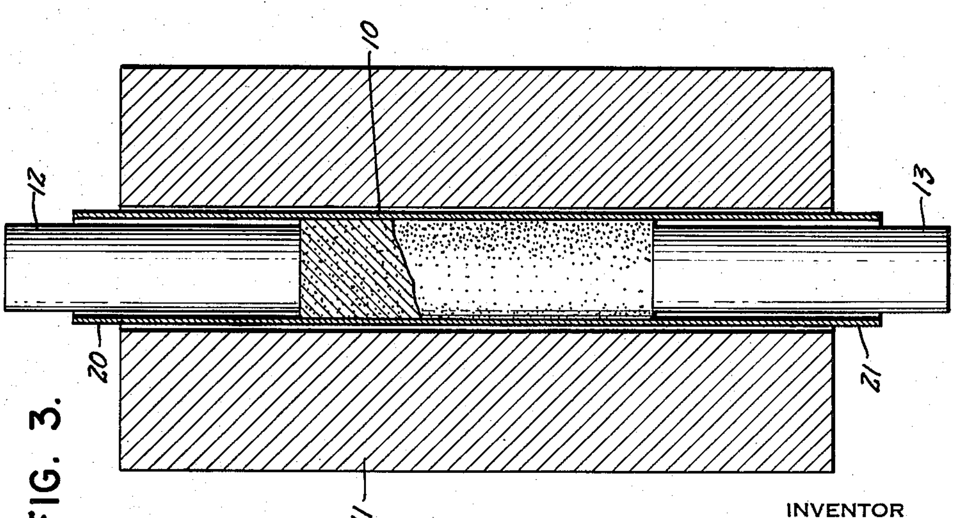

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FIG. 7.

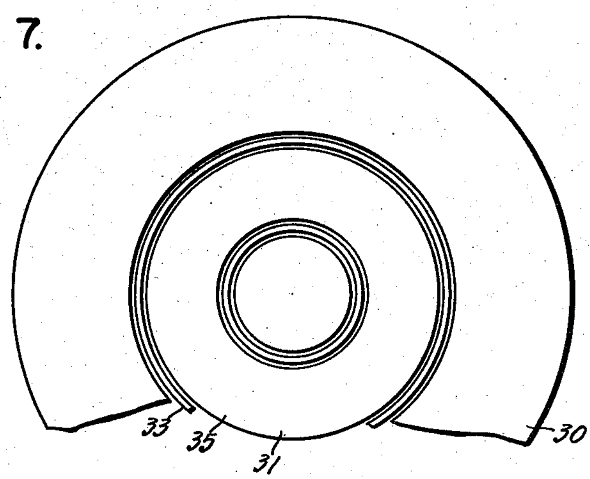
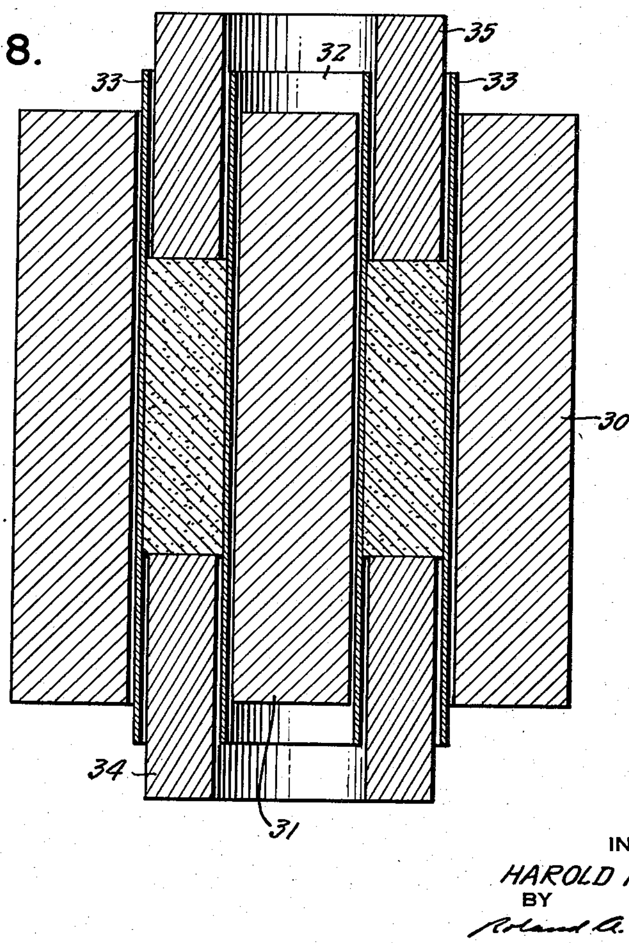


FIG. 8.



