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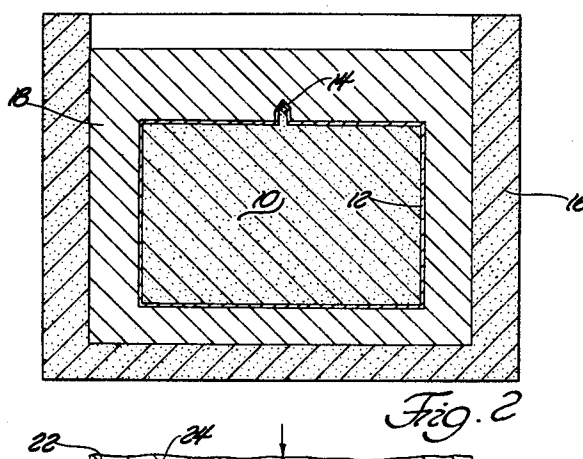
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(54) **Method of consolidating material with a cast pressure transmitter.**

(57) A quantity of material (10), which is at less than a predetermined density, such as powdered metal, is disposed within a sealed container (12) which is, in turn, encapsulated in a pressure-transmitting medium (18) which is, in turn, placed within a pot die (20) of a press where it is restrained as a ram (24) enters the pot die (20) and applies pressure to the pressure-transmitting medium (18) to densify the material within the container into a compact of a predetermined density. The invention is characterized by placing the container (18) with the powdered metal (10) therein within a casting mold (16) and pouring the medium (18) in the fluid state into the casting mold (16) to cast the medium completely about the container (12) to encapsulate the container (12). After casting, the medium (18) becomes rigid so as to retain its cast configuration while being removed from the casting mold (16) and thereafter for being handled. The medium (18), when subjected to pressure about the entire exterior thereof, becomes substantially fully dense and incompressible and capable of plastic flow at least just prior to the predetermined densification of the compact. The densification of the compact occurs by hydrostatic pressure being applied to the compact through the fluidic medium. In most instances the medium (18), the container (12) and the material (10) are heated to a compaction temperature prior to densification.



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TITLE

A method of consolidating material with a cast pressure transmitter.

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TECHNICAL FIELD

The subject invention is used for consolidating material of metallic and nonmetallic powder compositions and combinations thereof to form a more dense or fully densified compact.

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BACKGROUND ART

Consolidation is usually accomplished by evacuating a container and filling the container with a powder to be consolidated and thereafter hermetically sealing the container. Pressure is then applied to the filled and sealed container to subject the powder to pressure. Typically, heat is also applied to heat the powder to a compaction temperature. The combination of heat and pressure causes consolidation of the powder.

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It is well known to place a hermetically sealed container with the powder therein in an autoclave or hot isostatic press where it is subjected to heat and gas pressure.

Because of the expense and limitations of an autoclave or hot isostatic press, there have been significant developments made wherein the powder to be compacted is encapsulated in a substantially fully dense and incompressible pressure-transmitting medium which maintains its configurational integrity while being handled both at ambient temperatures and at the elevated compaction temperatures, yet becomes fluidic and capable of plastic flow when pressure is applied to the entire exterior surface thereof to hydrostatically compact the powder. Typically, the powder is hermetically encapsulated within the pressure-transmitting medium which is thereafter heated to a temperature sufficient for compaction and densification of the powder. After being sufficiently heated, the pressure-transmitting medium with the powder therein may be placed between two dies of a press which are rapidly closed to apply pressure to the entire exterior of the pressure-transmitting medium. The pressure-transmitting medium, at least immediately prior to a selected predetermined densification, must be fully dense and incompressible and capable of plastic flow so that the pressure transmitted to the powder is hydrostatic and, therefore, from all directions, i.e., omnidirectional.

