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PATENTS ACT 1952

B

APPLICATION BY ASSIGNEE OF INVENTOR

# DECLARATION IN SUPPORT OF AN APPLICATION FOR A PATENT

NAME OF APPLICANT

In support of an application made by:
Schweizerische Eidgenossenschaft vertreten durch die Eidg. Munitionsfabrik Thun der Gruppe für Rüstungsdienste, Allmendstrasse 74, CH-3602 Thun/Switzerland

TITLE

for a patent for an invention entitled:
HOLLOW CHARGE WITH A METALLIC LINING, METHOD AND DEVICE FOR ITS MANUFACTURING

FULL NAME AND ADDRESS OF SIGNATORY

Schweizerische Eidgenossenschaft vertreten durch die Eidg. Munitionsfabrik Thun der Gruppe für Rüstungsdienste, Allmendstrasse 74, CH-3602 Thun/Switzerland

do solemnly and sincerely declare as follows:

1. I am authorised by the above mentioned applicant for the patent to make this declaration on its behalf.

FULL NAME AND ADDRESS OF INVENTOR(S)

2. The name and address of each actual inventor of the invention is as follows:

NGUYEN, Cu Hai, Dr.
Fliederweg 14
CH-3138 Uetendorf/Switzerland

SEE NOTES OVER

3. The facts upon which the applicant is entitled to make this application are as follows:

The applicant is the assignee of the actual inventor

Agreement dated 26 January 1982

DELETE PARAGRAPHS 3 AND 4 FOR NON-CONVENTION APPLICATION

4. The basic application(s) as defined by Section 141 of the Act was (were) made as follows:

Country Switzerland on 17 November 1988

in the name(s) Schweizerische Eidgenossenschaft vertreten durch die Eidg. Munitionsfabrik Thun der Gruppe für Rüstungsdienste

PLACE AND DATE OF SIGNING

5. The basic application(s) referred to in the preceding paragraph was (were) the first application(s) made in a Convention country in respect of the invention the subject of this application.

Declared at Thun

this 22nd day of January 19 90

Signed EIDGENÖSSISCHE MUNITIONSFABRIK THUN

Position Leiter Patentkommission Stv. Kaufmännischer Leiter

i.V. [signature] F. [signature]

J. Mayor F. Schenk

GRIFFITH HACK & CO

PATENT AND TRADE MARK ATTORNEYS

MELBOURNE · SYDNEY · PERTH

(12) PATENT ABRIDGMENT (11) Document No. AU-B-45314/89
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 621684

(54) Title
HOLLOW CHARGE WITH A METALLIC LINING, METHOD AND DEVICE FOR ITS MANUFACTURING

International Patent Classification(s)
(51)[4] F42B 013/10
(51)[5] B22F 003/14 B22F 007/04

(21) Application No. : 45314/89 (22) Application Date : 17.11.89

(30) Priority Data

(31) Number (32) Date (33) Country
04264/88 17.11.88 CH SWITZERLAND

(43) Publication Date : 24.05.90

(44) Publication Date of Accepted Application : 19.03.92

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(56) Prior Art Documents
US 4613370
AU 23174/88 B22F 3/14
US 3388663

(57) Claim

1. A hollow charge for piercing armor plating built-up of layers to deflect a homogeneous hollow-charge jet, comprising an ammunition body with a rotationally symmetrical, ductile, metallic lining lockedly embedded in explosive, characterised in that the metallic lining has a three-dimensional isotropy and its density is at least 98% of the crystal density of the metal.

2. A method for manufacturing a metallic lining according to claim 1, comprising the following steps:

atomizing at least one metal in a stream of air or of inert gas;

mixing the resulting metal powder in a broad particle-size distribution;

filling the metal powder into the interspace of a rotationally symmetrical, double-walled, ductile, high-temperature-resistant container having at least approximately uniform wall thickness all around;

.../2

flushing and/or reducing the metal powder and the interspace of the double-walled container with hydrogen;

closing the double-walled container and sealing it in a gas-tight manner;

exposing the sealed container on all sides to an elevated gas pressure while heating at the same time, resulting in hot, isostatic pressing; and

removing the sealed container.