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METHOD OF FORMING ELONGATED COMPACTS

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Application July 14, 1954, Serial No. 443,451

5 Claims. (Cl. 75—226)

This invention relates to the art of preparing compacts from powdered materials and especially to a new and improved method and apparatus for forming elongated compacts of substantially uniform density. In general, however, the invention is suitable for forming homogeneous compacts as described, for cladding articles with compacted powder surfaces and for preparing compacted articles which later can be subjected to conventional die forging, coining and shaping operations. In a more limited aspect the invention is especially useful in the field of powder metallurgy wherein metal powders may be formed either with or without sintering into useful compacted articles. While for purposes of illustration, the invention is described in connection with the preparation of beryllium compacts, as an example of a metal powder, it will be apparent to those skilled in the art that the same teachings are equally applicable to other materials.

Conventional processes for forming compacts of metal powders have encountered great difficulty in forming articles of substantially uniform density when the length of the compact is greater than two diameters. As a result, recourse has been had to time consuming and expensive procedures for making elongated compacts progressively section by section. In general, this has been necessitated by the failure to provide adequate lubrication between the powder material being compressed and the confining die walls. Lack of adequate lubrication prevents powder flow at the compact surface and engenders extremely high frictional forces. In the absence of such lubrication the powder seizes the surface of the die, or die insert if such is employed, reducing the effective force acting to a fraction of the applied force and resulting in non-uniform densification of the compact. In some cases the result is a non-densification of the center portions of elongated compacts. In addition, the powder seizure leads to difficulty in removing the compact without damaging the same. Furthermore, in the preparation of many types of compacts the use of conventional high-pressure organic or inorganic lubricants cannot be considered in view of their contaminating influence on the powder being treated.

This invention, therefore, has as an object the provision of a simple and reliable method and apparatus for overcoming the above and other common disadvantages of the present practices for forming elongated compacts. In its broader sense the invention teaches the interposition of a suitably chosen metallic member between the material being compacted and the rigid die wall, such member being available for seizure by the powdered material and serving as the primary lubricant between the powdered material and die wall by itself undergoing plastic deformation during the compaction procedure. In contrast with the art wherein the compacted material is to remain within the confining member as a package, this invention is directed preferably to the manufacture of compacts wherein the formed article is to be removed from such confining member.

The invention, accordingly, has as an object the provision of an improved method and apparatus for forming elongated compacts of substantially uniform density and having a length of diameter ratio greater than two to one. Another object is the provision of an improved compacted powder article and articles having uncontaminated outer surfaces of compacted metal powder.

Another object is the provision of an improved method and apparatus for forming elongated compacts uncontaminated with lubricating material.

A further object is to provide an improved method for forming elongated compacts with reduced compacting forces resulting in lowered wear of dies and use of less expensive apparatus.

Still a further object is to provide an improved method suitable for forming an article clad with compacted powder surfaces.

An additional object is to provide an improved method suitable for forming elongated compacts in tubular form.

Other objects and advantages will become apparent to those skilled in the art when the following description is considered in conjunction with the accompanying drawing in which:

Figure 1 is a view showing the arrangement of dies and powder charge prior to compaction when using an open-ended metallic member for a lubrication function;

Figure 2 is a diagrammatic view of apparatus suitable for preheating of the powder charge illustrated in Figure 1;

Figure 3 is a view of the apparatus employed in Figure1 at the conclusion of the compaction stroke;

Figure 4 is a view of an alternate form of metallic member for the lubrication function and shown prior to compaction;

Figure 5 is a view of the alternate form of member at the conclusion of the compaction stroke;

Figure 6 is a view of the elongated compact following removal of the metallic member;

Figure 7 is a plan view of an alternate form of apparatus suitable for making elongated compacts in tubular forms; and

Figure 8 is a vertical section view of the alternate form of apparatus.