In order to obtain a densified compact, having a near net shape, i.e., the final shape has a high degree of predictability regardless of shape complexity to near finished dimensions, a large mass or volume of the pressure-transmitting medium is disposed about the less than fully dense material. This has been accomplished by forming the pressure-transmitting medium of two parts, such as two metal parts, each of which has formed therein one-half of the cavity for receiving the powdered metal, such as by machining. Thereafter, the two components are mated together in a fashion to provide a hermetic seal as by welding, or the like. A passageway is formed leading to

the cavity so that the cavity may be subjected to a vacuum before being filled with the powdered metal, after which the passageway is hermetically sealed.

5 SUMMARY OF THE INVENTION AND ADVANTAGES

 The subject invention is for consolidating powder material of metallic and nonmetallic compositions and combinations thereof to form a densified compact of a predetermined density wherein a quantity of such material, 10 which is less dense than the predetermined density, is contained in a sealed container to which external pressure is applied to the entire exterior of the container to cause the predetermined densification of the material therein. The invention is characterized by casting a 15 pressure-transmitting medium completely about the container to encapsulate the container in the medium with the medium being sufficiently fluid for casting and thereafter becomes rigid to retain the cast configuration while being handled and, when subjected to pressure about the entire 20 exterior thereof, becomes substantially fully dense and incompressible and capable of plastic flow at least just prior to the predetermined densification of the compact to cause the predetermined densification of the compact by hydrostatic pressure applied to the compact by the 25 pressure-transmitting medium.

 By casting the pressure-transmitting medium about a container containing the powdered metal to be compacted, there are no requirements for machining precise cavities in components which later are mated together to form the 30 pressure-transmitting medium, nor are there any problems in mating the components together to form a hermetic seal. The container for the powder may be configured to the exact shape or configuration of the compact very easily as by stamping, or the like. The container can also be 35 utilized to protect the powder therein from impurities or

reactive elements which may be in the pressure-transmitting medium.

BRIEF DESCRIPTION OF THE DRAWINGS

- 5 Other advantages of the present invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:
- 10 FIGURE 1 is a cross-sectional view of a container filled with less than fully dense powdered material;
- FIGURE 2 shows the container of FIGURE 1 disposed in a casting mold with the pressure-transmitting medium cast thereabout; and
- 15 FIGURE 3 is a cross-sectional view of the pressure-transmitting medium encapsulating the compact after full densification between a pot die and a ram of a press.

DESCRIPTION OF THE INVENTION

- 20 The subject invention may be utilized for consolidating various metallic powders and nonmetallic powders, as well as combinations thereof, to form a more dense or fully densified compact, i.e., a compact of a selected predetermined densification.
- 25 The invention relates to a method for consolidating material of metallic and nonmetallic compositions and combinations thereof to form a fully densified compact wherein a quantity of such material, which is less dense than the predetermined final density, is contained in a sealed
- 30 container to which external pressure is applied to the entire exterior surface of the container to cause the predetermined densification of the powdered material within the container.

 As the invention is illustrated, a quantity of less
35 dense powder 10 fills a thin-walled container 12. The container is evacuated by a vacuum through a tube 14 and

then is filled with the powder 10 under vacuum through the tube 14. After filling, the tube 14 is sealed to hermetically seal the container 12 with the powder 10 under vacuum therein. The container 12 may be filled and sealed 5 in accordance with the teachings of applicant's U.S. Patent 4,229,872 granted October 28, 1980 and assigned to the assignee of the subject invention. The container 12 is circular in cross section to define a cylinder and has a fill tube 14 extending upwardly from the top thereof. 10 It will be understood, however, that the configuration of the container will depend upon the desired configuration or shape of the end part or compact.

