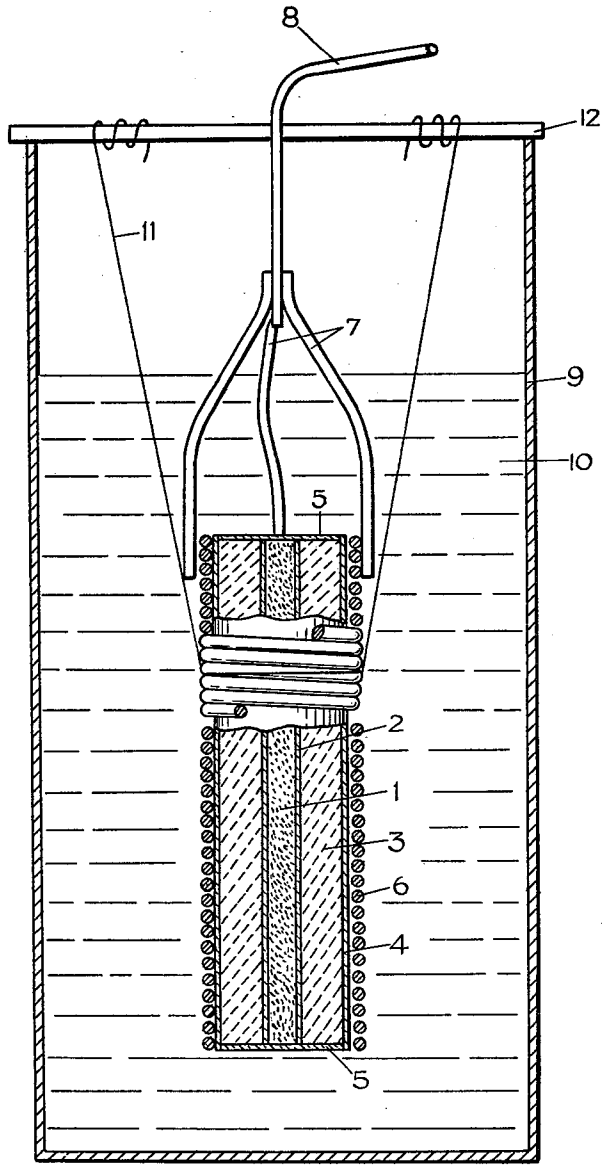
Nov. 26, 1963 W. T. MONTGOMERY ETAL 3,112,166

FORMATION OF HOLLOW BODIES FROM POWDERED MATERIALS

Filed March 8, 1961 3 Sheets-Sheet 1

FIG. 1.



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FORMATION OF HOLLOW BODIES FROM POWDERED MATERIALS

Filed March 8, 1961 3 Sheets-Sheet 2

Fig. 1a.

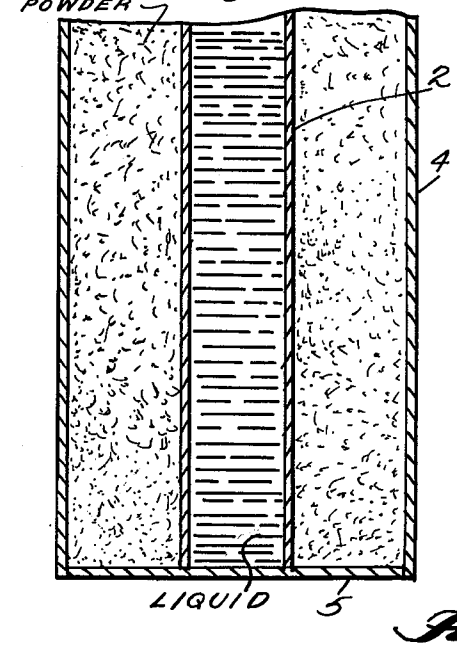


Fig. 1b.