The improved technique of compacting a powder, as taught by this invention, may be appreciated by reference to Figures 1 and 3, wherein a thin metal sheath or tube **10** contains the powder and is shown mounted within a conventional die member **11**. A coating of high pressure lubricant may be applied to the outer face of the tube or to the inner face of the die to enhance relative motion of these two faces during compaction of the powder. The tube may be sealed at each end by hardened steel punches **12** and **13** actuatable by any conventional press and preferably one which may have a capacity to apply a pressure as high as 100 tons per square inch. When it is desired to preheat the powder charge, the tube and punch assembly may first be disposed within any suitable heating means, for example a dielectric water-cooled heating coil **14**, such as illustrated in Figure 2, a resistance heating means, or any other conventional metal powder heating device. After heating, the assembly may then be mounted within die **11** in this preheated condition. The invention, however, comprehends the pressing of the powder in cold, warm or hot condition, ranging from ambient temperature to as high as 1100° C. It also will be understood that the powder charge may be loaded into the tube or may be pressed within die **11** in an environment of inert gas, or other specially chosen gas, if so desired. Conventional apparatus for providing such special atmospheres during pressing operations are known and accordingly are not illustrated. Likewise, if desired, the powder may be consolidated within the tube by means of vibration or tamping prior to conducting the heating or to inserting of the loaded tube within the pressing die.

Tube **10**, which for convenience may be termed the lubricating envelope, preferably is constructed of a metallic material such as mild steel, stainless steel, brass, molybdenum or the like having the ability to undergo a relatively high degree of plastic deformation coupled with intermediate hardness at the operating temperatures. Moreover, for production of the best compacts, the material of which the tube is made must be chemically resistant to the atmosphere used during pressing, to the die and to the powder under treatment.

Furthermore, for best results in order to obtain the most efficient action of the lubricating envelope and to avoid buckling, the wall thickness should be carefully chosen. In pressing compacts of beryllium powder having a length of five diameters, I have found for example that a steel tube with 0.016 inch wall thickness with an outer diameter of about 1.25 inches is satisfactory. In general, a wall thickness of at least 5 to 8 mils should be employed for the tube used in making beryllium compacts in the order of 1 inch diameter and for such compacts in the order of 2 inch diameter the wall thickness may be from 28 to 65 mils.

As a convenient feature, the tube **10**, as shown, may be longer than the powder column it contains by at least 1½ times its diameter at each end. This allows the punches **12** and **13** to fit snugly into the tube a distance of at least ¾ of their diameter in order to give good alignment to the punches. The inner squared ends of the punches are inserted into die **11**, a distance just sufficient to guarantee a start to the pressing operation. A tap fit may be used in sealing the ends of the tube with the punches, especially if loss of material to the air is to be avoided. Otherwise, a very loose fit is workable.

With the apparatus arranged as thus described, at the start of the compacting stroke immediate densification of the powder near the punches occurs and the powder and punches move, but the tube **10** does not. Sufficient density is quickly built up with concomitant pressure on the inner surface of the tube adjacent the punches so that the powder seizes the metal surface of the tube. Application of further pressure and movement of the punches then carries the seized portion of the tube along with the powder whereupon the tube wall is upset and thickened. As shown in Figure 3 representing the apparatus at the conclusion of the compacting stroke, most of the tubing wall in contact with the punch has been thickened and the overall length of tube **10** is materially shorter. The thus deformed tube, however, does not wrinkle since the powder receiving the pressure in turn exerts an outward pressure radially upon the central portion of the tube. Despite this radial pressure which is opposed by the confining wall of die **11**, the central portion of the tube does not adhere to the die wall when a proper type of tube material is employed. For compacting beryllium powder, aluminum is unsatisfactory as a tube material since it tends to adhere to the die, does not maintain the external lubricant coating and may in fact extrude past the punch permitting the powder to penetrate the tube and score the die wall. Lead likewise would be unsatisfactory due to its ease of extrusion, as exemplified by the Gero Patent 1,685,915.

Upon conclusion of the pressing stroke the punches and upset tube **10** containing the compact are removed from die **11**, the punches are removed and the tube **10** may be slit and peeled from the compact. A typical form of compact thus manufactured is illustrated in Figure 6 and may have a length of 2 to 6 and more times its diameter while possessing substantially uniform density throughout.

It will be apparent that pressing may be conducted from one end only by applying pressure to one punch, the other punch or plug being held rigidly upon any suitable support. It also will be apparent that intermediate plugs may be employed to press upon the powder by being interposed between the powder and the main punch exerting the pressure.

In one example of the thus described invention when using pressing from one direction only, a tube was filled with −200 mesh beryllium powder separated by thin, mild steel discs and was pressed at 425° C. using a mild steel tube **10** having a wall thickness of 5 mils. As shown by Table I, the total density variation over five diameters is seen to be only about 2%, a very marked deviation from conventional practices in which the density variation of 20% may be found in compacts of not more than two diameters.

