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(71) Demandeur/Applicant:
BENGTSSON, JAN-AKE, SE
(72) Inventeur/Inventor:
BENGTSSON, JAN-AKE, SE
(74) Agent: RIDOUT & MAYBEE LLP

(54) Titre : PROCEDE ET CARTOUCHE DE DESARMEMENT D'UNE CHARGE DE SAUTAGE NON EXPLOSEE DANS UN TROU DE FORAGE

(54) Title: A METHOD OF AND A CARTRIDGE FOR DISARMING AN UNEXPLODED BLASTING CHARGE IN A DRILL HOLE

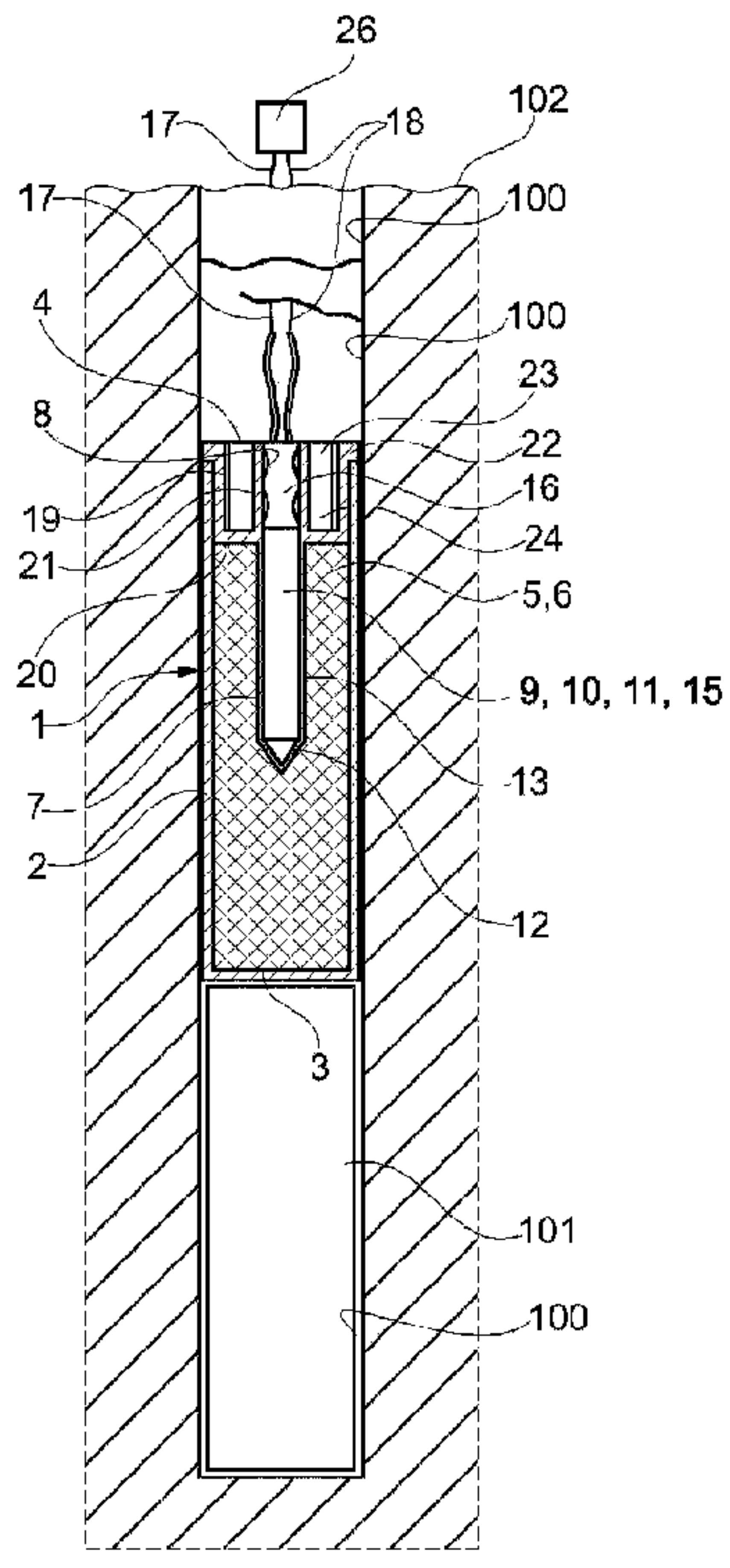

Fig. 3

(57) Abrégé/Abstract:
A method of disarming an unexploded blasting charge (101) in a drill hole (100), comprising: - providing a non-exploding cartridge (1) containing - a pyrotechnic composition (6) able to generate a high temperature fire, and - a blasting cap (10) for igniting the pyrotechnic composition (6); and - igniting the pyrotechnic composition (6) in the non-exploding cartridge (1) to burn away the blasting charge (101). The pyrotechnic composition (6) in the non-exploding cartridge (1) preferably is thermite.

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(72) Inventor; and
(71) Applicant: BENGTSSON, Jan-Åke [SE/SE]; Ollestad 4A, 524 95 LJUNG (SE).

(74) Agent: JOHANSSON, Lars E; 138, ., 683 23 HAGFORS (SE).

