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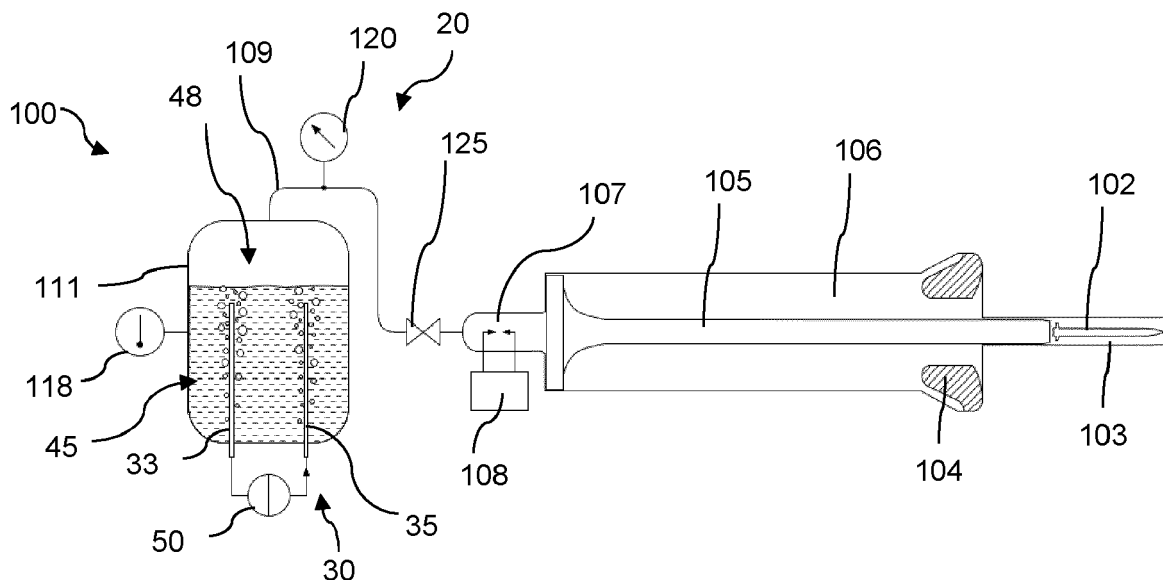
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(54) HANDHELD TOOL

(57) The invention discloses a handheld tool 100 comprising a tool housing 106 with a moveable tooling 105, and a gas generator 20 for operating the moveable tooling 105, said gas generator 20 is arranged in the tool housing 106 and comprises at least one electrolytic cell

30, whereby said at least one electrolytic cell 30 comprises at least one electrode pair. Said electrolytic cell 30 provides oxyhydrogen gas 48 for operating said moveable tooling 105.

**FIG 1**

Description

Handheld tool

[0001] The present invention relates to a handheld tool according to claim 1.

Technical field of the Invention

[0002] Various embodiments of the present invention concern to a cordless handheld tool, comprising a tooling that is accelerated by an oxyhydrogen combustion inside the tool before it operates in the desired manner.

Background of the Invention

[0003] Typically, in a cordless handheld tool according to the state of the art the tooling is accelerated by means of spring force, friction force or electromagnetic force. These handheld tools suffer from the weight of the high-power energy storage where the setting energy is stored prior to tooling operation, making them unattractive for high tooling energies (>120J). Other tools accelerate the tooling by means of gas pressure. The gas pressure is either generated by pre-compressed gas or by the combustion of a gunpowder charge or of a mixture of air and fuel gas. These tools generally benefit from their light-weight energy storage, but they suffer from other problems:

Pre-compressed gas tools of the gas-spring type typically operate with initial pressure and therefore require an airtight tooling seal and a large compression volume to limit the compression heating of the gas. This makes them complex and bulky for high nail setting energies (>120J). Pre-compressed gas tools with a high-pressure gas storage tank allow for a compact and lightweight design of the tool and allow a very high setting frequency but the high-pressure gas storage tank is rather expensive, and an additional expensive high-pressure compressor is required to refill the storage tank.

[0004] Gas tools with internal combustion of a mixture of air and fuel gas (gas nailer) also allow for high nail setting frequencies but the low combustion pressure of the uncompressed air-fuel mixture requires a large piston diameter, that would make tools for high setting energies (>120J) bulky. Furthermore, the usage of a fuel gas as a propellant is considered as problematic because of the combustion products and the dependency on the gas cartridges. The propellant consumption adds to the cost per fastening point. Attempts have been made to increase the initial pressure of the air (supercharging) to increase the setting energy. Typical tools using this technology are disclosed in WO13053002 A1 or WO07099819 A1.

[0005] Powder actuated tools, that drive the tooling by the pressure of the internal combustion of a gunpowder charge, enable the highest setting energies (up to 600J) having still compact tool size. This is due to the high

combustion pressure and the high energy density of the gunpowder charge. However, the combustion products are even more problematic than that of gas tools and the handling of the gunpowder charges is often regulated by law.

[0006] WO 2005/023709 A2 discloses a power-driven tool, utilizing hydrogen from a tank, which was filled by a gas generator comprising an electrolytic cell. The gas generator includes a base housing in which a switch that controls the flow of line voltage to the voltage rectifier and a microprocessor are located. The voltage rectifier supplies DC voltage to the anode and the cathode located in the containment vessel fitted into the base housing. The cylindrical chamber in the containment vessel is divided into generally semi-cylindrical chambers by a non-permeable divider that allows the liquid to flow freely in the bottom portion of the containment vessel for the free flow of electrons between the anode and the cathode. This non-permeable divider prevents gas migration once separation has occurred. Located in the chamber is the cathode which, when activated, generates hydrogen from the water in the chamber. When sufficient hydrogen gas is produced by the cathode the liquid level in chamber will be reduced and the liquid level indicator will send a signal to the microprocessor to activate the compressor. The hydrogen gas from the low-pressure hose is compressed in the compressor and hydrogen gas under a high pressure flows from the compressor into the top of a tank. The tank filled with hydrogen gas under pressure can be removed from the gas generator and used as a source of fuel for any number of mechanisms, including the lawnmower, gun nailer, and portable power tool system for operating saws, drills.