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**COMPLETE SPECIFICATION**

FOR OFFICE USE

Short Title:

Int. Cl:

Application Number:
Lodged:

Complete Specification-Lodged:
Accepted:
Lapsed:
Published:

Priority:

Related Art:

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TO BE COMPLETED BY APPLICANT

Name of Applicant: SCHWEIZERISCHE EIDGENOSSENSCHAFT VERTRETEN DURCH DIE EIDG. MUNITIONSFABRIK THUN DER GRUPPE FÜR RÜSTUNGSDIENSTE

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Complete Specification for the invention entitled:

HOLLOW CHARGE WITH A METALLIC LINING, METHOD AND DEVICE FOR ITS MANUFACTURING

The following statement is a full description of this invention, including the best method of performing it known to me/us:-

HOLLOW CHARGE WITH A METALLIC LINING, METHOD AND DEVICE FOR ITS MANUFACTURING

The present invention relates to a hollow charge for piercing armor plating consisting of layers to deflect a homogeneous hollow-charge jet, comprising an ammunition body with a rotationally symmetrical, ductile, metallic lining lockedly embedded in explosive; a method for manufacturing this lining; and a device for carrying out this manufacturing method.

Hollow charges have long been used against armor, leading to the development of the most varied countermeasures, such as, in particular, the building-up of armor plate of layers of materials of widely differing densities and hardnesses, causing the homogeneous hollow-charge jet to be deflected.

Subsequently, hollow charges were developed that had a lining composed of a pseudo-alloy of tungsten and copper (FR-A-2 530 800). This lining is prepared powder-metallurgically by sintering tungsten powder with a particle size smaller than 50$\mu$m, and copper powder, the tungsten component amounting to 80 wt.-%. Due to the sintering process, such linings are of a relatively low density and, particularly with layered armor, have a slight piercing capability only, although their deflection is less.

It is an object of the invention to provide a hollow charge having high piercing effect with respect to armor platings which deflect and/or interfere with conventional hollow-charge jets.

According to the invention, this is achieved by providing a metallic hollow-charge lining having a three-dimensional isotropy and the density of which is at least 98% of the crystal density of the metal.

It is equally an object of the invention to provide a method for manufacturing and a device for carrying out

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the method which permit an economically feasible manufacturing of the metallic lining of the hollow charge according to the invention.

The method of manufacturing of the metallic lining is characterised by the following steps:

atomizing at least one metal in a stream of air or of inert gas;

mixing the resulting metal powder in a broad particle-size distribution;

filling the metal powder into the interspace of a rotationally symmetrical, double-walled, ductile, high-temperature-resistant container having at least approximately uniform wall thickness all around;

flushing and/or reducing the metal powder and the interspace of the double-walled container with hydrogen;

closing the double-walled container and sealing it in a gas-tight manner;

exposing the sealed container on all sides to an elevated gas pressure while heating at the same time, resulting in hot, isostatic pressing; and

removing the sealed container.

The device for carrying out the manufacturing method is characterized in that the double-walled container is made of a structural steel, of a light metal or of a quartz glass and has on all sides a wall thickness of 0.8 to 3.0 mm.

Due to the three-dimensional isotrophy, the lining of the hollow charge according to the invention has a texture-free, crystalline structure which achieves more than 98% of the maximally possible density, i.e., the crystal density.

The hollow charge according to the invention has an enormous advantage inasmuch as, after detonation, the hollow-charge jet penetrates the armor plating in the pulverized, i.e., non-coherent state and is thus not deflected by a layered armor plating. Density

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of the jet is high; moreover, it is possible to use materials that are non-alloyable or not suitable for a sintering process.