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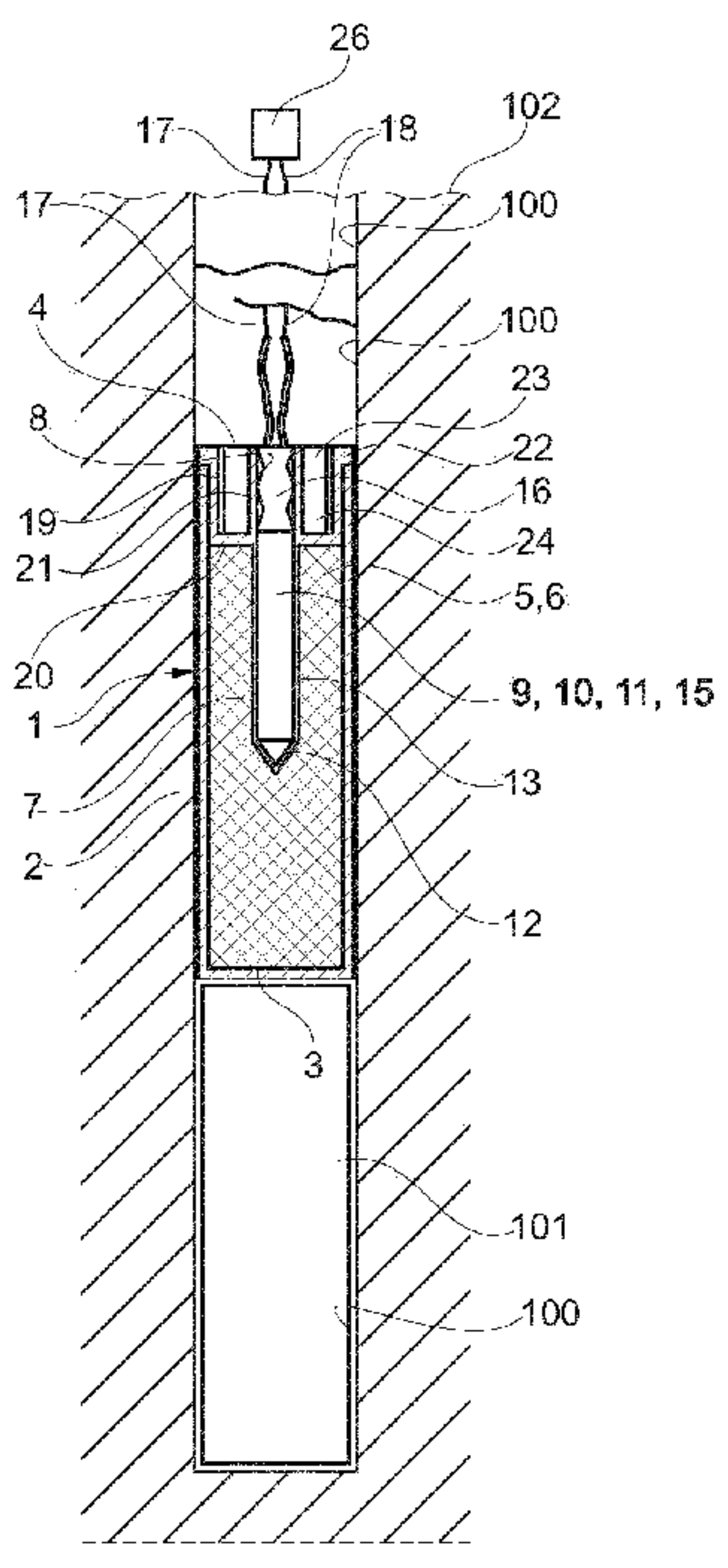

Fig. 3

(57) Abstract: A method of disarming an unexploded blasting charge (101) in a drill hole (100), comprising: – providing a non-exploding cartridge (1) containing – a pyrotechnic composition (6) able to generate a high temperature fire, and – a blasting cap (10) for igniting the pyrotechnic composition (6); and – igniting the pyrotechnic composition (6) in the non-exploding cartridge (1) to burn away the blasting charge (101). The pyrotechnic composition (6) in the non-exploding cartridge (1) preferably is thermite.

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A METHOD OF AND A CARTRIDGE FOR DISARMING AN UNEXPLODED BLASTING CHARGE IN A DRILL HOLE

TECHNICAL FIELD

The present invention relates to a method of disarming an unexploded blasting charge in a drill hole.

It also relates to a cartridge for disarming an unexploded blasting charge in a drill hole, comprising:

- a substantially cylindrical outer sleeve with an end wall in a first end;
- a plug, which, enclosing said outer sleeve, is inserted into and secured in an opposite second end of the outer sleeve;
- a main chamber in the outer sleeve between said end wall and said plug, which main chamber is filled with a pyrotechnic composition;
- an opening in one of said plug and/or end wall for receiving an igniting device including an igniting charge arranged to ignite said pyrotechnic composition, said pyrotechnic composition including a metal powder fuel and a metal oxide serving as an oxidizer, said composition upon ignition undergoing an exothermic reduction-oxidation (redox) reaction arranged to burn away said blasting charge.

BACKGROUND ART

Dynamite is usually sold in the form of cardboard cylinders about 20 cm (8 in) long and about 3.2 cm (1.25 in) in diameter, with a weight of about 190 grams. It consists of a mixture of nitroglycerine, an absorbent, and possible additives, like a stabilizer, a freezing point depressant, and a brisance improver. Dynamite will not detonate by heat and is moderately sensitive to shock. Shock resistance tests are usually carried out with a drop-hammer: about 100 mg of explosive is placed on an anvil, upon which a weight of between 0.5 and 10 kg is dropped from different heights until detonation is achieved. With a hammer of 2 kg, mercury fulminate detonates with a drop distance of 1 to 2 cm, nitroglycerin with 4 to 5 cm, dynamite with 15 to 30 cm, and ammoniacal explosives with 40 to 50 cm.