[0007] A disadvantage of this disclosure is, that the gas generator is a heavy and clunky stand-alone hydrogen generator with a complex setup, which fills a tank with compressed hydrogen. Another disadvantage is, that the output power of the internal combustion engine is limited by the low combustion pressure of near-atmospheric hydrogen-air mixtures.

[0008] US 7,063,247 B1 discloses a gas generator produces pressurized hydrogen and pressurized oxygen. The compressed hydrogen and oxygen are filled in a hydrogen tank and a second oxygen tank that both can be removed from the gas generator and used as a source of fuel for any number of mechanisms, including a lawnmower, nail gun, and portable power tools system for operating saws, drills. The use of compressed hydrogen and oxygen in an internal combustion engine greatly increases its output power, thus allowing for compact and high-power tools.

[0009] A disadvantage of this disclosure is, that the gas generator is a heavy and clunky stand-alone hydrogen generator with a complex setup, which fills a tank with compressed hydrogen and a second tank with compressed oxygen. Another disadvantage of this disclosure is, that the dosing mechanism in the handheld tool is complex because it needs to dose both hydrogen gas and

oxygen gas in the right quantity.

[0010] US 7,168,603 B1 discloses a power-driven tool, utilizing hydrogen gas from gas generator for driving a moveable tooling. Said gas generator is arranged in the tool housing and comprises an electrolytic cell, whereby said electrolytic cell comprises at least one electrode pair disposed in an aqueous electrolyte solution. The gas generator produces compressed hydrogen by means of electrolysis, eliminating the need for an external compressor.

[0011] A disadvantage of the disclosure is, that the output power of the internal combustion engine is limited by the low combustion pressure of near-atmospheric hydrogen-air mixtures.

Summary of the Invention

[0012] An object of the present invention is to overcome at least one of the disadvantages of the prior art. It is further an object of the present invention to create a lightweight, small and highly effective handheld tool with an alternative energy source that is also ergonomically designable and usable.

[0013] At least one of these objects has been solved by the features of the independent patent claims. Other preferred embodiments are indicated in the dependent claims.

[0014] In particular, according an aspect of the present disclosure, the object is achieved by a handheld tool comprising a tool housing with a moveable tooling, and a gas generator for operating the moveable tooling, said gas generator is arranged in the tool housing and comprises at least one electrolytic cell, whereby said at least one electrolytic cell comprises at least one electrode pair. Oxyhydrogen gas is produced by said electrolytic cell and used to power the aforementioned moveable tooling. The moveable tooling is propelled by said oxyhydrogen gas, which is a gas mixture of hydrogen and oxygen, and is produced on-the-fly in the handheld tool while in use. With comparable tool performance, the aforementioned gas generator is roughly three times lighter than, for instance, a brushless electromechanics drive. Additionally, the housing of the said tool, which at least partly houses a modest but effective electrolytic cell, is built noticeably smaller than that of comparable handheld tools driven by other means. So, a portable, lightweight tool is offered. The mentioned handheld tool is preferably a handheld nail-setting tool or a handheld propellant-free tool. For instance, using a gas generator to produce oxyhydrogen as an energy source results in a smaller piston diameter and, as a result, a smaller tool size, e.g., for a handheld nail-setting tool. While said moveable piston is being operated, a significant increase in power density is offered, enabling repeatable settings of nails with various setting requirements.

[0015] In an advantageous embodiment said at least one electrolytic cell consists of a single hollow cell body, whereby said hollow cell body comprises said at least one

electrode pair for generating said oxyhydrogen gas. Said at least one electrode pair comprises a first electrode and a second electrode, separated by an electrically non-conducting porous separator. Said at least one electrode pair and said electrically non-conducting and porous separator form a simple structure in said single cell body. Said first electrode and said second electrode are arranged in the hollow cell body in such a way that they form a void in the centre of the electrolytic cell. Said first electrode and second electrode may be permeable for the oxyhydrogen gas. This non-conductive porous separator structure allows the oxyhydrogen gas to flow in radial direction towards the void to the centre of hollow cell body. Said non-conductive separators may be non-permeable for the oxyhydrogen. Alternatively, at least one of said first electrode or second electrode is non-permeable for the oxyhydrogen gas. Said oxyhydrogen gas is led in-plane along said first and second electrodes to the void in the centre of the electrolytic cell.

[0016] Preferably said provided oxyhydrogen gas is a compressed oxyhydrogen gas, produced in said hollow cell body. An external compressor is not required. Combusting compressed oxyhydrogen gas provides a high-power working tool.

[0017] Preferably said at least one electrolytic cell comprises an electrolyte for producing said oxyhydrogen. Preferably said electrolyte is a liquid electrolyte, like e.g., water or other alkaline liquids or water-based liquids. Electrolysis of water in said single hollow cell body may produce a 2:1 mixture of hydrogen and oxygen gas, namely oxyhydrogen gas. The water consumption for the disclosed electrolytic cell is around 20 mg for 100 J setting energy and 50 mg for a 250J setting energy in a handheld nail-setting tool. The high energy density of the compressed oxyhydrogen gas allows for a compact tooling size even for high operation energies.

[0018] Preferably at least one additive is added to the electrolyte, like e.g., KOH (potassium hydroxide) or NaOH (sodium hydroxide), to increase the electrical conductivity of the electrolyte. Such a liquid electrolyte is inexpensive and provides a wide operating temperature range of -60 to 110 °C, especially in a 30%KOH solution with water. Here the mass fraction between said additive and said electrolyte is relevant, e.g., 1 kg electrolyte with 30 weight% demands 0.3 kg KOH and 0.7 kg water.

[0019] KOH is added preferably between 15 to 45 weight% to the electrolyte in the electrolytic cell, and alternatively NaOH is added preferably between 10 to 25 weight% to the electrolyte in the electrolytic cell. At these concentrations, the freezing point of the electrolyte is below -10 °C. To improve water separation, a suitable defoamer can be added to the electrolyte.