The method according to the invention for manufacturing the metallic lining of hollow charges has furthermore the great advantage that it achieves greater precision as to shape and dimensions with substantially less expenditure in material than is possible with the conventional methods. Manufacturing by the method according to the invention is thereby also more economical and less labor-intensive. During filling of the metal powder, it has proved useful to vibrate the double-walled container, to achieve a homogeneous and compact filling without gas or air inclusions in the interspace. The sealed-off metal container is subsequently removed by rough turning. This, however, can be achieved also with the aid of a laser cutting device.

The stripped lining is very precise with respect to shape and dimensions ("near net shaping") and therefore needs only a slight secondary operation, mostly by machining, for mounting in the ammunition body.

The method according to claim 3 results in a particularly homogeneous, isotropic structure of the pressure-molded component.

The method according to claims 4 to 7 has shown its value with metallic linings of copper, tantalum, tungsten and uranium.

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It will be appreciated, however, that the method according to the invention is also applicable to mixtures of the above-mentioned metal powders. The method parameters are then mainly determined by the metal having the largest share in the metal powder.

The selection of metals for the double-walled container according to claim 8 is particularly suitable for hot isostatic pressing at high gas pressures and temperatures.

Further advantages will become apparent in the subsequent description in which the invention is explained in greater detail with the aid of drawings representing embodiments given by way of examples.

In these drawings:

Fig. 1 is a schematic representation of the method steps for the manufacturing of a rotationally symmetrical, ductile metallic lining;

Fig. 2 shows a double-walled, conical container with a filling socket arranged at its top, and

Fig. 3 illustrates a double-walled, conical container with the filling socket arranged below.

In Fig. 1 the separate steps of the manufacturing method for a rotationally symmetrical, metallic lining are represented schematically and marked with capital letters:

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A: A double-walled container 1 is produced by conventional sheet-metal processing, such as bending and the use of a welding device 2.

Further details of the double-walled container 1 are explained in the subsequent description of Figs. 2 and 3.

B: A metal powder, for instance of copper, having a flat, broad particle-size distribution between 10 and 200 µm is poured from a filling container 3 into the double-walled container 1, while the filling container 3 is being vibrated (indicated by arrows), to achieve as high a filling density as possible.

The usual consignments of metal powders do not, normally, have the desired particle-size distribution, so that a mixture of several powder consignments is necessary. In some cases, certain powder charges must be sieved prior to use, as according to experience a particle size of 200 µm must not be exceeded.

The metal powders used have been produced by the per se known atomizing in an air or inert-gas stream. This makes it easy for the surfaces of the powder grains to oxidize, or for air or inert-gas inclusions to be formed in the powder. For reliable functioning of an ammunition explosive with ductile, metallic linings made of this metal powder, oxide and gas inclusions are, however, undesirable. With oxidizable metals, reduction or powder purification is therefore unavoidable.

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C: The oxidized metal powder in the filled, double-walled container 1 is purified, i.e., reduced, by flushing with hydrogen (indicated by arrows) for one hour at 400° C in a furnace 4.

D: Immediately after that, the double-walled container 1 is hermetically sealed (counterdirected arrows), which prevents further oxidation or other contamination of the metal powder. To this end, the filling tube of the double-walled container is crimped, cut, and closed by welding.

E: In an autoclave 5, the closed double-walled container 1 is subjected to treatment by the hot isostatic pressing method (HIP), details of which can be found in an article by P.E. Price and S.P. Kohler, "Hot Isostatic Pressing of Metal Powders," Metals Handbook, Powder Metallurgy, 9th ed., Vol. 7 (6/1984), p. 419 ff; Metals Park ASM. The autoclave 5 is of the type Graphite Furnace of Messrs. J. Dieffenbacher GmbH & Co., with a pressure resistance of 350 MPa and a temperature resistance of 3000° C.