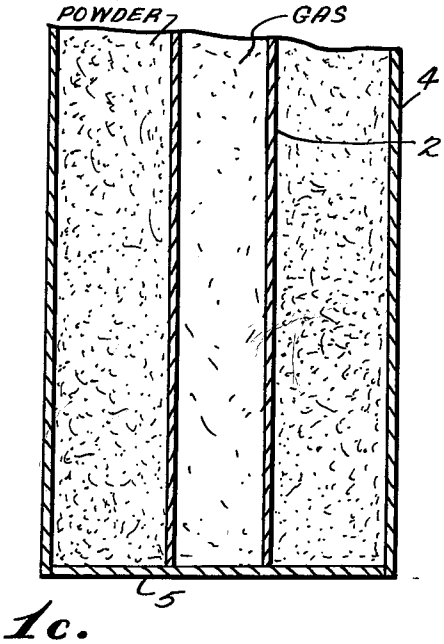
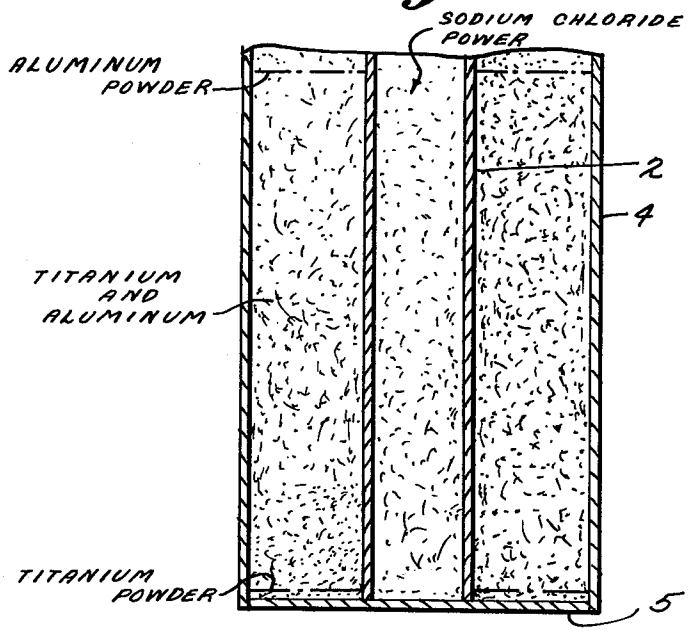


Fig. 1c.



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FORMATION OF HOLLOW BODIES FROM POWDERED MATERIALS

Filed March 8, 1961 3 Sheets-Sheet 3

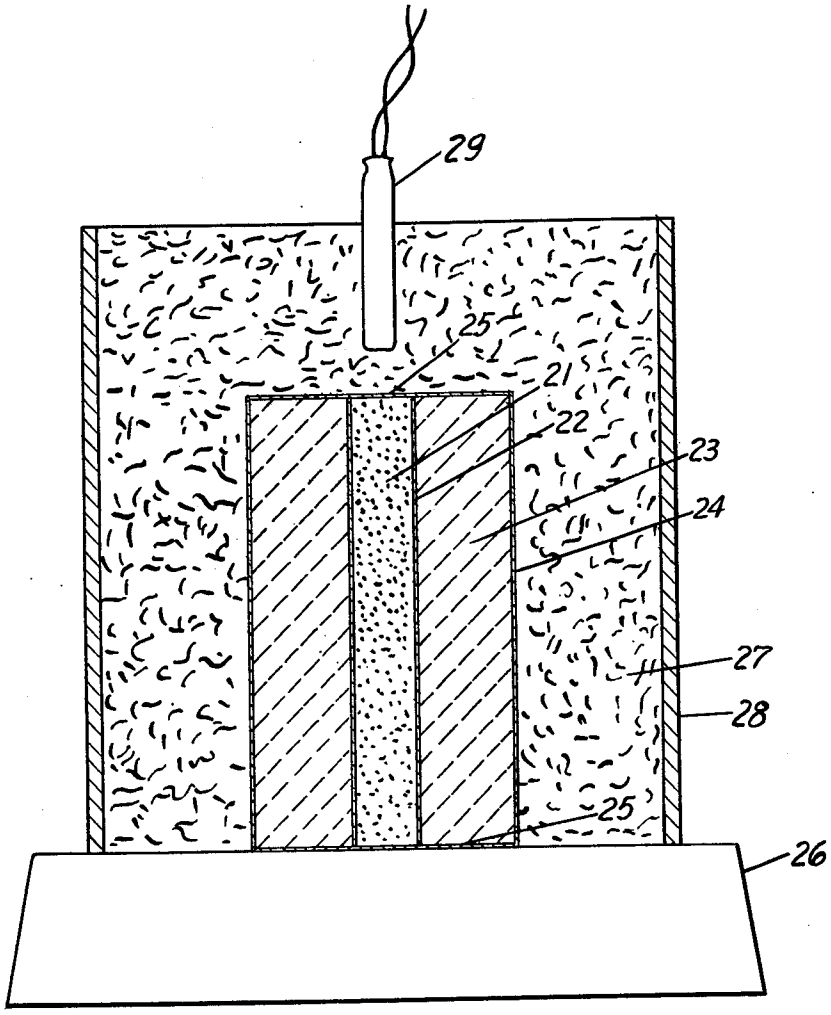


FIG. 2

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3,112,166

FORMATION OF HOLLOW BODIES FROM POWDERED MATERIALS

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Claims priority, application Great Britain Mar. 10, 1960
6 Claims. (Cl. 18—59.3)

This invention relates to the moulding of hollow bodies from powdered materials by subjecting the powder to the pressure pulse produced by the detonation of a high explosive.