When blasting rock with dynamite, e.g. for a building site, there are often used multiple charges, i.e. a plurality of drilled holes provided with dynamite. Not too rarely one or more of the charges do not ignite, but stay undetonated in the hole. This may cause death, if later an excavator unluckily hits and detonates the undetonated dynamite charge. Today specially trained dogs are used to find such undetonated charges to make it possible to remove them before starting excavating. However, the methods of today for removal of an undetonated dynamite charge from deep in a hole in the rock, i.e. digging it out, is very time consuming and dangerous.

US 6,765,121 B2 discloses a method and an apparatus for neutralization of the explosive content of mines and unexploded ordnance ("UXO"). Such ordnance includes not only unexploded shells, rockets, and fuses, but also ordnance that is designed to explode on contact or is triggered to explode by another activation mechanism, such as a detonator, such as a land, underwater, or shallow water mine. There exist many sources of UXO which must be destroyed. The idea is to essentially completely consume the explosive charge by combustion or decomposition before any explosion occurs. Similar methods, i.e. disposal of bombs, wherein a casing/shell surrounds an explosive material, are known from CN 203719554 and GB 2335971. 48341.

The method comprises reacting, on or near the surface of the mine or UXO, a charge of a compound that reacts with an extremely high heat-release rate. The intense exothermic reaction generates high temperature combustion products that will melt, burn, or otherwise disrupt, a metal, plastic, composite, or wooden casing, thus leading to combustion or decomposition of the explosive.

In an alternative embodiment, the high temperature in the casing decomposes the content thereof, causing the pressure in the casing to rise, fracturing the casing before the explosive detonates. In either case, the disrupted casing enables ignition of a large area of the explosive charge and provides easy access for atmospheric air to support active burnout of the explosive.

From FR 1348341 it is known to use a thermite charged vessel for nonexploding destruction of machinery instead of using explosive charges for the destruction.

WO 2009/120139 discloses a powder charged rock cracker cartridge of the kind stated in the second paragraph above. The pyrotechnic composition is gun powder, and the cracker cartridge satisfies the requirements of lowest explosive classification, which allows transportation and storing without those rigorous safety rules that apply for higher explosive classifications. Further, the cracker cartridge is easy to manufacture and easy to use, including easy to prime as well as to unprime safely on the working place.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a method of and a cartridge for disarming an unexploded blasting charge in a drill hole.

In a first aspect of the invention, this object is achieved in that the method comprises the steps of:

- providing a non-exploding cartridge containing a pyrotechnic composition able to generate a high temperature fire, and an igniting device for igniting the pyrotechnic composition; and,
  introducing the non-exploding cartridge into a drill hole containing said unexploded blasting charge, and,
  igniting the pyrotechnic composition in the non-exploding cartridge to burn away the blasting charge.

Thereby, the unexploded blasting charge will be disarmed by combustion or decomposition without any risk of detonation. Thanks to the invention a much more efficient procedure is achieved, e.g. providing significantly less labor and being significantly quicker. Further the invention may result in reduced costs, especially as in the preferred case a cartridge is used that already exist on the market. Moreover, the invention may result in increased safety, especially as in the most preferred case a specific extra safe cartridge is used that already exist on the market.

Preferably, the pyrotechnic composition contains thermite. Thermite is a pyrotechnic composition of metal powder fuel, e.g. aluminum (Al), and metal oxide, e.g. Fe_2O_3 or Fe_3O_4. When ignited by heat, thermite undergoes an exothermic reduction-oxidation (redox) reaction, e.g.

$$Fe_2O_3 + 2\ Al \rightarrow 2\ Fe + Al_2O_3$$

The reaction is used in thermite welding, e.g. to join rail tracks, and in demolition of munitions, and occurs, because aluminum forms stronger, more stable, bonds with oxygen than iron. The same reaction applies to other metal powder fuels and other metal oxides, but as aluminum has a high boiling point and a low melting point, so that the reaction can occur mainly in the liquid phase, and both aluminum and red iron(III) oxide are inexpensive, a mixture of aluminum and red iron(III) oxide is preferred.

In a second aspect of the invention, the object stated above is achieved in that the pyrotechnic composition referred to in the second paragraph above includes a metal powder fuel and a metal oxide serving as an oxidizer, said composition upon ignition undergoing an exothermic reduction-oxidation (redox) reaction. Thereby, the unexploded blasting charge will be disarmed by combustion or decomposition without any risk of detonation.

Preferably, the pyrotechnic composition includes thermite. As explained above, thermite is a pyrotechnic composition of metal powder fuel, e.g. aluminum (Al), and metal oxide, e.g. Fe_2O_3 or Fe_3O_4. When ignited by heat, thermite undergoes an exothermic reduction-oxidation (redox) reaction, and the unexploded blasting charge will be disarmed by combustion or decomposition without any risk of detonation.

Suitably the metal fuel is selected from the group consisting of aluminum, magnesium, titanium, zinc, silicon, and boron. In principle, any reactive metal could be used instead of aluminum. This is rarely done, because the properties of aluminum are nearly ideal for this reaction:

- It is by far the cheapest of the highly reactive metals. For example, in Dec 2014, tin was 19,830 USD/metric ton, zinc was 2,180 USD/ton and aluminum was 1,910 USD/ton.
- It forms a passivation layer making it safer to handle than many other reactive metals.
- Its relatively low melting point (660 °C) means that it is easy to melt the metal, so that the reaction can occur mainly in the liquid phase and thus proceeds fairly quickly.
- Its high boiling point (2519 °C) enables the reaction to reach very high temperatures, since several processes tend to limit the maximum temperature to just below the boiling point. Such a high boiling point is common among transition metals (e.g., iron and copper boil at 2887 °C and 2582 °C respectively), but is especially unusual among the highly reactive metals (cf. magnesium and sodium, which boil at 1090 °C and 883 °C respectively).