The container 12 with the less dense powder 10 therein is then placed in a casting mold 16 wherein a 15 pressure-transmitting medium 18 is cast about the container 12 to encapsulate the entire container 12 and the less dense powder material 10 therein. The pressure-transmitting medium 18 is sufficiently fluid for casting so as to be poured into the casting mold 16. Typically, a 20 layer of the medium may be poured into the casting mold 16 and then the container 12 placed thereon with the remainder of the medium then being poured into the casting mold to completely encapsulate the container 12. Thereafter, the medium 18 becomes rigid, as by cooling and/or 25 curing, so that it will retain the cast configuration after it is removed from the mold 16 and is handled for further processing. The medium 18 is cast of sufficient thickness so as not to closely follow the contour of the container 12. The container 12 can be of various 30 different configurations, but typically the cast medium 18 will have a configuration that conforms closely to the interior of the pot die 20 and not necessarily to the configuration of the cavity of the container. For example, the medium 18 may define a "thick walled" container having 35 external walls which do not closely follow the contour of the cavity in which the less dense material 10 is

encapsulated. Such would be the case if the container 12 were in the shape of an hourglass and encapsulated in the medium 18 having the same outer configuration as illustrated.

5 Sometime later the medium 18, which encapsulates the container 12 and the less dense powder 10, is placed in a press having a cup-shaped pot die 20 which has interior walls 22 extending upwardly from the upper extremity of the medium 18. A ram 24 of the press is moved downwardly
10 in close sliding engagement with the interior walls 22 to engage the pressure medium 18. The ram 24 therefore applies a force to a portion of the exterior of the pressure-transmitting medium 18 while the pot die 20 restrains or contains the remainder of the pressure-
15 transmitting medium 18 so that external pressure is applied omni-directionally to the entire exterior surface of the pressure-transmitting medium 18. When subjected to pressure about the entire exterior, the medium becomes substantially fully dense and incompressible and fluidic
20 so as to be capable of plastic flow at least just prior to the predetermined densification of the compact 10'. The compact 10' becomes densified by hydrostatic pressure applied to the compact 10' by the medium 18.

Typically the medium 18, the container 12 and the
25 less dense powder 10 are heated to a compaction temperature before being placed in the pot die 20. Such heat may be necessary for compaction to the predetermined and/or full densification to produce the compact 10', but also may facilitate the fluidity of the pressure-
30 transmitting medium 18.

The walls of the container 12 are typically thin walls and are a substantially constant thickness. However, the less dense material 10 may be disposed in a "thick walled" container of sufficient thickness so that
35 its exterior configuration does not closely follow the contour of the cavity and material in the container and

with the container material being substantially fully dense and incompressible and capable of plastic flow to effect the predetermined densification in response to the omni-directional pressure applied to the "thick walled" container by the medium 18 in which it is encapsulated. The material of the container 12 may also have substantially the same plastic flow characteristics as the medium 18 when at the compaction temperature. In other words, the container 12 and the pressure-transmitting medium 18 may act as one homogeneous fluidic-type mass which can undergo plastic flow to apply hydrostatic pressure to the powder 10 to compact and densify it into the compact 10' of a predetermined density.

Various different materials may be utilized as the medium 18 so long as they have the characteristics whereby they may be cast about a container 12 and then solidify or rigidify to retain their configuration while being handled and heated to compaction temperature and placed in a press and thereafter when subjected to the forces of the press become fluidic and capable of plastic flow so as to apply hydrostatic pressure at least at the point of full densification. Examples of materials which have been found satisfactory for the medium 18 are some metals, such as copper or copper-nickel alloy, or combination materials such as a ceramic skeleton structure supporting glass therein as disclosed and claimed in application P-353 filed concurrently herewith and assigned to the assignee of the subject invention.

The invention has been described in an illustrative manner, and it is to be understood that the terminology which has been used is intended to be in the nature of words of description rather than of limitation.

Obviously, many modifications and variations of the present invention are possible in light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims wherein reference

numerals are merely for convenience and are not to be in any way limiting, the invention may be practiced otherwise than as specifically described.

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CLAIMS

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

- 5 1. A method for consolidating material (10) of metallic and nonmetallic compositions and combinations thereof to form a densified compact (10') of a predetermined density wherein a quantity of such material (10) which is less dense than the predetermined density is
10 contained in a sealed container (12) to which external pressure is applied to the entire exterior of the container (12) to cause the predetermined densification of the material therein, characterized by casting a pressure-transmitting medium (18) completely about the
15 container (12) to encapsulate the container (12) in the medium (18) with the medium (18) being sufficiently fluid for casting and thereafter becoming sufficiently rigid to retain the cast configuration while being handled and, when subjected to pressure about the entire exterior
20 thereof, becomes substantially fully dense and incompressible and capable of plastic flow at least just prior to the predetermined densification of the compact (10') to cause the predetermined densification of the compact (10')

by hydrostatic pressure applied to the compact (10') by the medium (18).