In our U.K. Patent No. 833,673, a method has been proposed for converting metal powder into a coherent mass wherein the bounding surfaces of the particles of the metal have been sufficiently destroyed to confer upon the body a substantial degree of continuity of texture, which comprises positioning a detonatable high explosive of at least sufficient power explosively to transmit pressure to the contents of a watertight container containing the said metal powder, surrounding the said container and the detonatable high explosive around it by a stemming bath of liquid, and detonating the said high explosive. This method is applicable to the formation of ingots of certain metals and alloys which cannot be conveniently made by the normal fusion method. The method is particularly advantageous for compacting fine titanium powder to give a solid ingot which can be subjected to further metal working operations.

An object of the present invention is the provision of a convenient method for producing hollow shaped bodies from finely divided powders.

According to the invention a process for the formation of a hollow shaped body from finely divided powder capable of being compacted when subjected to the pressures generated by detonating explosives or mixtures of such powders comprises embracing one or more cores of non-explosive yieldable material capable ultimately of being removed from the formed body with a layer of the powder contained in a thin-walled container, positioning a layer of high explosive in proximity around a predetermined portion of the outer surface of the powder container, and detonating the said high explosive. Each core advantageously consists of a thin-walled container and a filling material therein. The result is that on detonation of the explosive all the powder adjacent to the predetermined portion of the powder container surface is compacted to form a hollow body.

The invention also includes hollow bodies so formed from powdered materials.

To further illustrate the invention, examples of the application of the process to the formation of tubular elements using various combinations of core and powdered materials will be described with reference to the accompanying drawings in which:

FIGURE 1 shows mainly in axial sectional elevation the operative disposition of core, powdered material to be compacted, explosive layer and surrounding water as assembled in Examples 1–13;

FIGURE 1*a* is a fragmentary view illustrating the use of a core composed of a liquid as in Example 6;

FIGURE 1*b* is a fragmentary view illustrating the use of a core composed of a gas as in Example 7;

FIGURE 1*c* is a fragmentary view illustrating the compaction of different powdered materials into a single article as in Example 13; and

FIGURE 2 shows in axial sectional elevation the operative disposition of core, powdered graphite to be compacted and explosive layer as assembled in Example 20.

The invention is particularly useful in forming hollow bodies, for example tubular bodies from finely divided metal or non-metallic powders. It provides a convenient method for the formation of hollow bodies from mixtures of metal powders which cannot be alloyed by fusion. It is also useful for forming hollow bodies, for example tubular bodies, having a varying composition throughout the mass.

In one convenient form of the invention the explosive layer is surrounded by a liquid medium and water has been found to be particularly suitable.

Metal powders, for example powdered aluminium, titanium, nickel, etc., and many non-metallic powders, for example graphite, inorganic salts and powdered ceramic materials which are stable at elevated temperatures, may be formed into hollow bodies by the invention.

The explosive layer may contain any detonating explosive, but explosives containing PETN, pentaerythritol tetranitrate, TNT, trinitrotoluene, or nitroglycerine are convenient. A particularly convenient form of explosive for this purpose is commercial detonating fuse cord, containing a core of PETN, enclosed in a waterproof plastic envelope. This can be wrapped helically or otherwise disposed around the metal powder container to form the required layer of explosive. When this form of explosive layer is used a more even compacting force is obtained from the detonation if the explosive is surrounded by a substantial volume of liquid, preferably water.

Although the explosive layer may be at some distance from the container of the powder, it is generally preferred to have it in contact with this container. However, in compacting powder to form relatively thin-walled hollow bodies it is often advantageous to interpose a buffering layer of some powdered material which is not intended to form permanently any part of the final hollow body between the layer of the explosive and the powder which is to be compacted into the form of the desired hollow body. This buffering layer may be contained in any suitable thin-walled outer container so that the material is in contact with the thin-walled container of the powder to be compacted to form the desired hollow body. This container separating the buffering layer from the powder to be compacted into the desired body may be for instance of aluminium, paper, cardboard or the like. The use of such a buffering layer avoids the tendency for the formation of cracks in the wall of the desired hollow body. The compacted material of the buffering layer may be removed by any convenient method, e.g. by cutting, chipping, grinding, dissolving, burning or otherwise according to its nature.