F: This diagram shows pressure and temperature during the separate stages of hot isostatic pressing as a function of time, the pressure curve (p,t) being denoted by solid lines and the temperature curve (T,t) by broken lines. Starting at point $\alpha$ at normal pressure ($p_o$) and normal temperature ($T_o$), evacuation of the autoclave 5 is initiated (time $t_o$), up to point $\beta$ (time $t_1$), when a negative pressure

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of $p_1$ of 10 Pa is attained. Then the autoclave 5 is filled with argon up to a pressure of $p_2$ of 30 MPa (point $\gamma$ ; time $t_2$). Starting from this point, the temperature is raised from $T_o$ (ambient temperature $\approx 20^oC$) to a temperature $T_1$ to be determined according to the metal selected (point $\delta$ ; time $t_3$). The HIP temperature $T_1$ lies mostly between the recrystallization temperature which amounts to approximately half the melting temperature, and the melting temperature of the metal. For copper, $T_1$ lies between 650°C and 1050°C, preferably at 800°C. For tantalum, $T_1$ lies between 1700°C and 2980°C, preferably at 2200°C, for tungsten between 1000°C and 1800°C, preferably at 1430°C, and for uranium between 600°C and 1120°C, preferably at 850°C. Too low a HIP temperature causes an undesirable porosity of the workpiece; too high a HIP temperature produces an undesirable growth of crystallites.

At this temperature rise, pressure in the autoclave 5 increases due to the expansion of the gas (law of Boyle-Gay-Lussac) to a pressure $p_3$, which should be at least 100 MPa and at most 320 MPa. A preferred pressure $p_3$ is 130 MPa. To keep manufacturing costs low, as many workpieces (filled double-walled containers) as possible are simultaneously hot-isostatically pressed in the autoclave 5.

During a certain time interval ($t_4$-$t_3$) which is between 1 and 6 hours, preferably about 3 hours, temperature $T_1$ and pressure $p_3$ are maintained constant (point $\varepsilon$ ), after which the temperature is per-

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mitted to cool down to ambient temperature $T_0$ and pressure is reduced to normal pressure $p_0$ (point θ ). Cooling of the workpieces in the containers 1 should proceed slowly, to prevent allotropic transformations, especially martensitic transformation in the welding seams. These are liable to lead to hardening and embrittlement, which would make the subsequent turning operations more difficult and would impair the isotropy of the lining produced.

G: After the hot isostatic pressing, the double-walled container 1 as well as the oversize of the workpiece are removed in two turning operations. The first is a rough cut, for which the container is pneumatically chucked at its interior wall on a lathe. The exterior wall is then rough-machined, using a lathe tool 6, until the exterior container wall is fully removed. The rough-machined exterior wall is then chucked, and the interior wall rough-machined, until it, too, is removed. The second turning operation is a finishing operation, causing the workpiece surfaces to become smooth. This operation must be performed with great care so as not to produce structural changes in the hot isostatically pressed metal. It is, however, possible to remove the container also with the aid of a laser cutting device.

The lining for a hollow charge produced in this way has a texture-free, crystalline structure and is practically isotropic, i.e., has the same physical properties in any direction.

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The same reference numerals have been used in Fig. 2 and 3 for the same components.

Fig. 2 is a more detailed representation of the double-walled container 1. The container 1 consists of a metallic internal-cone wall 7', a metallic external-cone wall 7" and a filler tube or socket 8. The lower edge of the internal-cone wall 7' is flanged towards the outside and, by means of a lower welding seam 9, welded to the exterior-cone wall 7". The filler socket 8 is mounted on an opening 10 at the apex of the exterior-cone wall 7" and is welded thereto via an upper welding seam 11.