It is also suitable that the oxidizer is selected from the group consisting of iron (III) oxide, iron (II, III) oxide, manganese (IV) oxide, chromium (III) oxide, silicon (IV) oxide, copper (II) oxide, bismuth (III) oxide, boron (III) oxide, and lead (II, IV) oxide. Similarly, hematite or red iron (III) oxide (Fe_2O_3) is most preferred, but magnetite or iron (II, III) oxide (Fe_3O_4) also works satisfactorily. Other oxides are occasionally used for special purposes but are not preferred in the present application, such as MnO_2 in manganese thermite, Cr_2O_3 in chromium thermite, quartz in silicon thermite, or copper (II) oxide (CuO) in copper thermite. In special applications, fluoropolymers may be substituted for the metal oxides, PTFE with magnesium or aluminum being a relatively common example. Fluoropolymer containing pyrotechnic compositions are usually called "pyrolants", but the word "thermite" is used interchangeably with, and more commonly than, "pyrolant".

Even though many different forms of igniting devices may be used to ignite the composition, e.g. fuse wire, NONEL, blasting caps, etc. Blasting caps may be preferred in many situations. The blasting cap may be a non-electric cap or a fuse cap. In most situations it preferably is an electric cap, e.g. an electrically triggered detonator, i.e. containing an easy-to-ignite primary explosive that provides the initial activation energy to start the detonation in the main charge. Preferably the igniting device is stored separately and not inserted into the main explosive charge until just before use, keeping the main charge safe.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following, a preferred embodiment of the invention will be described in more detail with reference to preferred embodiments and the appended drawings.

Fig. 1 shows a preferred embodiment of a cartridge in a cross sectional side view, suitable for disarming an unexploded blasting cartridge according to the invention,

Fig. 2 shows, at a larger scale, a preferred embodiment of an insert unit, which in Fig. 1 is shown inserted in the upper end of the cartridge, and

Fig. 3 is longitudinal cross section through the primed cartridge of Fig. 1 and 2 inserted in a drill hole, where there is an unexploded blasting charge.

MODE(S) FOR CARRYING OUT THE INVENTION

In figs. 1 and 2 there are shown a preferred embodiment of a cartridge suitable for disarming an unexploded blasting cartridge according to the invention. As is evident for the skilled person various designs of blasting devices 10, e.g. blasting caps may be used to fulfill the object of the invention.

In the following the invention will be described in more detail by referring to said preferred cartridge 1. The cartridge 1 may be seen to comprise basically two parts; an outer plastic sleeve 2 and an insert unit 25, which in turn comprises a plug 4 and an inner sleeve 7.

The plug 4 and the inner sleeve 7 may, according to a preferred embodiment, be made of an acetal plastic material, more specifically of an acetal (POM) copolymer and are molded jointly to form an integrated unit.

The outer sleeve 2 may preferably be made of so called ABS plastic and has the shape of an elongated circular-cylindrical tube, preferably with a flat end wall 3. The interior of the outer sleeve 2 forms a main chamber 5 which is filled with a non-exploding pyrotechnic composition charge 6. The plug 4 has a circular-cylindrical outer wall 19, a preferably flat, annular end wall 20, which faces the main chamber 6 and applied against the powder charge 6, and a tubular portion 21, which defines a through hole 8 that is coaxial with the outer sleeve 2. Radial supporting beams 24 may be arranged to improve strength, preferably extending between the tubular portion 21 and the cylindrical wall. Wedge-shaped, material saving recesses 23 are preferably arranged between the beams 24. An upper flange is designated 22.

The inner sleeve 7, which is coaxial with the outer sleeve 2, extends from the end wall 20 of the plug 4 into the non-exploding pyrotechnic composition charge 6 in the outer sleeve to a sufficient depth in the non-exploding pyrotechnic composition charge 6 as is illustrated in Fig. 3. The inner sleeve 7 preferably has a very thin wall 13. It may optionally be provided with longitudinal, external stiffening protrusions 14 in order to increase its strength. Its cylindrical inside surface is preferably completely smooth. Its nose portion 12 may be tapered. More specifically, the nose portion 12 is preferably tapered at an acute angle according to the disclosed embodiment.

The plug 4 is pressed into the mouth section of the outer sleeve 2 so far that the flange 22 abuts the upper edge of the outer sleeve 2 and the end wall 20 of the plug with some pressure contacts the pyrotechnic composition charge 6. When entering the insert unit 25, the inner sleeve 7 will be pressed into the non-exploding pyrotechnic composition charge 6, which is facilitated by its pointed nose portion 12. The amount of powder of the non-exploding pyrotechnic composition charge 6 is adapted to the space which shall accommodate the powder, e.g. such that the non-exploding pyrotechnic composition charge 6 will be compacted to some degree, which may be advantageous because that prevents the powder from moving to any essential degree during transportation, and it also guarantees a good contact between the outer surface of the inner sleeve 7 and the powder. On the other hand, the pressure exerted by the insert unit 25 may not be exaggerated such that the thin wall 13 of the inner sleeve 7 is damaged or pressed together to any significant degree.

In the thus assembled cartridge 1, the interior inner sleeve forms a direct continuation of the through hole 8 in the plug 4 and it also has the same cross section shape and area as the hole 8. This means that the hole 8 and the space in the inner sleeve 7 in combination form an integrated chamber, denominated priming chamber 9. In the priming chamber 9, that section of the priming chamber which is defined by the inner sleeve 7 is referred to as igniting chamber 11 in this context.