[0020] Alternatively, or additionally, a polymer electrolyte membrane (PEM) is used in said electrolytic cell to produce oxyhydrogen gas. The PEM may be introduced to overcome partial load issues, low current density, and low-pressure operation in the electrolytic cell.

[0021] Preferably said first electrode and said second electrode are wound up to form a reel inside the hollow cell body. Said first electrode and said second electrode are separated by the electrically non-conducting separator. The reel structure allows a large electrolytic area in a compact volume of said hollow cell body. The electrodes on the flat faces of the reel are respectively connected to the first electrode contact and the second electrode contact for electrical supplying the first electrode and the second electrode. The electrodes may be axially displaced relative to the non-conductive separators, so that the electrodes respectively can be contacted at with the electrode contacts. Advantageous is the simple fabrication of the cell. This electrode-separator structure allows the oxyhydrogen gas to flow in radial direction towards the void to the centre of the electrolytic cell. Furthermore, said oxyhydrogen gas may flow advantageously in axial direction to the ends of the electrolytic cell and towards the void to the centre of the electrolytic cell.

[0022] In another advantageous embodiment said first electrode and said second electrode comprise a disc-shaped structure and form a stack in the hollow cell body, where said disc-shaped structure comprises a void in the centre of its structure. Said first electrode and said second electrode are separated by the non-conductive separator. Said first electrode and said second electrode are arranged on an individual disc. Several individual disks are stacked on top of each other, with an electrically non-conductive separator sandwiched between adjacent discs in each case. This electrode-separator structure allows the oxyhydrogen gas to flow radial direction to the void in the centre of the electrolytic cell. Furthermore, said oxyhydrogen gas may flow advantageously in axial direction to the ends of the electrolytic cell and towards the void to the centre of the electrolytic cell.

[0023] For example, a series connection of many flat, disc-shaped cells is used. For this purpose, unperforated bipolar plates and separator membrane blanks are stacked alternately. A bipolar plate serves as a first electrode (anode) for one cell and as a second electrode (cathode) for the neighbouring cell. An advantage is the low cell current for a given gas generation rate due to the large number of cells.

[0024] Alternatively said first electrode and said second electrode comprise a circular involute structure in the hollow cell body, where said circular involute structure comprises a void in the centre of its structure. Said first electrode and said second electrode are connected in parallel and are separated by said non-conductive separators. Said non-conductive separators are non-permeable for the oxyhydrogen gas. Alternatively, at least one of said first electrode or second electrode is non-permeable for the oxyhydrogen gas. Said oxyhydrogen gas is led in-plane along said first and second electrodes. Said oxyhydrogen gas is led to the void along the circular involute structure of the electrodes. Since the oxygen gas cannot react with the cathode during gas transport in the electrolytic cell, this structure results in a

high efficiency in the electrolytic cell. Typically, the process of gas production in an electrolytic cell generates heat. Improved heat dissipation occurs in the electrolytic cell when the electrodes are designed with a circular involute structure.

[0025] Preferably said circular involute structure comprises several sheets and said several sheets are divided into first electrodes and second electrodes, while said first electrodes are used as anodes and said second electrodes are used as cathodes. All first electrodes may be connected in parallel, and all second electrodes may be connected in parallel.

[0026] For example, an electrolytic cell consisting of many electrodes connected in parallel and bent in the shape of a circular involute with a separator in between. The electrodes are each displaced in the axial direction so that the electrodes can be easily contacted with said electrode contact. This cell has the advantage of good radial thermal conductivity. In addition, the oxyhydrogen gas produced can flow along the electrodes in a radial direction into void in the centre of the electrolytic cell and the electrolyte can be drawn in from the hollow cell body wall. No counterflow occurs and electrolyte entrained with the gas flow additionally cools the electrolytic cell convectively.

[0027] Preferably said electrodes of said electrode pair are made of stainless steel. Thus, increased electrolysis efficiencies, larger than 60%, are achieved. Furthermore, said electrodes may comprise a metal sheet, a metal wire mesh, e.g., a plain weave or a metal fibre fleece. A practical and economical electrode is a mesh made of metal wire. For example, stainless steel or nickel alloy sheet or wire mesh would be useful.

[0028] In an advantageous embodiment said non-conductive separator comprises a porous material, in particular a mesh, fabrics or nonwoven made of e.g., polypropylene (PP), having a hydrophilic behaviour. The porous separator absorbs and distributes the electrolyte in the electrolytic cell by means of capillary action. Preferably said porous material is chemical resistant to concentrated additives, like KOH or NaOH. Thus, the efficiency of the oxyhydrogen production in the electrolytic cell is stable.

[0029] In an advantageous embodiment said at least one electrolytic cell comprises a power supply. Said first electrode and said second electrode are electrically supplied by said power supply, thus providing an anode and a cathode in said electrolytic cell. A DC-DC converter may be used for load regulation in said electrolytic cell. Advantageously said power supply is a current supply providing a desirable current for operating said at least one electrolytic cell.

[0030] In particular said power supply is a battery or an accumulator, connectable to a first electrode and to a second electrode of the at least one electrode pair. Those power supplies are inexpensive and easy to exchange. Furthermore, those power supplies are safe, well tested and are provided with different voltages. Especially, using

rechargeable batteries as the primary energy source of the tool eliminates the dependency on propellant (fuel gas or powder cartridges) or on the supply of pressurized air.

[0031] In an advantageous embodiment said gas generator comprises a pressure vessel. Said electrolytic cell is arranged in said pressure vessel and allows to produce pressurized oxyhydrogen gas because the oxyhydrogen gas is compressed by means of electrolysis. This is advantageous for buffering gas for more compact gas storage. Additionally, this is advantageous for higher power density and efficiency in the combustion engine, where the oxyhydrogen gas is consumed. The voltage of the electrolytic cell increases for internal compression in said electrolytic cell is max. 3-4% for 25 bar, 4-5% for 50 bar and 4-6% for 100 bar oxyhydrogen gas pressure. Said pressure vessel needs to withstand the oxyhydrogen gas pressure and more important a pressure from an internal explosion of the oxyhydrogen gas without bursting of the vessel.