The core as a whole must be non-explosive and should be of such a nature that it does not combine to any undesirable extent during the process, with the powder being formed into the hollow body. It should also be of such a nature that the volume actually embraced by the powder required to form the hollow body is capable of sudden substantial reduction whenever the explosion takes place. It will be understood that the core as a whole must not act as a rigid body during the explosion since this could cause the compacted body to crack. The thin-walled container must itself be readily deformable, and, if its length does not exceed that of the body of the powder to be embraced by explosive, its closure must normally be easily rupturable or deformable so as to provide an escape for the filling by flow from the embraced space when the explosion is brought about unless the material of the filling is itself highly compressible such as, for example in the case of a gaseous filling. The core container should not be permeable to the core filling material but it may be of soft material and may be destructible in the process. When a liquid is used as the core filling material the sudden substantial reduction in its embraced volume is achieved by displacement of a portion of the liquid in a direction trans-

verse to that of the action of the explosive following rupture of the core container. With core fillings of powdered solids of easily compressible or fusible character the reduction in volume may often be possible without substantial displacement of material outside the confines of the original embraced space occupied by the core. Although gases may be used as core filling, solids which generate gases in large volume or very rapidly under the action of the explosive, for instance ammonium nitrate, are less suitable since the pressure developed by the gases actually within the embraced hollow body formed at the instant of the explosion may be sufficient to crack the formed body before the gas can escape from the end of the container. Salts of alkaline and alkaline earth metals in granular form are usually good core materials, and sodium chloride and mineral barytes give particularly good results. Cores of the latter two materials are, however, compacted in the process, and require to be removed afterwards, e.g. by leaching with water. When a material like hydrated sodium sulphate is used, it dissolves in its water of crystallisation during the process and usually flows out of the formed hollow body. This type of core material is therefore often advantageous.

The invention is especially suitable for the formation of tubes having substantially circular cross-section and substantially uniform wall thickness. Such tubes are formed according to the invention by symmetrically disposing a uniformly thick layer of powder in a suitable container around a cylindrical axially disposed core of suitable material, placing uniformly over the powder container surface a suitable charge of high explosive and detonating it. In this way the invention may be applied in the formation of tubes from non-metal powders like graphite, and from a wide variety of metal powders. It is particularly useful in the formation of tubes from titanium, aluminium, nickel, and iron powders and mixtures of these powders, and certain powdered steels. It also provides a ready means of forming hollow bodies from compacted mixtures of metal powders even if such mixtures cannot be alloyed and shaped by the normal fusion processes. Similarly the invention provides a means of joining tubes made from materials which are not readily joined by fusion. For example aluminium is notoriously difficult to weld to other metals, but a tube consisting of a length of aluminium connected to a length of other metal can readily be formed by subjecting suitably arranged portions of aluminium powder and the other powdered metal to the process of the invention.

In a similar manner tubes may be formed which can be controllably varied in composition along their length or across their diameter. For example tubes may be formed which consist of one metal at one end and another metal at the other end, and having an intervening portion containing both metals in intimate admixtures, so that the composition is gradually varied along this intervening portion, the proportion of one metal increasing and of the other metal decreasing along the length of this portion of the tube. Tubes having an inner lining of one metal surrounded by an outer layer of another metal can also be readily formed by the invention. This application is particularly advantageous where the inner layer is necessarily an expensive metal and the outer portion, which is used only to provide the necessary strength, is of a cheaper metal. Such types of metal tubes are commonly used in chemical plants and neither can be formed by a fusion method. Tubes may also be readily formed in which any portion of the length of the tube is made from a metal and the remainder is made from a non-metal powder such as graphite or from mixtures of the metal and non-metal powder. A tube having an outer layer of a metal and an inner lining of a non-metallic material may be formed; conversely the outer layer of the tube may be non-metallic and the lining metallic.

Hollow bodies having a plurality of passages may be made by inserting a plurality of the aforedescribed cores into the powdered material to be compacted so that each core is completely surrounded by the powdered material. Thus, for example a cylindrical metal body may be formed with a plurality of passages whose axes are parallel to the axis of the body.