TABLE I

Compacting of −200 mesh beryllium powder variation in density along length of compact

No. of Diameters From Punch	Length of Segment, inches	Density of Segment, g./cc.
0.29	0.580	1.832
0.86	0.547	1.827
1.39	0.514	1.824
1.94	0.559	1.816
2.50	0.550	1.810
3.07	0.586	1.803
3.66	0.597	1.800
4.22	0.490	1.799
4.75	0.551	1.797
5.27	0.502	1.790

Compacting pressure=100 TSI.
Compact diameter=1″.
Pressing in one direction only.

In general, when forming articles of beryllium powder at room temperature having a length of 2 to 6 diameters, an average density of 88% of theoretical may be secured without difficulty in the practice of the invention.

As a further example of the invention, the variation in wall thickness of the lubricating member during the manufacture of compacts from beryllium powder within a type 304 stainless steel tube having a wall thickness of 35 mils may be noted in Table II. It will be observed that the finished compact has a length to diameter ratio greater than four to one.

TABLE II

Variation in diameter along length of compacts illustrating extent of tube thickening during compaction

Compact Pressed at 54 TSI and 420° C.		Compact Pressed at 76.5 TSI and 430° C.		Compact Pressed at 90 TSI and 435° C.	
Distance from end	Compact Diameter, inches	Distance from end	Compact Diameter, inches	Distance from end	Compact Diameter, inches
at one end	1.191	at one end	1.190	at one end	1.195
½″	1.174	½″	1.164	½″	1.184
1″	1.170	1″	1.162	1″	1.153
2″	1.169	1¾″	1.160	2″	1.153
3″	1.165	3″	1.159	3¼″	1.157
4″	1.164	4½″	1.160	4¼″	1.162
5″	1.167	5½″	1.164	4¾″	1.167
5½″	1.174	6″	1.175	5″	1.177
6″	1.191	6 7/16″	1.187	5¼″	1.194
at other end	----------	at other end.	----------	at other end.	----------

Compacting Die I.D. was 1.250″.
Tube was Type 304 S.S. 0.035″ wall.

The invention may be practiced without the use of the open-ended tubes by enclosing the powder within a sealed metal can or container **22** such as shown in Figure 4. Upon mounting this container within die **11** between the punches **12** and **13** and applying pressure thereto, a similar lubricating action is secured and the upsetting of the can walls occurs in the same manner as above described with the tube. At the end of the compacting stroke the can is shortened as shown in Figure 5 and after being stripped from the compact, a final product as shown in Figure 6 is produced.

Experience has shown that in carrying out the process a clearance of 0.3 to 1.0% of the radius of the die opening may be provided between the outer surface of the tube or can and the inner surface of the die wall for ease of insertion of the assembly into the die. Conventional practice wherein no lubricating member is employed is limited to clearances of between 0.05 and 0.1% of the radius of the die. Preferably, I employ a die cavity of uniform cross section with a hardened die material and with the surface ground or honed. In the following this technique wear of the expensive die is lessened and friction values between the lubricating envelope and the die wall are reduced to only about 10–20% of the friction values obtained when the powder is compacted in direct contact with such wall.

While the foregoing has described the invention in connection with the manufacture of compacts in rod-like form with a high volume to surface ratio it is apparent that compacts of other shapes may be formed following the same teaching. For example in Figures 7 and 8, apparatus for forming elongated compacts of tubular form is disclosed. In this arrangement the surrounding compacting die **30** has an inner mandrel **31** located concentrically therein and two lubricating tubes **32** and **33** are arranged concentrically adjacent the mandrel and die respectively. Tubular punches **34** and **35** project a suitable distance within said tubes and enclose the powder therein. After the compaction stroke of the punches the assembly is removed from the die and mandrel and the punches withdrawn from the upset tubes. Thereafter, the tubes are stripped from the compact leaving an elongated compact of substantially uniform density but in tubular form.

As will be apparent to those skilled in the art, the essential features of the invention can be applied in the fabrication of various other designs and shapes of articles. For example, a metallic rod to be clad with another metal can be disposed concentrically within an envelope with the powder disposed between such rod and envelope. Upon application of pressure to the rod and to the powder, the powder is compacted axially and radially, the rod of material meanwhile exerting complementary pressure upon the powder by its own deformation. Articles of uranium clad with beryllium have been formed in this manner, although the invention is in no way limited solely to these particular metals.