[0032] Preferably said pressure vessel comprises a tough and strong steel alloy material, because of the good absorption of the energy coming from an internal explosion. Furthermore, said pressure vessel comprising said materials provide a good thermal conductivity and a good chemical resistance for the alkaline electrolyte.

[0033] Alternatively said pressure vessel comprises a composite overwrapped vessel, preferably wrapped with a structural fiber composite, to allow for a lightweight pressure vessel.

[0034] Said pressure vessel may comprise an insulation for insulating said pressure vessel from said electrode pair. Said insulation comprises a first insulation disc for the first electrode contact and a second insulation disc for the second electrode contact. Said hollow cell body may comprise an insulating layer on the inner side of the hollow cell body. Said pressure vessel may comprise gaskets for sealing the electrolytic cell.

[0035] In an advantageous embodiment a combustion chamber is provided in the tool housing for combusting the oxyhydrogen gas, whereby said combustion chamber is preferably arranged adjacent to said movable tooling. By such an arrangement of the combustion chamber, combusting of said oxyhydrogen gas is easily driving said movable tooling, without unexpected losses. E.g., combusting oxyhydrogen is a clean and fast combustion suitable for a high combustion efficiency and the combustion product is again water. Said combustion efficiency is around 30% for initial pressure of 30 bar. The high combustion temperatures of the oxyhydrogen of around 4000 K gives a high thermodynamic efficiency of the tooling drive.

[0036] Preferably the diameter of the combustion chamber is smaller than the tooling, e.g. piston, diameter. Preferably, the tooling is held back at its initial position during gas dosing. A combustion chamber with reduced diameter reduces the tooling retention force. A combustion chamber with reduced diameter also facilitates the

integration of a magnetic tooling retention system.

[0037] In an advantageous embodiment an ignition device is provided to igniting the oxyhydrogen gas in the combustion chamber. Said ignition device is preferably arranged in said combustion chamber. Preferably, said ignition device is a high-voltage source for effectively igniting of said oxyhydrogen gas. E.g., using oxyhydrogen as operation gas said ignition temperature is higher than 400°C. The internal combustion of the oxyhydrogen gas in the combustion chamber is e.g., initiated by means of an electric arc. The combustion reaction rapidly raises the gas temperature to typically 3500 K to 4500 K and the gas pressure to around 9 to 11 times its initial pressure. The combustion pressure is used to accelerate the tooling. The high combustion pressures of compressed oxyhydrogen gas allow for a compact tooling size even for high operation energies. In a preferred embodiment the initial gas pressure is around 1 to 50 bar.

[0038] In a preferred embodiment the hot combustion product (e.g. water vapor) is partially exhausted in to atmosphere after the tooling reaches a desired position. The vacuum from further cooldown and eventually condensation of the combustion product in the combustion chamber is used to return the tooling to its initial position. Thus, no additional returning mechanism for said tooling is necessary, which further provides a light and inexpensive tool.

[0039] In an advantageous embodiment a dosing valve is connected to said at least one electrolytic cell for dosing said oxyhydrogen gas extending out of the at least one electrolytic cell, preferably into said combustion chamber. Only a single valve may be used. Said dosing valve is actuated for dosing of oxyhydrogen gas from the pressurized storage volume into the combustion chamber. E.g., by controlling a valve opening interval, said amount of oxyhydrogen gas leading into the combustion chamber. Thus, the energy and the operation efficiency of the tooling is controllable. During and after gas dosing the elevated gas pressure in the combustion chamber exerts a driving force on the tooling. Preferably a tooling retention mechanism can be used to hold the tooling at its initial tooling prior to ignition.

[0040] Said electrolytic cell comprises a gas storage volume which buffers the oxyhydrogen gas pressure for the intermittent gas demand of the gas dosing valve. It also serves as an inexpensive, lightweight and compact energy storage for burst setting operation. The volume of the gas generator that is not filled up with electrolyte may also contribute to the gas storage volume.

[0041] In an advantageous embodiment a gas pressure measurement device is provided for measuring said gas pressure of the oxyhydrogen gas. Said oxyhydrogen gas produced in said hollow cell body of said electrolytic cell, comprises a high initial gas pressure, without a further compressor. Said oxyhydrogen gas is preferably measured with a single pressure measurement device. Said compression of the oxyhydrogen gas is affected by the electrolytic process in said hollow cell body. Pres-

tures of 10 to 100 bar are reachable using said gas generator. A high initial gas pressure may provide an improved combustion efficiency and an improved power density. E.g., using a water-based electrolyte, oxyhydrogen gas is separated from the water and dosed from a pressurized storage volume into the combustion chamber. This provides an inexpensive, lightweight and compact energy storage in the tool.

[0042] In particular said gas pressure measurement device is provided for measuring of said oxyhydrogen gas extracting from said hollow cell body. Thus, said initial gas pressure for said combustion chamber is measured to provide a desired combustion efficiency. In a preferred embodiment the gas pressure of the oxyhydrogen gas is around 2 to 50 bar.

[0043] In an advantageous embodiment a temperature measurement device is provided to measure an electrolytic cell temperature. Monitoring said temperature of said electrolytic cell provides a reliable and safe production of the oxyhydrogen gas.

[0044] In an advantageous embodiment a power electric circuit is provided for load regulation of said at least one electrolytic cell. Thus, the production of the oxyhydrogen gas is controllable. In particular, said power electric circuit is a buck converter circuit. A buck converter circuit is a simple load regulator, which is easy programmable. Preferably a processor and a memory are arranged in said power electric circuit, using a computer program with instructions for controlling the power electric circuit.

[0045] In an advantageous embodiment said power electric circuit is connected to said ignition source. Thus, said ignition is easily controllable by said power electric circuit and said moveable tooling is working in a reproducible manner.

[0046] Alternatively or supplementary said power electric circuit is connected to said dosing valve. Said oxyhydrogen gas is reproducible led to the combustion chamber and said moveable tooling works with a reliable power density, controlled by said power electric circuit.