The container 1 is made either of a light-metal alloy comprising Al and Mn, Al and Mg, or Al, Mg and Si for a HIP-temperature range of up to 600°C, or of commercially available structural steel, i.e. a steel containing less than 2% carbon, for a HIP-temperature range from 600°C to 1500°C, or of a high-melting-point quartz glass for a HIP-temperature range from 1500°C to 3000°C. The cone walls 7' and 7", and the filler socket 8 are of identical thickness which varies between 0.8mm and 3.0mm. The wall thickness is selected so that, on the one hand, it is heavy enough to absorb the high pressure of hot isostatic pressing and, on the other, thin enough to bear the compression of the metal powder without cracking or warping. To achieve a maximally homogeneous pressure distribution (isostatic), the interspace 12 between the cone walls 7' and 7" should be made as small as possible. The width of the interspace 12 also depends on the material o. the double-walled container 1, on the metal powder 13 to be comp[illegible]sed and on the compaction of the latter in the as-poured state. For, e.g., structural steel and copper powder, this width is 2.0mm, and for quartz glass and tungsten powder, 3.0mm, corresponding to a wall thickness of the hot-isostatically pressed workpiece of 1.2mm.

During the hot isostatic pressing process, the cone walls 7', 7" will be most strongly deformed in the middle region, as the end regions are fixed by the welding seams 9 and 11, the width of the interspace 12 being therefore hardly reduced at these zones. Besides, a geometry-dependent safety margin is provided which will compensate for the deformation of the cone walls 7' and 7" occurring during the hot isostatic pressing. Furthermore, the apex angle of the double-walled container 1 will slightly increase, i.e., by about $1^{\circ}$. This deformation can be allowed for by an additional widening of the interspace 12 or, preferably, by a reduction of the apex angle.

The filling level 14 of the metal powder 13 to be filled in is determined empirically:

- the metal powder 13 must not be blown out of the double-walled container proper during hydrogen flushing, and

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- sufficient compressed metal powder should be present at the extremities (welding seam 9 and 11) to prevent the workpiece from becoming porous at these points after hot isostatic pressing.

Fig. 3 shows a double-walled container 1 with a filler socket 8 at the lower end. This is advantageous when trouble-free pouring is demanded, as well as perfect compaction at the extremities of the container 1, such as here at the cone apex. During pouring, the container 1 is vibrated, e.g., by ultrasound, so that a high degree of compaction of the metal powder 13 is achieved in the entire container 1.

In the above-described manufacturing method it is particularly important that, during hot isostatic pressing, the rotationally symmetrical container 1 as such should be crushed as little as possible. This demand can be met by a container, closed on one side as in the above conical shape, or with a onesidedly closed cylindrical shape.

The thus manufactured conical linings are lockedly embedded in an ammunition body and, together with the latter, form a hollow charge, the hollow-charge jet of which is nonhomogeneous. Such hollow charges are particularly suitable for piercing armor plating built up of layers with differing physical properties and behavior.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A hollow charge for piercing armor plating built-up of layers to deflect a homogeneous hollow-charge jet, comprising an ammunition body with a rotationally symmetrical, ductile, metallic lining lockedly embedded in explosive, characterised in that the metallic lining has a three-dimensional isotropy and its density is at least 98% of the crystal density of the metal.

2. A method for manufacturing a metallic lining according to claim 1, comprising the following steps:

atomizing at least one metal in a stream of air or of inert gas;

mixing the resulting metal powder in a broad particle-size distribution;

filling the metal powder into the interspace of a rotationally symmetrical, double-walled, ductile, high-temperature-resistant container having at least approximately uniform wall thickness all around;

flushing and/or reducing the metal powder and the interspace of the double-walled container with hydrogen;

closing the double-walled container and sealing it in a gas-tight manner;

exposing the sealed container on all sides to an elevated gas pressure while heating at the same time, resulting in hot, isostatic pressing; and

removing the sealed container.

3. A method for manufacturing a metallic lining as claimed in claim 2, characterised in that in the exposing step the double-walled container is exposed to a gas pressure of at least 100 MPa and brought to a temperature lying approximately between the recrystallization temperature and the melting temperature of the metal to

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be processed.