Referring to FIGURE 1 the core filling material **1** was contained in a cardboard cylinder **2** having a wall thickness of 0.25 mm. axially disposed in the metal powder **3** contained in a thin-walled aluminium tube **4** having a diameter of 5.5 cm. and a wall thickness of 0.05 cm. a portion of which latter is represented in the drawing as a front view. Thin Celluloid discs **5** were glued to the ends of the tubes **2** and **4** containing the core filling material **1** and the metal powder **3** respectively, to render the tubes watertight. The explosive charge **6**, a portion of which is also represented in the drawing as a front view, was a single layer of plastic covered detonating fuse cord containing 44 grains PETN per foot wound in helical manner tightly around the outer surface of the aluminium tube **4** containing the metal powder, so as to completely and evenly cover the said surface. The ends of four fuseleads **7** equal in length were attached by means of adhesive tape to one end of the explosive charge **6** at points evenly spaced around the circumference. The other ends of the fuseleads **7** were attached by adhesive tape to one end of a common fuselead **8** whose other end was attached to a detonating means (not shown). The fuseleads **7** and the common fuselead **8** consisted of suitable lengths of plastic covered detonating fusecord containing 44 grains PETN per foot. By arranging the fuseleads **7** in this manner the explosive charge **6** was initiated at four points simultaneously thereby reducing the chance of getting uneven strains in the end portion of the explosively formed tube which can happen when the charge is initiated from one point only. Ideally the charge should be initiated simultaneously all around the circumferences at one end, but it is more difficult to arrange such initiating means. However, as the detonation quickly evens out to become a steadily propagating detonation along the length of the charge, only a small portion at the end of the explosively formed metal tube is affected by the slightly uneven strains due to multiple point initiation; for the size of the tube being formed in the examples initiation at four points was found to be convenient. This end effect could be eliminated by extending the explosive charge beyond the powder at the end nearer the initiator, but usually it is more convenient to use an assembly as shown in the drawing and to remove any portion at the end which is deformed or otherwise unsatisfactory. The complete assembly was placed inside a large container **9** containing water **10**, and was maintained in position therein with a supporting wire **11**, wrapped around a supporting bar **12** so that the explosive charge **6** was surrounded with a thick layer of stemming water **10**.

The core filling material **1**, the core container **2**, the metal powder charge **3**, the metal powder container **4** and the explosive charge **6** were all 23 cm. in length. The explosive charge **6** consisted of 7.5 m. of detonating fuse cord.

Examples 1 to 12

In the accompanying table details are given of the dimensions of metallic tubular elements compacted by assembling 12 examples of combinations of core materials and metal powders as shown in FIGURE 1 and detonating the explosive layer surrounding the metal powder.

The aluminum powder used in Examples 1–7 had a bulk density of 1.25 g./cc. and a particle size such that it all passed a 60 mesh B.S. sieve and was retained on a 100 mesh B.S. sieve. FIGURE 1*a* illustrates a water core as used in Example 6. FIGURE 1*b* illustrates an air core as used in FIGURE 7. The titanium powder used in Examples 8–12 had a bulk density of 1.30 g./cc. and all of it passed a 200 mesh B.S. sieve. The barytes used as the core filling material in Examples 2 and 9 had a bulk density of 2.22 g./cc. and all of it passed a 240 mesh B.S.

sieve. The sodium chloride used as the core filling material in Examples 1 and 8 had a bulk density of 1.22 g./cc. and a particle size such that all of it passed a 60 mesh B.S. sieve and was retained on a 100 mesh B.S. sieve. The anhydrous sodium sulphate used as the core filling material in Examples 3 and 10 had a bulk density of 1.19 g./cc. and its particle size was such that all of it passed a 30 mesh B.S. sieve and was retained on a 60 mesh B.S. sieve. The hydrated sodium sulphate used as the core filling material in Examples 4 and 11 had a bulk density of 0.89 g./cc. and had a particle size such that all of it passed an 8 mesh B.S. sieve and all of it was retained on a 30 mesh B.S. sieve.

On detonating the explosive the powdered materials 3 in these examples were in most cases formed into tubes having a uniform degree of compaction throughout. The dimensions of the core 1 and the layer of powdered material 3 in the shots which gave ruptured tubes in Examples 1, 7, 8 and 12 indicate the minimum thickness of material which could be compacted by the technique used in these examples where the explosive layer is adjacent to the layer of material being compacted. However, the wall thickness can be reduced by interposing a protective layer of powdered material between the explosive and the material which is being formed into the tube. This technique is illustrated in Examples 14, 15 and 16. The inner and outer surfaces of the compacted metal tubes were, in most cases, somewhat uneven, but were easily smoothed by machining to uniform dimensions. The dimensions given for the diameter of the core after compaction is in fact the diameter of the bore of the compacted metal tube. When water or hydrated sodium sulphate were used as the core filling material they separated from the metal tube in the process.