When priming the cartridge 1, which is carried out on the blasting site, a blasting cap 10 may be entered into the priming chamber 9. The blasting cap 10 may contain an igniting charge which can be ignited electrically, for example, and if desired also a delay element, all of which may be enclosed in a cylindrical capsule 15, e.g. of aluminum. When the blasting cap 10 is an electric one, it has two fuse wire leads 17, 18 (Fig. 3). Their outer ends are to be connected to an apparatus generally called a blasting machine 26.

When the cartridge 1 is primed, it is inserted in a drill hole 100 in a surface of exposed rock 102 until it makes contact with the unexploded blasting charge 101 as shown in Fig. 3. The drill hole 100 may have a diameter within the range of 22-85 mm. The outer sleeve 2 of the cartridge 1 will have an adapted diameter to properly fit into the hole 100, i.e. in the range of 16- 80 mm, more preferred 30-50 mm. The inner ends of the fuse wire leads 17, 18 are connected to each other by a thin bridge wire in direct contact with the igniting charge. When the blasting cap 10 is entered into the priming chamber 9, Fig. 3, at least that part of the capsule 15 which contains the igniting charge is in direct contact with the inside surface of the inner sleeve 7 in the igniting chamber 11. When the igniting charge is ignited by an electric spark, it develops such a high pressure and such a violent flame of fire that the thin-walled inner sleeve 7 will be torn to pieces and the non-exploding pyrotechnic composition charge 6 will be ignited and start burning at sufficiently high temperature to burn away the unexploded blasting charge 101.

The non-exploding pyrotechnic composition 6 includes a metal powder fuel and a metal oxide serving as an oxidizer. Upon ignition, the composition undergoes an exothermic reduction-oxidation (redox) reaction producing a sufficiently high temperature. Thereby, the unexploded blasting charge 101 will be disarmed by combustion or decomposition without any risk of detonation.

Preferably, the non-exploding pyrotechnic composition 6 includes thermite. As explained above, thermite is a pyrotechnic composition of metal powder fuel, e.g. aluminum (Al), and metal oxide, e.g. Fe_2O_3 or Fe_3O_4. When ignited by heat, thermite undergoes an exothermic reduction-oxidation (redox) reaction, and the unexploded blasting charge will be disarmed by combustion or decomposition without any risk of detonation.

Although the reactants are stable at room temperature, they burn with an extremely intense exothermic reaction when they are heated to ignition temperature. The products emerge as liquids due to the high temperatures reached (up to 2500 °C with iron(III) oxide) – although the actual temperature reached depends on how quickly heat can escape to the surrounding environment. Thermite contains its own supply of oxygen and does not require any external source of air. Consequently, it cannot be smothered and may ignite in any environment, given sufficient initial heat. It will burn well while wet and cannot be easily extinguished with water, although enough water will remove heat and may stop the reaction. Small amounts of water will boil before reaching the reaction. Even so, thermite is used for welding underwater. Consequently, even if the unexploded blasting charge 101 in a drill hole 100 is covered by rainwater, for example, the cartridge 1 of the present invention can be used to burn away the unexploded blasting charge 101.

The thermites 6 are characterized by almost complete absence of gas production during burning, high reaction temperature, and production of molten slag. The fuel should have high heat of combustion and produce oxides with low melting point and high boiling point. The oxidizer should contain at least 25% oxygen, have high density, low heat of formation, and produce metal with low melting and high boiling point (so the energy released is not consumed in evaporation of reaction products). Organic binders can be added to the composition to improve its mechanical properties, however they tend to produce endothermic decomposition products, causing some loss of reaction heat and production of gases.

Suitably the metal fuel is selected from the group consisting of aluminum, magnesium, titanium, zinc, silicon, and boron. In principle, any reactive metal could be used instead of aluminum. This is rarely done, because the properties of aluminum are nearly ideal for this reaction:

- It is by far the cheapest of the highly reactive metals. For example, in Dec 2014, tin was 19,830 USD/metric ton, zinc was 2,180 USD/ton and aluminum was 1,910 USD/ton.
- It forms a passivation layer making it safer to handle than many other reactive metals.
- Its relatively low melting point (660 °C) means that it is easy to melt the metal, so that the reaction can occur mainly in the liquid phase and thus proceeds fairly quickly.
- Its high boiling point (2519 °C) enables the reaction to reach very high temperatures, since several processes tend to limit the maximum temperature to just below the boiling point. Such a high boiling point is common among transition metals (e.g., iron and copper boil at 2887 °C and 2582 °C respectively), but is especially unusual among the highly reactive metals (cf. magnesium and sodium, which boil at 1090 °C and 883 °C respectively).

It is also suitable that the oxidizer is selected from the group consisting of iron (III) oxide, iron (II, III) oxide, manganese (IV) oxide, chromium (III) oxide, silicon (IV) oxide, copper (II) oxide, bismuth (III) oxide, boron (III) oxide, and lead (II, IV) oxide. Similarly, hematite or red iron (III) oxide (Fe_2O_3) is most preferred, but magnetite or iron (II, III) oxide (Fe_3O_4) also works satisfactorily. Other oxides are occasionally used for special purposes but are not preferred in the present application, such as MnO_2 in manganese thermite, Cr_2O_3 in chromium thermite, quartz in silicon thermite, or copper (II) oxide (CuO) in copper thermite. In special applications, fluoropolymers may be substituted for the metal oxides, PTFE with magnesium or aluminum being a relatively common example. Fluoropolymer containing pyrotechnic compositions are usually called "pyrolants", but the word "thermite" is used interchangeably with, and more commonly than, "pyrolant".