4. The method for manufacturing a metallic lining as claimed in claim 3, characterised in that the at least one metal which is atomized is copper, and that in the exposing step the double-walled container is exposed to a gas pressure of between 100 MPa and 320 MPa, preferably 130 MPa, and is heated to a temperature of between 550°C and 1050°C, preferably 800°C, for a period of time of 1 hour to 6 hours, preferably 3 hours.

5. The method for manufacturing a metallic lining as claimed in claim 3, characterised in that the at least one metal which is atomized is tantalum, and that in the exposing step the double-walled container is exposed to a gas pressure of between 100 MPa and 320 MPa, preferably 130 MPa, and is heated to a temperature of between 1700°C and 2980°C, preferably 2200°C, for a period of time of 1 hour to 6 hours, preferably 3 hours.

6. The method for manufacturing a metallic lining according to claim 3, characterised in that the at least one metal which is atomized is tungsten, and that in the exposing step the double-walled container is exposed to a gas pressure of between 100 MPa and 320 MPa, preferably 130 MPa, and is heated to a temperature of between 1000°C and 1800°C, preferably 1430°C, for a period of time of 1 hour to 6 hour, preferably 3 hours.

7. The method for manufacturing a metallic lining as claimed in claim 3, characterised in that the at least one metal which is atomized is uranium, and that in the exposing step the double-walled container is exposed to a gas pressure of between 100 MPa and 320 MPa, preferably 130 MPa, and is heated to a temperature of between 600°C and 1120°C, preferably 850°C, for a period of time of 1

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hour to 6 hours, preferably 3 hours.

8. A device for carrying out the manufacturing method as claimed in any one of claims 2 to 7, characterised in that the double-walled container is made of structural steel, of a light metal or of a quartz glass, and has a wall thickness, on all sides, of 0.3 to 3.0 mm.

9. A hollow charge substantially as herein described with reference to the accompanying drawings.

10. A method for manufacturing a metallic lining substantially as herein described with reference to the accompanying drawings.

Dated this 3rd day of January 1992
SCHWEIZERISCHE EIDGENOSSENSCHAFT VERTRETEN
DURCH DIE EIDG. MUNITIONSFABRIK THUN
DER GRUPPE FÜR RÜSTUNGSDIENSTE

By their Patent Attorney
GRIFFITH HACK & CO.