[0047] In particular said power electric circuit is connected to said pressure measurement device. Thus, said gas pressure of said oxyhydrogen gas is measured under controllable conditions. Said measured data is provided for controlling said gas generator.

[0048] Alternatively or supplementary, said power electric circuit is connected to temperature measurement device. Thus, said hollow cell body temperature is monitored under controllable conditions. Said measured data is provided for controlling said gas generator.

[0049] In particular said power electric circuit is configured to control the ignition device depending on the operation of said dosing valve. Thus, an advanced control of the operation of said moveable tooling with a controlled power density is possible.

[0050] In an advantageous embodiment a further electrolytic cell is provided, preferably connected in series with said at least one electrolytic cell. Thus, the oxyhydrogen gas is generated with a higher efficiency. The

required operating voltage for a single electrolytic cell is around 2 V. With a series connection of several electrolytic cells the operating voltage of the gas generator can be adopted to the battery voltage, eliminating the need for complex power electronic circuitry. Only a buck converter circuit is preferably required for load regulation. A further electrolytic cell increases the required electrolysis voltage but also reduces the electrolysis current and thus the ohmic losses in the gas generator. The advantage is that the current can be reduced for the same gas production rate and thus the ohmic resistance losses are smaller.

[0051] Preferably a bipolar contact plate is placed between the first electrolytic cell and the further electrolytic cell to reduce leakage currents. A plurality of independent, spring-loaded contact points provides a good contact quality. Preferably said bipolar contact plate is unperforated, thus the contribution for the gas production of both electrolytic cells is increased, which increases the efficiency.

[0052] In an advantageous embodiment a flame arrestor is provided to improve the safety of the handheld tooling. Preferably, said flame arrestor is arranged between the at least one electrolytic cell and said combustion chamber.

[0053] In an advantageous embodiment a liquid reservoir is provided, which is connected to the at least one electrolytic cell. Said electrolyte, e.g. water, is provided in said liquid reservoir. Therefore, said tool may be used for higher working cycles. Preferably a pump is provided to transport a liquid from the liquid reservoir to said electrolytic cell, if required. Said electrolyte may be constantly provided in said at least one electrolytic cell.

[0054] In an advantageous embodiment said hollow cell body comprises a refill opening for refill an electrolyte into said electrolytic cell. Thus, a permanent operation of the electrolytic cell is possible. Preferably said refill opening is arranged at one of the first electrode contact or at one of the second electrode contact. Thus, said refill opening is arranged opposite to the inlet section of said gas extraction tube.

[0055] In an advantageous embodiment said at least one electrolytic cell comprises a gas extraction tube, which is arranged in a hollow cell body of the at least one electrolytic cell. Said gas extraction tube is on the one hand used for extraction of the oxyhydrogen gas out of the hollow cell body and on the other hand it prevents the electrolyte from leaking out of the hollow cell body. Such a gas generator operates constantly independent on its spatial orientation, which makes the gas generator especially suitable for a handheld tool. A permanently change of the spatial orientation of a handheld tool in operation is possible without losing the electrolyte. Said electrolytic cell is advantageously constructed that no liquid electrolyte lacks out of the electrolytic cell nor out of the handheld tool. Said handheld tool is usable in every spatial orientation.

[0056] In an advantageous embodiment said hollow cell body comprises a length in at least one dimension

and said gas extraction tube extends at least between one third and two thirds of the length of the hollow cell body. Thus, the amount of electrolyte in the electrolytic cell is optimizable, and no leakage of the electrolyte during operation occurs.

[0057] Preferably said gas extraction tube extends less than 50 percent of the length of the hollow cell body in said void. Thus, the oxyhydrogen gas is effectively transported out of said void and preventing any electrolyte leakage out of the gas generator. Preferably said gas extraction tube extends at least 45 percent of the length of the hollow cell body in said void. Thus, the operation gas is ideally transported out of said void and preventing any electrolyte leakage out of the gas generator.

[0058] Preferably said gas extraction tube is connected to an opening of one of a first electrode contact or of a second electrode contact. The oxyhydrogen gas is collected and compressed in the hollow cell body and lead out from the gas extraction tube through said opening of the first electrode contact or the second electrode contact. Said electrode contacts electrically contact respectively the first electrodes and the second electrode with an electric supplier, like a battery. Thus, the first electrode acts as an anode and the second electrode acts as a cathode.

[0059] In an advantageous embodiment said gas extraction tube extends in the void of said reel or said structures. Said gas extraction tube is only connected with one of the contacts of the electrodes and does not contact another part of the electrolytic cell, so that the gas extraction tube is mostly exposed in the void. The oxyhydrogen gas is collected in the void and exits the electrolytic cell exclusively through the gas extraction tube.

[0060] In an advantageous embodiment a hydrophobic filter is arranged at the gas extraction tube. The hydrophobic filter ensures that no electrolyte leaves the electrolytic cell if there is a surplus of electrolyte in the gas generator. For example, filters made of sintered or expanded polytetrafluoroethylene (PTFE), polypropylene (PP) or polyethylene (PE) would be advantageous due its high hydrophobic properties.

[0061] By means of the following figures, the invention is explained in more detail by means of examples of embodiments. The list of references is part of the disclosure.

[0062] Positional indications, such as "above", "below", "right" or "left" are in each case related to the corresponding embodiments and are not to be understood as restrictive.

[0063] Indications, such as "first", "second", or "further" are in each case related to the corresponding device and are not to be understood as restrictive or enumeration.

Brief Description of the Drawings

[0064] In order to facilitate better understanding of the present invention, reference is made below to the drawings. These show only exemplary embodiments of the

subject matter of the invention. These embodiments, offered not to limit but only to exemplify and teach the invention, are shown and described in sufficient detail to enable those skilled in the art to implement or practice the invention. Thus, where appropriate to avoid obscuring the invention, the description may omit certain information known to those of skill in the art.

[0065] In the figures and the associated description, identical or functionally analogous parts are provided with the same reference numerals.

[0066] The invention also encompasses individual features shown in the figures, even if they are shown there in connection with other features and/or are not mentioned above.