The temperature achieved during the reaction is dependent on the availability of oxygen. For example, the type of metal oxide has dramatic influence to the amount of energy produced; the higher the oxide, the higher the amount of energy produced. A good example is the difference between manganese (IV) oxide (MnO_2) and manganese (II) oxide (MnO), where the former produces a very high temperature and the latter is barely able to sustain combustion; to achieve good results a mixture with proper ratio of both oxides should be used.

The reaction rate can be also tuned with particle sizes; coarser particles burn slower than finer particles. The effect is more pronounced with the particles requiring being heated to higher temperature to start reacting. This effect is pushed to the extreme with nano-thermites.

Even though ignition device 10 may be of various kinds a conventional blasting cap may be preferred. The blasting cap 10 may be a non-electric cap or a fuse cap, it preferably is an electric cap, more precisely an electrically triggered detonator. A blasting cap contains an easy-to-ignite primary explosive that provides the initial activation energy to start the detonation in the main charge. Explosives commonly used in blasting caps include mercury (II) fulminate ($Hg(CNO)_2$), lead azide ($Pb(N_3)_2$), lead styphnate (lead 2,4,6-trinitroresorcinate $C_6HN_3O_8Pb$) and tetryl (2,4,6-trinitrophenylmethylnitramine $C_7H_5N_5O_8$) and DDNP (diazodinitrophenol $C_6H_2N_4O_5$).

The cartridge 1 of the invention may advantageously be manufactured in a number of different standard lengths, corresponding to diameters and lengths of the blasting charges. Dynamite is usually sold in the form of cardboard cylinders about 20 cm (8 in) long and about 3.2 cm (1.25 in) in diameter, with a weight of about 190 grams (½ troy pound). A stick of dynamite thus produced contains roughly 1 MJ of energy. Other sizes also exist.

The invention is not limited to what has been described above, but may be varied within the scope of the appended claims. It is evident for the skilled person, for example, that the expression plug has to be interpreted in a broad manner, e.g. also including use of an end wall member that may be arranged integrally with outer shell, and also other variations that are within the ambit of the normal design procedure of the skilled person producing such enclosures.

INDUSTRIAL APPLICABILITY

The method of and a cartridge of the present invention are applicable for disarming an unexploded blasting charge in a drill hole by burning away the charge.

CLAIMS

1. A method of disarming an unexploded blasting charge (101) in a drill hole (100), comprising:
   - providing a non-exploding cartridge (1) containing
   - a non-exploding pyrotechnic composition (6) able to generate a high temperature fire, and
   - a blasting device (10) for igniting the non-exploding pyrotechnic composition (6); and
   - introducing the non-exploding cartridge (1) into a drill hole (100) containing said unexploded blasting charge (101),
   - igniting the non-exploding pyrotechnic composition (6) in the non-exploding cartridge (1) to burn away the blasting charge (101).

2. A method as claimed in claim 1, wherein the non-exploding pyrotechnic composition (6) contains a composition that will generate a temperature within the range of 600C° to 5000C°, preferably 700-2500C°.

3. A method as claimed in claim 2, wherein the non-exploding pyrotechnic composition (6) contains thermite.

4. A method as claimed in any of claims 1-3, wherein said non-exploding cartridge (1) is produced by using an on the market existing non-exploding cartridge device (1) and filling said non-exploding cartridge device (1) with said non-exploding pyrotechnic composition (6).

5. A cartridge for disarming an unexploded blasting charge (101) in a drill hole (100), comprising:
   - a substantially cylindrical outer sleeve (2) with an end wall in a first end (3);
   - a plug (4) which, enclosing said outer sleeve, is inserted into and secured in an opposite second end of the outer sleeve (2);
   - a main chamber (5) in the outer sleeve (2) between said end wall (3) and said plug (4), which main chamber (5) is filled with a non-exploding pyrotechnic composition (6),
   - an opening (8) in one of said plug (4) and/or end wall (3) for receiving an igniting device (10) including an igniting charge arranged to ignite said non-exploding pyrotechnic composition (6),

– said non-exploding pyrotechnic composition (6) including a metal powder fuel and a metal oxide serving as an oxidizer, said composition upon ignition undergoing an exothermic reduction-oxidation (redox) reaction arranged to burn away said blasting charge (101).

6. A cartridge as claimed in claim 5, further comprising,
   - a substantially cylindrical inner sleeve (7), which is coaxial with the outer sleeve (2), and connected to said plug (4), and extending into the non-exploding pyrotechnic composition (6) in the main chamber (5);
   - a central through hole (8) in said plug (4), which communicates with the inner sleeve (7) that is closed at its inner end, which plug (4) is inserted into the non-exploding pyrotechnic composition (6);
   - the inner sleeve (7) and the hole (8) in the plug (4) in combination forming a priming chamber (9) for receiving said igniting device (10) including an igniting charge, said priming chamber (9) having a shape corresponding to an outer shape of the blasting cap (10).