Example 13

In this example illustrated schematically in FIGURE 1*c*, two tubes of circular cross-section were formed, of which a portion at one end consisted of aluminium, a portion at the other end consisted of titanium and the intermediate portion contained both these metals in admixture the proportion of aluminium increasing and the proportion of titanium decreasing along this intermediate portion from the end attached to the titanium portion. The tubes were formed by the process used in Examples 1–12 the disposition and lengths of the single axial core, the metal powder 3 to be compacted, the containers 2 and 4 and the layer of detonating fuse cord were the same as in the previous examples. The core filling in this example was sodium chloride of the kind previously used in Examples 1 and 8 and the core diameter was 1.5 cm. The outside diameter of the metal powder charges were 5.5 cm. The charge of metal powder was varied along its length in the following manner starting from the bottom end.

	Cm.
Titanium powder	0–7
Mixture containing 9 parts Ti to 1 part Al by weight	7–8
Mixture containing 8 parts Ti to 2 parts Al by weight	8–9
Mixture containing 7 parts Ti to 3 parts Al by weight	9–10
Mixture containing 6 parts Ti to 4 parts Al by weight	10–11
Mixture containing 5 parts Ti to 5 parts Al by weight	11–12
Mixture containing 4 parts Ti to 6 parts Al by weight	12–13
Mixture containing 3 parts Ti to 7 parts Al by weight	13–14
Mixture containing 2 parts Ti to 8 parts Al by weight	14–15
Mixture containing 1 part Ti to 9 parts Al by weight	15–16
Aluminium powder	16–23

The aluminium powder was the same as that used in Examples 1–7; for one tube the titanium powder was the same as that used in Examples 8–12 and for the other it was of a particle size such that all of it passed a 16 mesh B.S. sieve and was retained on a 100 mesh B.S. sieve.

The tubes formed on detonation of the explosive and subsequent removal of the core both had an external diameter of 3.5 cm. at the titanium ends and 4.1 cm. at the aluminium end, the internal diameters being fairly uniformly 1.3 cm. all along the length of each tube. The tubes were very firmly compacted, rigid, strong, free from cracks and were easily machined and polished at all parts.

Example 14

In this example a tube of circular cross-section and substantially uniform wall thickness was formed from powdered natural graphite of a particle size such that all of it passed a 100 mesh B.S. sieve. The technique used to form this tube was similar to that used in the previous examples but in this case a layer of aluminium powder was placed around the layer of graphite to avoid the formation of cracks in the tube produced. The lengths of the various items and their disposition before the detonation of the explosive were as in the previous examples. In this case the outside diameter of the aluminium powder was 5.5 cm. and it was contained in the aluminium tube 4 as before. The core filling 1 was sodium chloride of the kind previously used and the outside diameter of the core was 1.7 cm. The outside diameter of the annular graphite charge was 3.5 cm. The aluminium and graphite layers were separated by a layer of paper 0.25 mm. thick. The tube formed on firing the explosive and subsequent removal of the core had an external diameter of 2.5 cm. and an internal diameter of 1.4 cm. the density of the compacted graphite being 2.13 g./cc. This tube was uniformly compacted, free from cracks, rigid, strong and its surface was easily polished. Such tubes are useful as nozzles for flame gases.

Example 15

In this example a tube of a circular cross-section and uniform wall thickness was formed from powdered silicon of a particle size such that all of it passed a 100 mesh B.S. sieve and all of it was retained on a 250 mesh B.S. sieve. The technique used was the same as that used to form the graphite tube in Example 14, and the disposition and the lengths of the various items in the assembly were the same as before. The core filling was sodium chloride as used in Example 14 and the core diameter was 1.7 cm. The external diameter of the annular layer of silicon placed around the core was 3.0 cm. and this layer was separated from the surrounding layer of aluminium powder by a layer of paper 0.25 mm. thick. The external diameter of the annular layer of aluminium powder was 5.5 cm.

The tube of silicon formed on detonation of the explosive and subsequent removal of the core had an external diameter of 2.5 cm. and an internal diameter of 1.3 cm. It was uniformly compacted, rigid and free from cracks.