As a distinct practical advantage resulting from use of the described invention, it now is possible to provide fabricated articles from reactive metals such as beryllium, uranium, titanium, zirconium, molybdenum, vanadium and the like which will be uncontaminated with lubricants. The interposition of the lubricating metal envelope or shield provides a positive barrier to contact between the article under fabrication and the lubricant material adjacent the die surface.

Compacts such as above described may be formed at ambient or at elevated temperatures. The limits to the temperature used in carrying out the invention are determined by the elevated temperature properties of the material being pressed, of the lubricating envelope, and of the die materials. Such limits are reached when the powdered material becomes molten or the envelope or die materials become too weak to withstand the pressures required at the temperatures involved. The above-described relatively large clearances, made possible by this invention, are found to aid in preventing interference in the fitting of the parts, which otherwise would occur due to thermal expansion at elevated temperatures. When employing a die material, such as hardened high speed tool steel, to press beryllium powder in mild steel lubricating envelopes, pressures of up to 100 tsi may be used at die temperatures of up to 600° C. In the hot pressing technique taught by the invention, the metal envelope has also been found to provide adequate lubrication with temperatures as high as 1100° C.

While the above embodiments of my invention have been described as preferred forms, it is to be understood that the invention may take other forms all of which are intended to come within the spirit and scope of claims appended hereto.

I claim:

1. The method of forming an elongated compacted article having a length to diameter ratio greater than two from a mass of metal powder comprising, confining said powder within a thin deformable elongated container, mounting said container within a die with clearance between said container and the adjacent wall of said die to permit upsetting of said container, applying pressure to said powder in a direction along the longitudinal axis of said container thereby to establish an initial compaction of the powder therein and to cause said initially compacted powder to seize the inner surface of said container, continuing the application of pressure to establish a further degree of compaction while simultaneously upsetting and shortening the length of said seized container, relieving the pressure upon the shortened container and removing the compacted article from said shortened container.

2. The method of forming an elongated compacted article having a length to diameter ratio greater than two from a mass of metal powder comprising, confining said powder within a thin deformable elongated container having the outer wall thereof lubricated, mounting said container within a die with clearance between said die wall and said container to permit upsetting of said container material, applying pressure to said powder in a direction along the longitudinal axis of said container thereby to establish an initial compaction of the powder therein and to cause said initially compacted powder to seize the inner surface of said container, continuing the application of pressure to establish a further degree of compaction while simultaneously upsetting and shortening the length of said seized container, relieving the pressure upon the shortened container and removing the compacted article from said shortened container.

3. The method of forming an elongated compacted article having a length to diameter ratio greater than two from a mass of metal powder comprising, confining said powder within a thin deformable elongated container, heating the powder and container, mounting said heated container within a die with clearance between said die wall and said container to permit upsetting of said container material, applying pressure to said heated powder in a direction along the longitudinal axis of said container thereby to establish an initial compaction of the heated powder therein and to cause said initially compacted powder to seize the inner surface of said container, continuing the application of pressure to establish a further degree of compaction while simultaneously upsetting and shortening the length of said seized container, relieving the pressure upon the shortened container and removing the compacted article from said shortened container.

4. A method of forming an elongated uniformly dense beryllium compacted article having a length-to-diameter ratio greater than two from a mass of beryllium powder comprising confining said powder within a thin deformable container, heating the powder and container, mounting said heated container within a die with clearance between said die wall and said container to permit upsetting of said container material, applying pressure to said heated powder in a direction along the longitudinal axis of said container thereby to establish an initial compaction of the heated powder therein and to cause said initially compacted powder to seize the inner surface of

said container, continuing the application of pressure to establish a further degree of compaction while simultaneously upsetting and shortening the length of said seized container, relieving the pressure upon the shortened container and removing the compacted article from said shortened container.

5. A method of forming an elongated uniformly dense beryllium compacted article having a length-to-diameter ratio greater than two from a mass of beryllium powder comprising confining said powder within a thin deformable metal container, mounting said container within a die with sufficient clearance between said die wall and said container to permit upsetting of said container material, applying a pressure of 50 to 100 tons per square inch to said powder in a direction along the longitudinal axis of said container thereby to establish an initial compaction of the powder therein and to cause said initially compacted powder to seize the inner surface of said container, continuing the application of pressure to establish a further degree of compaction while simultaneously upsetting and shortening the length of said container, relieving the pressure upon the shortened container and removing the compacted article from said shortened container.

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