7. A cartridge as claimed in claim 6, further comprising,
   – said inner sleeve (7) having an inner wall (13) arranged to be penetrated by the flame of fire that is formed when the igniting charge of the blasting cap (10) is ignited, thereby igniting the non-exploding pyrotechnic composition (6);

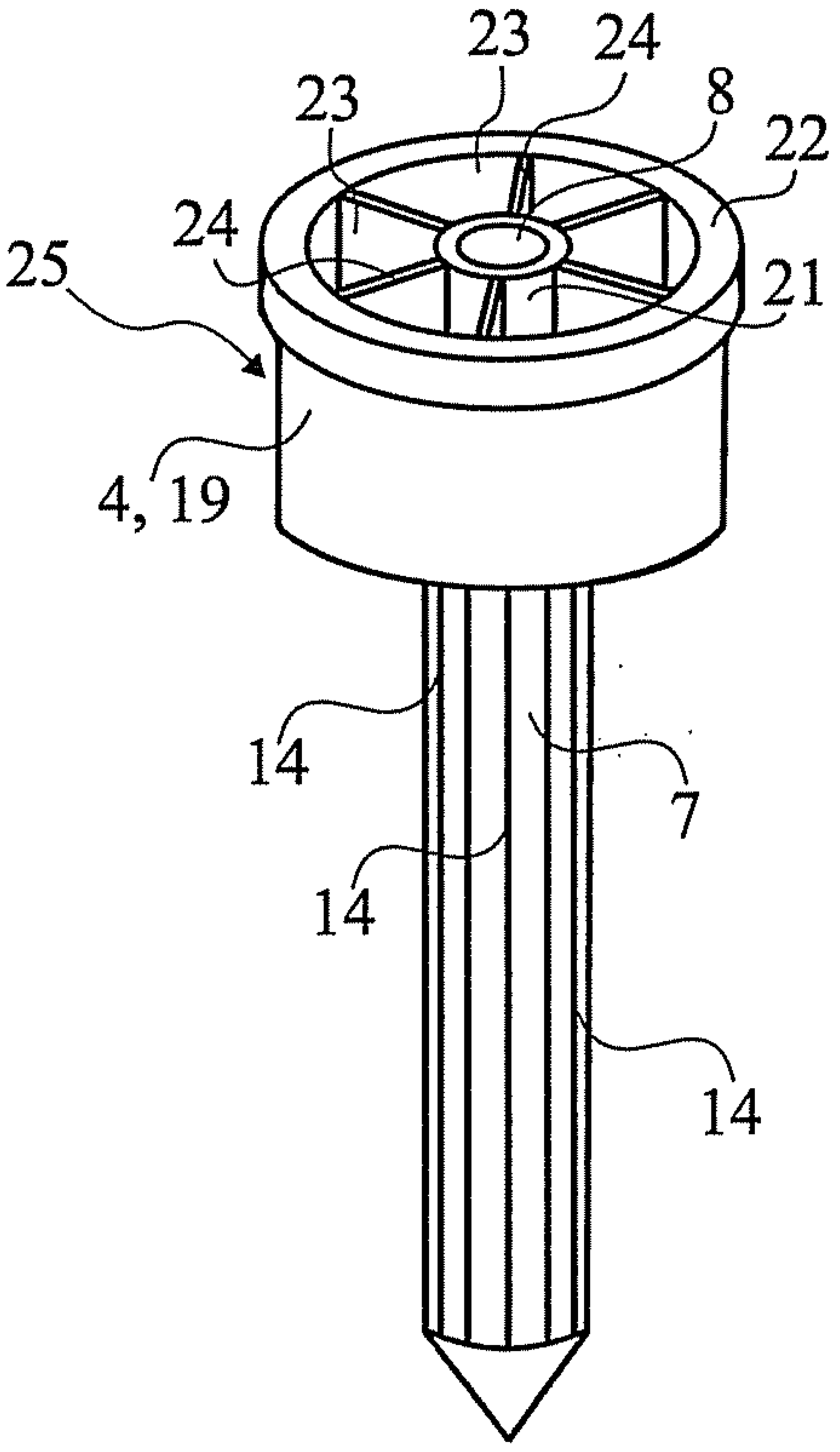
8. A cartridge as claimed in any of claims 5-7, wherein the non-exploding pyrotechnic composition (6) includes thermite.

9. A cartridge as claimed in any of claims 5-8, wherein the metal fuel is selected from the group consisting of aluminum, magnesium, titanium, zinc, silicon, and boron.

10. A cartridge as claimed in any one of any of claims 5-9, wherein the oxidizer is selected from the group consisting of iron (III) oxide, iron (II, III) oxide, manganese (IV) oxide, chromium (III) oxide, silicon (IV) oxide, copper (II) oxide, bismuth (III) oxide, boron (III) oxide, and lead (II, IV) oxide.

11. A cartridge as claimed in any one of claims 5-10, wherein the igniting device is a blasting cap (10), preferably an electrically triggered blasting cap (10).