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MVS

Nomenclature

A–G - Steps of the manufacturing method

α, β, γ, δ, ε, θ – points on the HIP–process diagram

1 Double-walled container

2 Welding device

3 Filling container

4 Furnace

5 Autoclave

6 Lathe tool

7' Metallic interior-cone wall

7" Metallic exterior-cone wall

8 Filler socket

9 Lower welding seam

10 Opening

11 Upper welding seam

12 Interspace

13 Metal powder

14 Filling level

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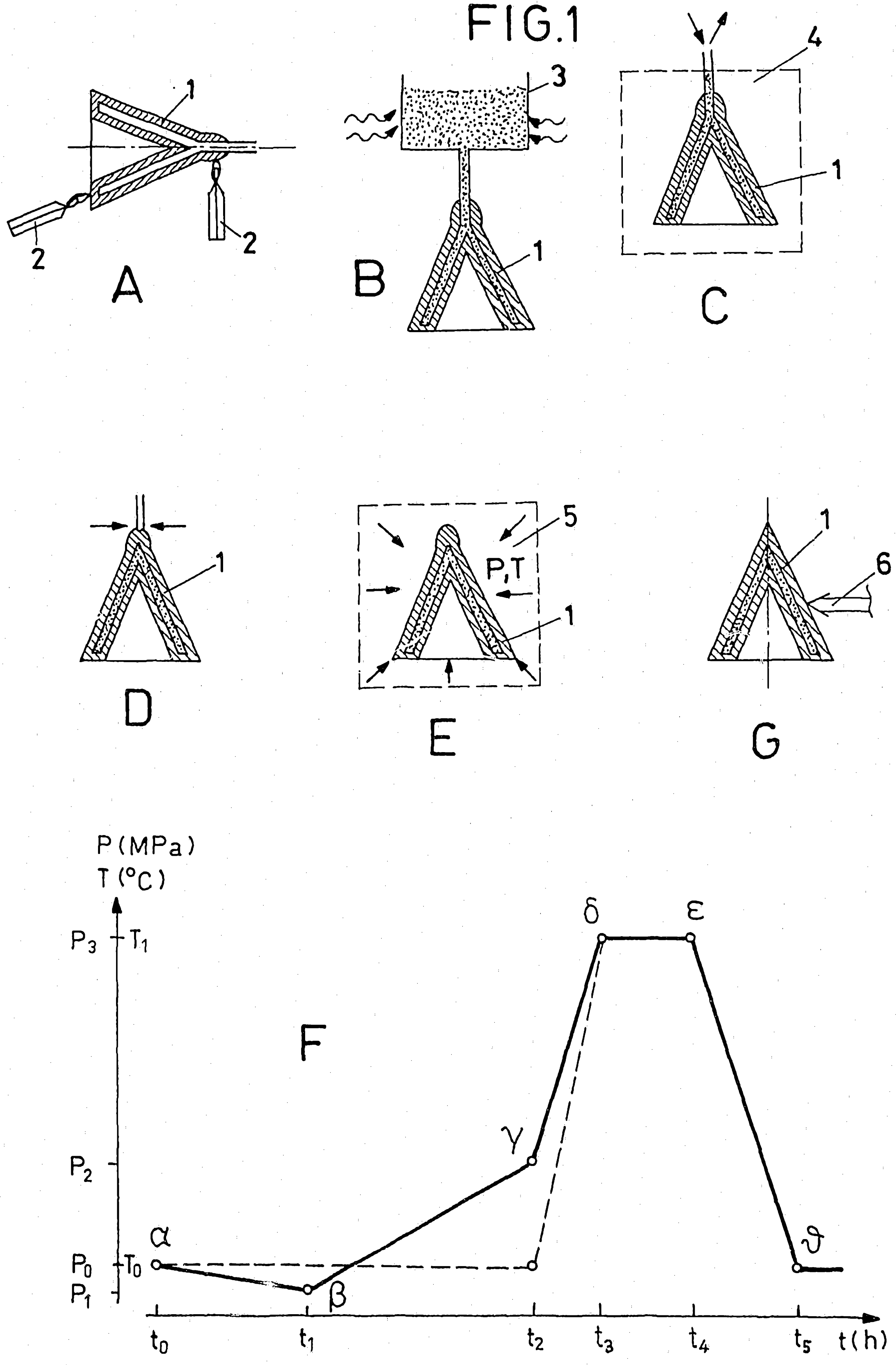
FIG.1