Example 16

In this example a tube of circular cross-section and uniform wall thickness in which the composition was varied from aluminium at one end to graphite at the other was prepared. The technique used to form the tube was identical to that used in Examples 14 and 15, an annular layer of powdered aluminium again being placed between the explosive layer and the layer of powder to be compacted into the desired tube, these two layers being separated by a layer of paper 0.25 mm. thick. The core filling 1 was sodium chloride as in the previous example and the outside diameter of the core was 1.7 cm. The charge of material to be compacted had an outside diameter of 3.5

cm. and its composition along its length starting from its bottom end was:

	Cm.
Graphite	0–6.5
Mixture containing 8 parts graphite and 2 parts Al by weight	6.5–8.5
Mixture containing 6 parts graphite and 4 parts Al by weight	8.5–10.5
Mixture containing 5 parts graphite and 5 parts Al by weight	10.5–12.5
Mixture containing 4 parts graphite and 6 parts Al by weight	12.5–14.5
Mixture containing 2 parts graphite and 8 parts Al by weight	14.5–16.5
Aluminium	16.5–23.0

The grades of graphite and aluminium used were the same as those used in previous examples.

The tube formed on detonating the explosive and subsequent removal of the core had an external diameter of 2.5 cm. and an internal diameter of 1.4 cm. It was uniformly compacted, free from cracks, rigid, strong and was easily polished. There was no apparent weakness in that portion of the tube in which the composition progressively varied from metal to non-metal. The overall density of the compacted mass was 2.5 g./cc.

Example 17

In this example a tube of circular cross-section and uniform wall thickness was formed in which an outer annular layer of the tube was made from aluminium and an inner annular layer was made from titanium. The technique used to form the tube was similar to that used in all the previous examples the disposition and the lengths of the core, the material to be compacted and the explosive layer being the same as in previous examples. The core filling in this case was sodium chloride of the kind previously used and the core diameter was 1.5 cm. The cylindrical core was surrounded by an annular layer of titanium powder having an external diameter of 3.3 cm. and this in turn was surrounded by an annular layer of aluminium powder having an external diameter of 5.5 cm., the two layers being in intimate contact at the interface. The grades of aluminium and titanium were those used in Examples 1–7 and 8–12 respectively. The tube formed on detonation had an internal diameter of 1.3 cm. and an external diameter of 4.0 cm. The inner layer of titanium was intimately joined to the outer layer of aluminium, the inner layer having an external diameter of approximately 2.5 cm. The tube was uniformly compacted, free from cracks and was easily machined and polished to the desired dimensions.

Example 18

In this example a tube of circular cross-section and uniform wall thickness was formed having an outer annular layer of aluminium and an inner lining of graphite. The technique use was identical to that used in Example 17. The core diameter in this example was 1.7 cm., the external diameter of the surrounding annular layer of powdered graphite was 4.0 cm. and the external diameter of the annular layer of powdered aluminium was 5.5 cm. The tube formed on detonating the explosive and subsequent removal of the core had an internal diameter of 1.5 cm. and an external diameter of 3.9 cm. The inner and outer layers were intimately joined together, the inner layer having an external diameter of approximately 2.6 cm. The compacted mass had an overall density of 2.5 g./cc. The tube was uniformly compacted throughout, was free from cracks and its surfaces were easily polished.

Example 19

In this example a tubular body having 3 separate internal passages parallel to the longitudinal axis of the body was formed from powdered aluminium of the grade used

in previous examples. The technique of forming the body was similar to that used in the previous examples but instead of using only one core entirely surrounded by the powdered material to be compacted, three separate cylindrical cores were used and these were so disposed within the powdered aluminium that their curved surfaces were entirely surrounded by a layer of the powdered aluminium. The cores were in fact placed so that in cross-section their centres were symmetrically spaced on a circle of approximately 27 cm. in diameter. The cores consisted of sodium chloride of the kind used in previous examples contained in a cardboard container having a wall thickness of 0.076 mm. and an external diameter of 1.1 cm. The outside diameter of the charge of aluminium was 5.5 cm. As before this charge was contained in a thin-walled aluminium tube 4 which was surrounded on its curved surface by a helically wound layer of detonating fuse 6 and the whole assembly immersed in water before detonating the explosive.

The cylindrical body formed on detonating the explosive and subsequent removal of the core had an external diameter of 4.2 cm. and had three completely separate passages formed along its length. The cross-sections of the passages were not true circles but were somewhat oval, the elongation being in a transverse direction with respect to the cross-sectional diameter of the formed body. The cross-sectional dimensions of the passages were approximately 1.0 to 1.1 cm. across the wider part and 0.9 cm. across the narrower part. The cross-section of the centres of the passages were evenly spaced on the circumference of a circle having a diameter of 1.8 cm. and concentric with the cross-section of the formed body.

The mass appeared to be compacted uniformly throughout and the body was free from cracks.