2. A method as set forth in claim 1 further characterized as casting the medium (18) by pouring the medium 5 into a mold (16) about the container (12) and allowing the medium (18) to rigidify and then removing the medium (18) from the mold (16).

3. A method as set forth in any one of claims 1 or 2 further characterized by heating the medium (18) and the 10 container (12) and the material (10) in the container (12) to a compaction temperature prior to reaching the predetermined densification.

4. A method as set forth in claim 1 further characterized as applying pressure to the entire exterior of the 15 medium (18) while at a compaction temperature by applying force (24) to a portion of the exterior of the medium (18) while restraining the remainder of the medium (18).

5. A method as set forth in claim 2 further characterized by casting the medium (18) of sufficient thickness 20 so that its exterior configuration does not closely follow the contour of the container (12).

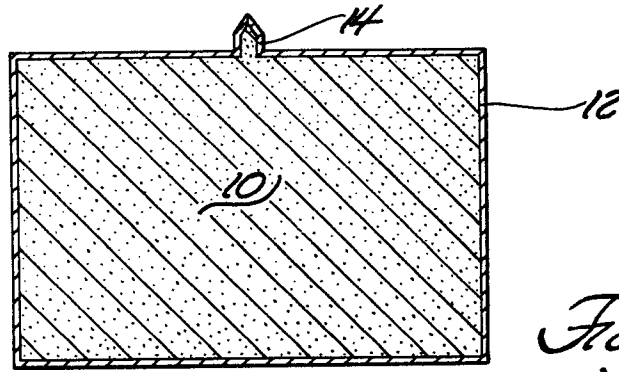
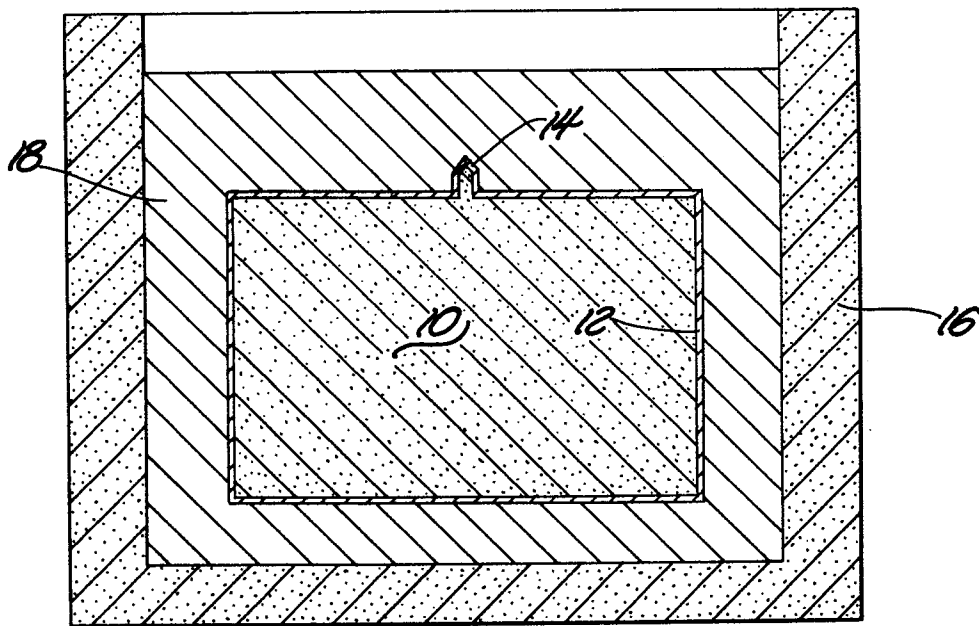
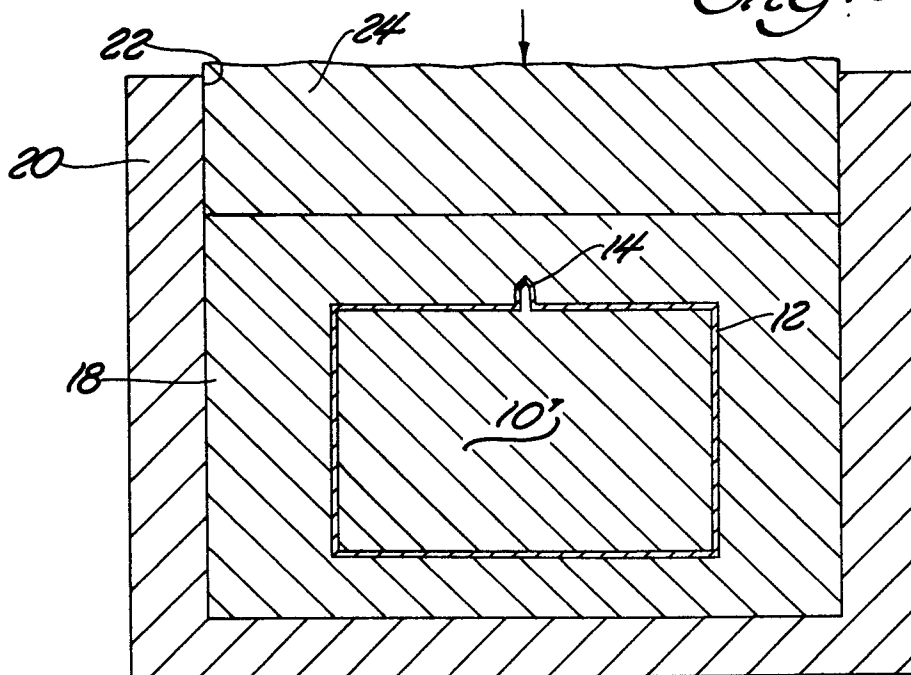
6. A method as set forth in claim 5 further characterized by placing the medium (18) at a compaction temperature in a pot die (20) which supports and closely 25 surrounds the medium (18) and applying the force by inserting a ram (24) into the pot die (20) to engage and pressurize the medium (18).