[0067] Further, the term "comprising" and derivatives thereof do not exclude other elements or steps. Likewise, the indefinite article "a" or "one" and derivatives thereof do not exclude a plurality. The functions of multiple features recited in the claims may be performed by a hollow unit. The terms "substantially", "approximately", "about" and the like in connection with a characteristic or a value define, in particular, also exactly the characteristic or exactly the value. All reference signs in the claims are not to be understood as limiting the scope of the claims.

Fig. 1 shows a first embodiment of the inventive handheld tool in a simplified view,

Fig. 2 shows a handheld nail-setting tool with the tool according to Fig. 1 in a schematic view,

Fig. 3 shows a gas generator of the handheld tool according to Fig. 1 in a schematic view,

Fig. 4 shows a further embodiment of a gas generator of the handheld tool according to Fig. 1 in a perspective view,

Fig. 5 shows a further embodiment of the gas generator of the handheld tool according to Fig. 1 in a perspective view,

Fig. 6 shows a further embodiment of the gas generator of the handheld tool according to Fig. 1 in a perspective view, and

Fig. 7 shows a further embodiment of the gas generator of the handheld tool according to Fig. 1 in a perspective view,

Detailed Description

[0068] Figure 1 shows an inventive handheld tool 100 comprising a tool housing 106 with a moveable tooling 105, which is in this embodiment a piston, and a gas generator 20 for operating the moveable tooling 105. Said gas generator 20 is arranged in the tool housing 106 and comprises an electrolytic cell 30, whereby said

electrolytic cell 30 comprises at least one electrode pair. Said electrolytic cell 30 is used to provide oxyhydrogen gas 48 for operating said moveable tooling 105, which is combusted in a combustion chamber 107 in said tool 100. Said oxyhydrogen gas 48 is a gas mixture of hydrogen and oxygen, which are produced respectively by electrolysis on the first electrode 33 and on the second electrode 35, when said electrodes 33, 35 are electrically sourced by e.g., a battery 50. A temperature of the electrolytic cell 30 is monitored with a temperature measurement device 118 during electrolysis. Said gas generator 20 comprises a pressure vessel 111. Said electrolytic cell 30 is arranged in said pressure vessel 111 and allows to produce pressurized oxyhydrogen gas 48, which is compressed by means of electrolysis. Said tool 100 comprises an ignition device 108 to igniting the oxyhydrogen gas 48 in the combustion chamber 107. Said ignition device 108 is arranged in said combustion chamber 107 and is a high-voltage source for effectively igniting said oxyhydrogen gas 48. Inside said combustion chamber 107 a damping 104 for said moveable tooling 105 is arranged.

[0069] Said oxyhydrogen 48 produced in said gas generator 20, leaves said electrolytic cell 30 of said tool 100 by gas pipes 109 and passes a gas pressure measurement device 120 for measuring the gas pressure and a dosing valve 125 for dosing of said oxyhydrogen gas 48. The dosing valve 125 is actuated for the dosing of oxyhydrogen gas 48 from the pressurized storage volume in the electrolytic cell 30 into the combustion chamber 107. By controlling a valve opening interval, said amount of oxyhydrogen gas 48 led into the combustion chamber 107 is monitored.

[0070] Figure 2 shows the tool 100 shown by Figure 1 in form of a handheld nail-setting tool 200 for setting nails 102, which are initially arranged in a nail channel 103. Said tool 200 comprises a tool housing 201, said moveable tooling 105, and said gas generator 20 for operating the moveable tooling 105. Said tool 200 comprises a liquid reservoir 210 for storing water 212. Said liquid reservoir 210 is connected via pipes 211 to the electrolytic cell 30. Said electrolytic cell 30 comprises KOH as an additive for the water 212. A pump 215 is provided for transporting said water 212 into the electrolytic cell 30. In addition, a check valve 214 is connected in between to avoid backflow.

[0071] Said tool 200 comprises a power electric circuit 207 for load regulation of said electrolytic cell 30, whereby said power electric circuit 207 is connected to said battery 50. Said power electric circuit 207 is configured to control an ignition device 108 for ignition of the oxyhydrogen gas 48 in the combustion chamber 107 depending on the operation of said dosing valve 125 and is further connected to said pressure measurement device 120 and said temperature measurement device 118.

[0072] Said gas generator 20 is described in detail in Figure 3 and Figure 4. Further embodiments of a gas generator 60, 70, 90 for the handheld tools 100, 200 are described in the Figures 5 to Figure 7.

[0073] Figure 3 and Figure 4 show a gas generator 20 comprising an electrolytic cell 30 with a hollow cell body 31, an electrode pair 32 with a first electrode 33 and a second electrode 35. Said first electrode 33 and said second electrode 35 are wound up to form a reel 39 inside the hollow cell body 31. Said first electrode 33 and said second electrode 35 are separated by two non-conductive, porous separators 37, 38 in said hollow cell body 31. The electrodes 33, 35 are respectively connected on the flat faces of the reel 39 to the first electrode contact 34 and the second electrode contact 36 for electrical supplying the first electrode 33 and the second electrode 35. Said non-conductive porous separators 37, 38 are wound up with the electrode pair 32. Said first electrode 33 and said second electrode 35 are arranged in the hollow cell body 31 in such a way that they form a void 40 in the centre of the hollow cell body 31. The electrodes 33, 35 are axially displaced relative to the non-conductive, porous separators 37, 38.

[0074] Said electrodes 33, 35 respectively are contacted with the electrode contacts 34, 36. Said electrode contacts 34, 36 are connected to an electric supplier, here a battery 50. When electrically contacted via a wiring 51, said first electrode 33 provides an anode and said second electrode 35 provides a cathode. Said hollow cell body 31 is at least partially filled with water comprising KOH (potassium hydroxide) as an additive, as a liquid electrolyte 45. Said additive stays in said electrolytic cell 30, while said water is refilled occasionally. The electrically contacted electrodes 33, 35 produce oxyhydrogen as an oxyhydrogen gas 48 by electrolysis, which moves in the direction of the void 40. Said first electrode 33 and second electrode 35 are permeable for the oxyhydrogen gas 48. Said reel 39 allows the oxyhydrogen gas 48 to flow in radial direction and axial direction towards the void 40 to the centre of the electrolytic cell 30. Said first electrode contact 34 comprises a refill opening 43 for refill water into said electrolytic cell 30.