Example 20

In this example a tube of circular cross-section and uniform wall thickness was formed from powdered natural graphite of the kind used in Example 15. The disposition of the explosive, the core and the surrounding layer of powdered graphite is shown diagrammatically in sectional elevation in FIG. 2 of the accompanying drawings. The cylindrical core consisted of a filling of sodium chloride 21 as used in Example 1 contained in a tubular cardboard container 22 having a wall thickness of 0.25 mm. and 1.35 cm. external diameter and a length of 9.0 cm. This core was covered over its entire curved surface by an annular layer of powdered graphite 23 having an external diameter of 5.3 cm. contained in a tubular aluminium container 24 having a wall thickness of 0.5 mm. Thin Celluloid discs 25 were glued to the ends of the tubular containers 22 and 24 to retain the powdered contents in position. The lower end of container 24 was placed on a lead plate 26 having a thickness of 3.0 cm. and surrounded on its curved and its upper surface by a layer of explosive 27 in powder form contained in a carboard container 28, the average thickness of this layer being 3.3 cm. The explosive composition was 8.3 parts nitroglycerine, 6.7 parts plant fibre, 56.2 parts ammonium nitrate and 29 parts sodium chloride. The explosive was detonated by means of a detonator 29 placed in the explosive directly above the axial core filling 21 as shown. On detonation of the explosive the powdered graphite was uniformly compacted into a tube having an external diameter of 4.0 cm. and an internal diameter of 1.3 cm., which was free from cracks.

Although in the examples given only short tubes were compacted, much longer hollow bodies could be formed by the process of the invention; for instance it is envisaged that lengths of up to 3 metres could be formed without difficulty. The other dimensions of core diameters and thicknesses of the powder layers are also capable of wide variation.

FORMATION OF TUBES FROM METAL POWDER

Example	Metal powder	Core material	Core diameter, cm.		Outside diameter of powdered metal, cm.	
			Before Compaction	After Compaction	Before Compaction	After Compaction
1	Aluminium	Sodium Chloride	1.7	1.3	5.5	4.0
			2.8	2.4	5.5	4.0
			2.8	2.5	5.5	4.2
			3.5	3.0	5.5	4.2
			4.2	(1)	5.5	(1)
2	do	Barytes	1.7	1.4	5.5	3.9
			2.8	2.5	5.5	4.0
3	do	Sodium Sulphate	1.7	1.2	5.5	3.9
			2.8	2.2	5.5	3.9
4	do	Sodium Sulphate (Hydrated)	1.7	1.4	5.5	3.8
5	do	Sodium Carbonate	2.8	2.5	5.5	4.2
6	do	Water	1.7	1.7	5.5	4.3
			2.8	2.8	5.5	4.5
7	do	Air	1.7	0.9	5.5	4.0
			3.5	(1)	5.5	(1)
8	Titanium	Sodium Chloride	1.7	1.2	5.5	3.5
			2.2	1.1	5.5	3.4
			2.8	2.5	5.5	3.8
			3.5	(1)	5.5	(1)
9	do	Barytes	1.7	1.4	5.5	3.5
			2.8	2.4	5.5	3.8
			2.8	2.4	5.5	3.9
10	do	Sodium Sulphate	1.7	1.2	5.5	3.5
			2.8	2.1	5.5	3.8
11	do	Sodium Sulphate (Hydrated)	1.7	1.4	5.5	3.5
12	do	Water	1.7	1.6	5.5	3.5
			2.8	(1)	5.5	(1)

[1] Tube ruptured.

What we claim is:

1. A process for the formation of a hollow shaped body from finely divided powder capable of being compacted when subjected to the pressures generated by detonating explosives comprising embracing at least one yieldable core consisting predominantly of non-explosive pourable material capable ultimately of being removed from the formed body with a layer of the powder contained in a thin-walled container, the volume of said core embraced by said powder being capable of sudden substantial reduction upon detonation of the explosive; positioning a layer of high explosive in proximity around a predetermined portion of the outer surface of the powder container and detonating the said high explosive.

2. A process as claimed in claim 1 wherein each yieldable core consists of a readily deformable thin walled container and a filling material therein.

3. A process as claimed in claim 2 in which the filling material is a particulate solid which after the detonation is in a form capable of flow with respect to the deformed container.

4. A process as claimed in claim 2 in which the filling material is a liquid and in which said liquid is displaced upon detonation of the explosive so as to achieve sudden substantial reduction in volume of that part of the core embraced by the powder.

5. A process as claimed in claim 2 in which the filling material is a gas.

6. A process as claimed in claim 1 in which the composition of the finely divided powder is varied from portion to portion so that a hollow body having different compositions in different portions is formed.

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