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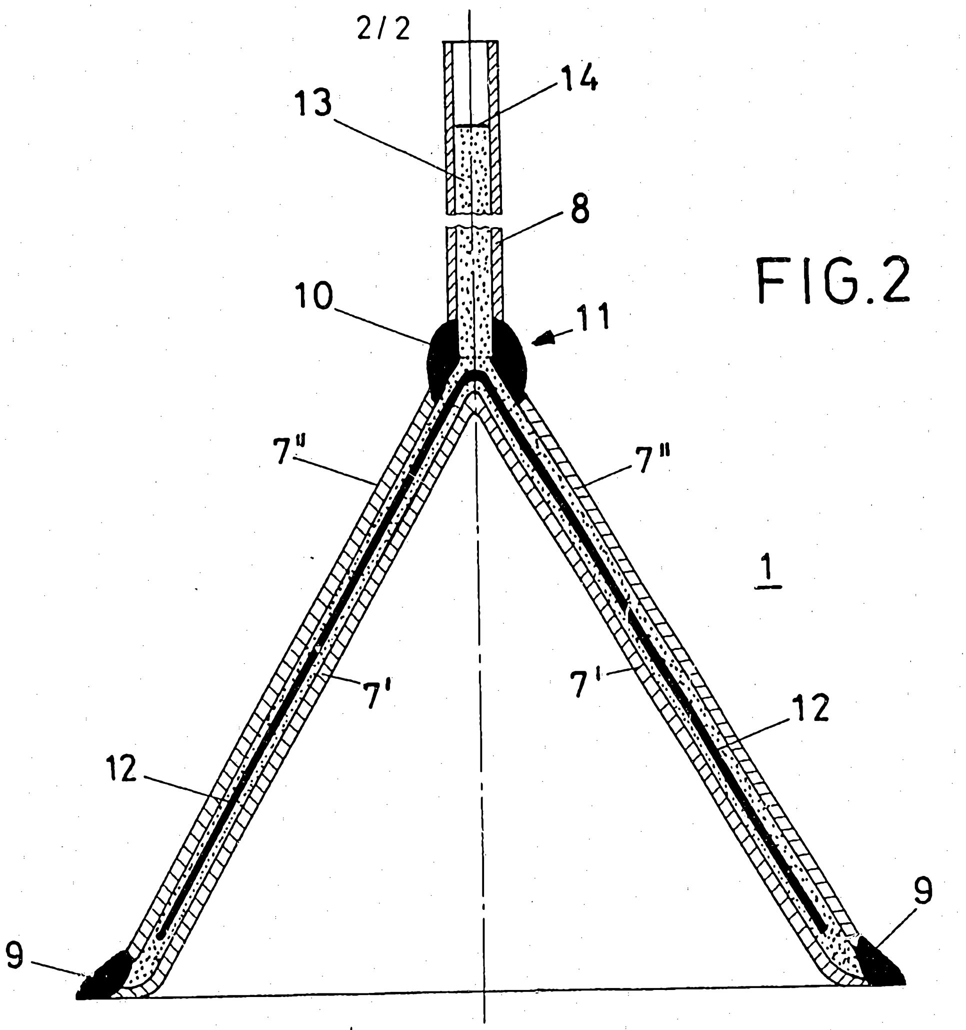


FIG.2

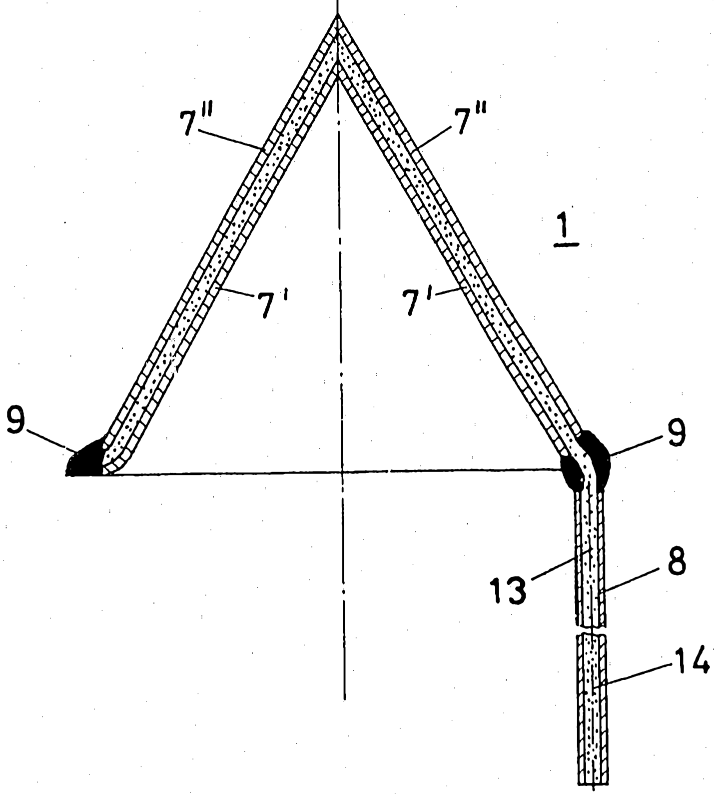


FIG.3