[0075] Said electrodes 33, 35 are wire meshes, made of stainless steel. Said non-conductive separators 37, 38 comprise a porous material, namely a wire mesh made of polypropylene (PP). Alternative materials to said electrodes 33, 35 or non-conductive separators 37, 38 are mentioned above.

[0076] Said electrolytic cell 30 comprises a gas extraction tube 55, which is arranged in the hollow cell body 31. Said gas extraction tube 55 is connected to an opening 44 of said second electrode contact 36. Said hollow body 31 comprises a length L in at least one dimension and said gas extraction tube 55 extends at least less than to the half of the length L of the hollow cell body 31. Said gas extraction tube 55 extends in the void 40 of said reel 39. Said gas extraction tube 55 is only connected with said second electrode contact 36 and does not contact another part of the electrolytic cell 30, so that the gas extraction tube 55 is mostly exposed in the void 40. The oxyhydrogen gas 48 is collected in the void 40 and exits the electrolytic cell 30 exclusively through the

gas extraction tube 55.

[0077] Said gas generator 20 comprises a housing 22 to cover said hollow cell body 31 and is in this embodiment said pressure vessel 111. Said housing 22 comprises an insulation 24 for insulating said housing 22 from said electrodes 33, 35. Said insulation 24 comprises a first insulation disc 25 adjacent to the first electrode contact 34 and a second insulation disc 26 adjacent to the second electrode contact 38. Said hollow cell body 31 comprises an insulating layer 28 on the inner side of the hollow cell body 31. Said housing comprises gaskets 29 for sealing the electrolytic cell 30 - see **Figure 3**.

[0078] Said gas extraction tube 55 is further connected to a dosing valve 125 for dosing said oxyhydrogen gas 48 extending out of the at least one electrolytic cell 30. By controlling a valve opening interval, said amount of oxyhydrogen gas 48 leading into a combustion chamber 107 of the moveable tooling 105 is controlled - see **Figure 2**.

[0079] **Figure 5** shows a further embodiment of a gas generator 60. Said gas generator 60 comprises in general the same structural and functional components as the gas generator 20 concerning the **Figure 3** and **Figure 4**. Said gas generator 60 additionally comprises a second electrolytic cell 65, connected in series to the electrolytic cell 30. Said second electrolytic cell 65 is equally constructed as said electrolytic cell 30, wherein said first electrode 66 and said second electrode 67 form a reel 68. An unperforated bipolar contact plate 69 is placed between the electrolytic cell 30 and the second electrolytic cell 65 to reduce leakage currents. A plurality of independent, spring-loaded contact points between the electrodes 33, 35 and 66, 67 provides a good contact quality.

[0080] **Figure 6** shows a further embodiment of an inventive gas generator 70. Said gas generator 70 comprises in general the same structural and functional components as the gas generator 20 concerning the **Figure 3** and **Figure 4**, and differs in the structure of the electrodes. Said gas generator 70 comprises an electrolytic cell 75 with a large number of first electrodes 76 and a large number of second electrode 77 connected in series. Said first electrode 76 and said second electrode 77 comprise a disc-shaped structure and form a stack in the hollow cell body 31, where said disc-shaped structure comprises a void 40 in the centre of its structure. For this purpose, unperforated bipolar plates 74 and separator membrane blanks 78 made in this example of polyethersulfone (PES) are stacked alternately. A bipolar plate serves as a first electrode 76 for one cell and as a second electrode 77 for the neighbouring cell. Said gas extraction tube 55 extends in the void 40. Said gas extraction tube 55 is only connected with said second electrode contact 34 and does not contact another part of the electrolytic cell 75, so that the gas extraction tube 55 is mostly exposed in the void 40.

[0081] **Figure 7** shows a further embodiment of a gas generator 90. Said gas generator 90 comprises in general the same structural and functional components like

the gas generator 20 concerning the **Figure 3** and **Figure 4**, and differs in the structure of the electrodes. Said gas generator 90 comprises an electrolytic cell 95 with a large number of first electrodes 96 and a large number of second electrodes 97 connected in parallel and bent in the shape of a circular involute 99 with a non-conductive separator 98 in between. The electrodes 96, 97 and said separators 98 are each displaced in the axial direction so that the electrodes 98,97 can be contacted with said electrode contacts 34, 36. Said oxyhydrogen gas 48 is led to the void 40 along the circular involute structure 99 of the electrodes 96, 97. Said gas extraction tube 55 extends in the void 40. Said gas extraction tube 55 is only connected with said second electrode contact 34 and does not contact another part of the electrolytic cell 95, so that the gas extraction tube 55 is mostly exposed in the void 40.

Reference List

[0082]

20	gas generator
22	housing
24	insulation
25	insulation disc
26	insulation disc
28	insulation layer
29	gasket
30	electrolytic cell
31	hollow cell body
32	electrode pair
33	first electrode of 32
34	first electrode contact
35	second electrode of 32
36	second electrode contact
37	separator
38	separator
39	reel
40	void
43	refill opening
44	opening
45	electrolyte
48	oxyhydrogen gas
50	battery
51	wiring
55	gas extraction tube
L	Length of 30
60	gas generator
65	electrolytic cell
66	first electrode of 65
67	second electrode of 65
68	reel
69	contact plate
70	gas generator
74	bipolar plates
75	electrolytic cell
76	first electrode of 75

77 second electrode of 75
 78 membrane
 90 gas generator
 95 electrolytic cell
 96 first electrode of 95
 97 second electrode of 95
 98 separator
 99 circular involute
 100 tool
 102 nail
 103 nail channel
 104 damping
 105 tooling
 106 tool housing
 107 combustion chamber
 108 ignition device
 109 gas pipes
 111 pressure vessel
 118 temperature measurement device
 120 gas pressure measurement device
 125 dosing valve
 200 tool
 201 tool housing
 207 electric power circuit
 210 reservoir
 211 pipes
 212 water
 214 check valve
 215 pump