Fig. 2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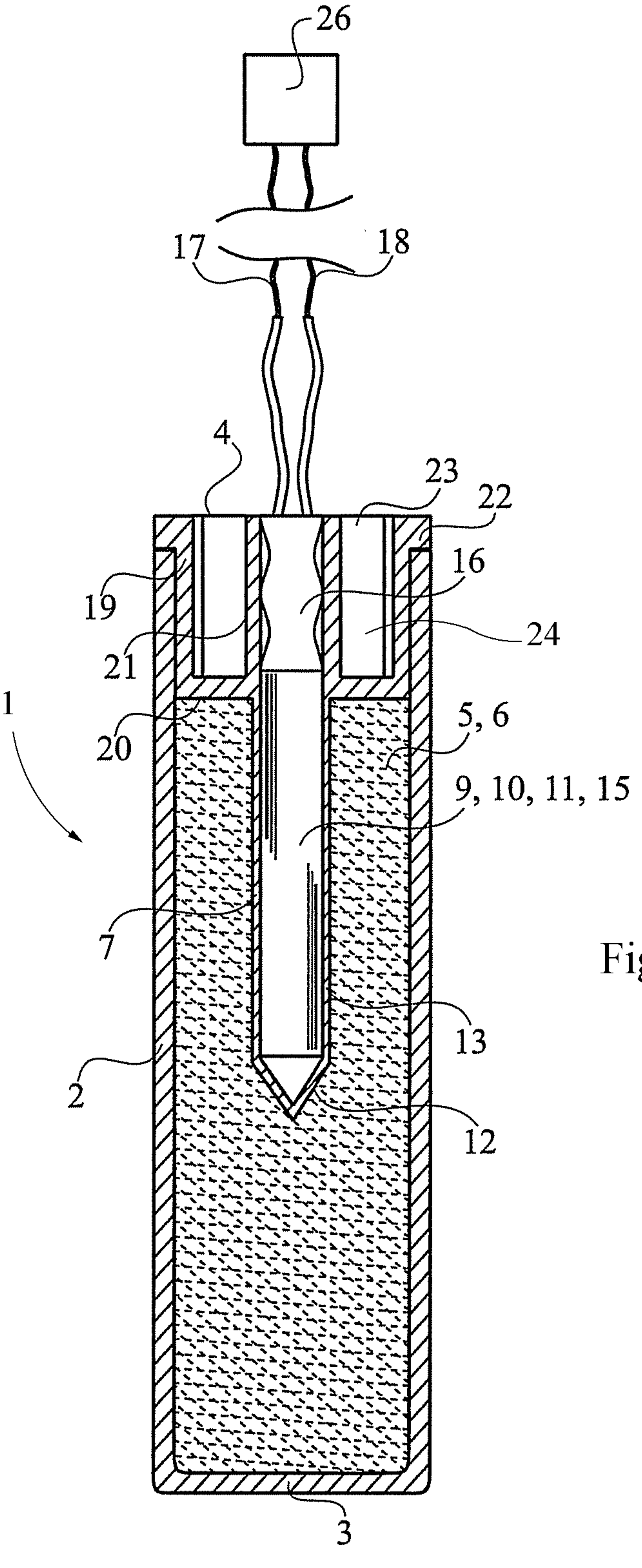
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Fig. 1

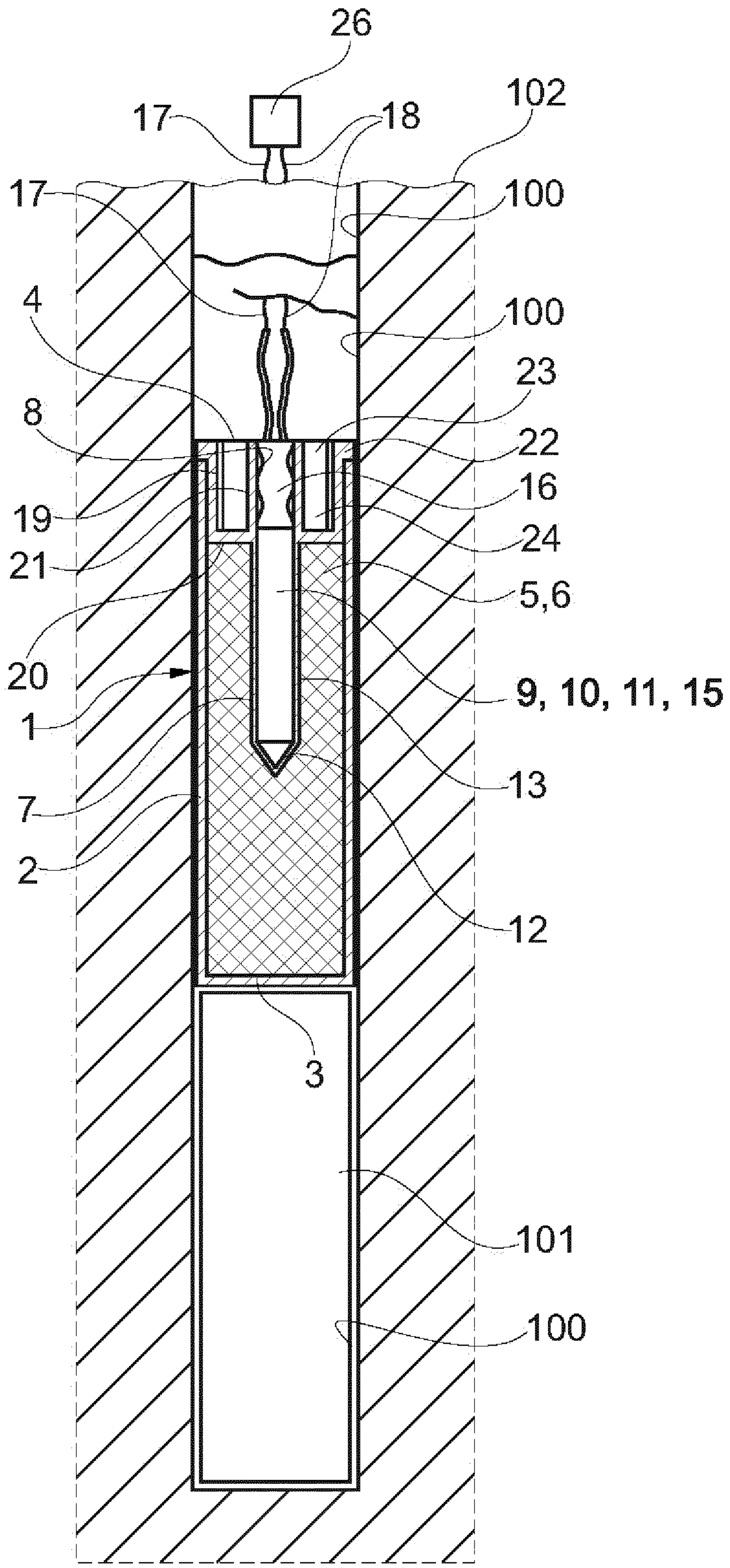
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Fig. 3


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Fig. 3