7. A method as set forth in any one of claims 1 or 2 further characterized by utilizing a container (12) having 30 thin walls of a substantially constant thickness.

8. A method as set forth in any one of claims 1 or 2 further characterized by disposing the material (10) in a container of sufficient thickness so that its exterior configuration does not closely follow the contour of the 35 material containing cavity in the container and of a container material which is substantially fully dense and

incompressible and capable of plastic flow to effect the predetermined densification in response to omni-directional pressure applied thereto by the medium (18).

9. A method as set forth in any one of claims 1 or 2
5 further characterized by utilizing a container made of material having substantially the same plastic flow characteristics as the medium at the compaction temperature.

*Fig. 1**Fig. 2**Fig. 3*



European Patent
Office

EUROPEAN SEARCH REPORT

0094164

Application number

EP 83 30 2302

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 3)
Y	EP-A-0 039 014 (ASEA) * Whole document *	1-7	B 22 F 3/14 B 30 B 11/00 B 22 F 3/00
Y	FR-A-2 455 940 (ASEA) * Claim 1 *	1-7, 9	
Y	US-A-2 510 546 (J.B. BRENNAN) * Column 2, lines 19-33 *	1-3, 5	
Y	GB-A-1 088 560 (HOWE SOUND CO.) * Claims 8, 10 *	1-2, 5	
Y	DE-A-2 724 524 (KELSEY-HAYES) * Claim 1 *	5, 8	
P, Y	EP-A-0 053 753 (F. KRUPP) * Claim 1 *	1-3, 5	TECHNICAL FIELDS SEARCHED (Int. Cl. 3) B 22 F
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 05-08-1983	Examiner SCHRUEERS H.J.
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document	