Claims

1. Handheld tool (100), preferably a cordless handheld tool or handheld nail-setting tool (200), comprising a tool housing (201) with a moveable tooling (105), and a gas generator (20; 60; 70; 90) for operating the moveable tooling (105), said gas generator (20; 60; 70; 90) is arranged in the tool housing (201) and comprises at least one electrolytic cell (30; 65; 75; 95), whereby said at least one electrolytic cell (30; 65; 75; 95) comprises at least one electrode pair, **characterized in that**, said at least one electrolytic cell (30; 65; 75; 95) provides oxyhydrogen gas (48) for operating said moveable tooling (105).
2. Handheld tool according to claim 1, **characterized in that**, said at least one electrolytic cell (30; 65; 75; 95) consists of a hollow cell body (31), whereby said hollow cell body (31) comprises said at least one electrode pair for generating said oxyhydrogen gas (48).
3. Handheld tool according to claim 1 or 2, **characterized in that**, said at least one electrolytic cell (30; 65; 75; 95) comprises a power supply, in particular a battery (50) or an accumulator, connectable to a first electrode (31; 66; 76; 96) and to a second electrode (35; 67; 77; 97) of the at least one electrode pair.

4. Handheld tool according to one of the previous claims, **characterized in that**, said gas generator (20; 60; 70; 90) comprises a pressure vessel (111).
5. Handheld tool according to one of the previous claims, **characterized in that**, a combustion chamber (106) is provided in the tool housing (107) for combusting the oxyhydrogen gas (48), whereby said combustion chamber (106) is preferably arranged adjacent to said movable tooling (105).
6. Handheld tool according to one of the previous claims, **characterized in that**, an ignition device (108) is provided to igniting the oxyhydrogen gas (48) in the combustion chamber (106).
7. Handheld tool according to one of the previous claims, **characterized in that**, a dosing valve (125) is connected to said at least one electrolytic cell (30; 65; 76; 95) for dosing said oxyhydrogen gas (48).
8. Handheld tool according to one of the previous claims, **characterized in that**, a gas pressure measurement device (120) is provided for measuring said gas pressure of the oxyhydrogen gas (18), in particular of said oxyhydrogen gas (48) extracting from said hollow cell body (31), and/or a temperature measurement device (118) is provided to measure an electrolytic cell temperature.
9. Handheld tool according to one of the previous claims, **characterized in that**, a power electric circuit is provided for load regulation of said at least one electrolytic cell (30; 65; 75; 95), whereby in particular said power electric circuit is a buck converter circuit.
10. Handheld tool according to claim 9, **characterized in that**, said power electric circuit (207) is connected said ignition device (108) and/or said dosing valve (125), and is in particular connected to said pressure measurement device (120) and/or temperature measurement device (118).
11. Handheld tool according to one of the previous claims, **characterized in that**, a further electrolytic cell (75) is provided, in particular connected in series with said at least one electrolytic cell (30; 65; 95).
12. Handheld tool according to one of the previous claims, **characterized in that**, a flame arrestor is provided, arranged between said at least one electrolytic cell (30; 65; 75; 95) and said combustion chamber (107).
13. Handheld tool according to one of the previous claims, **characterized in that**, a liquid reservoir (210) is provided, which is connected with the at

least one electrolytic cell (30; 65; 75; 95), whereby preferably a pump (215) is provided to transport a liquid from the liquid reservoir (210) to said electrolytic cell (30; 65; 75; 95).

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- 14.** Handheld tool according to one of the claims 2 to 13, **characterized in that**, said at least one electrolytic cell (30; 65; 75; 95) comprises a gas extraction tube (55), which is arranged in said hollow cell body (31) of the at least one electrolytic cell (30; 65; 75; 95).

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- 15.** Handheld tool according to claim 14, **characterized in that**, said hollow cell body (31) comprises a length (L) in at least one dimension and said gas extraction tube (55) extends at least between one third and two thirds of the length of the hollow cell body (31).

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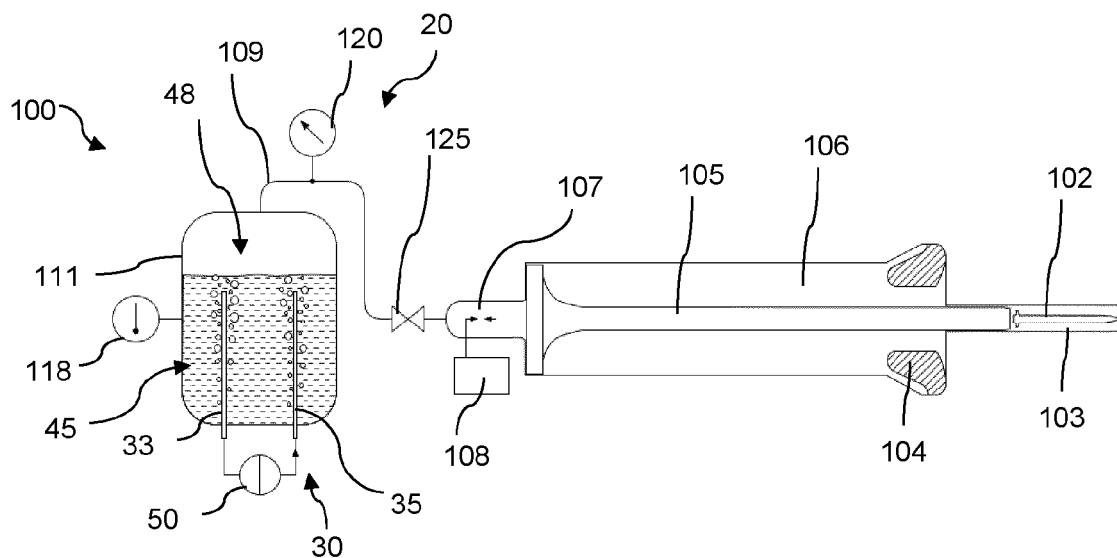


FIG 1

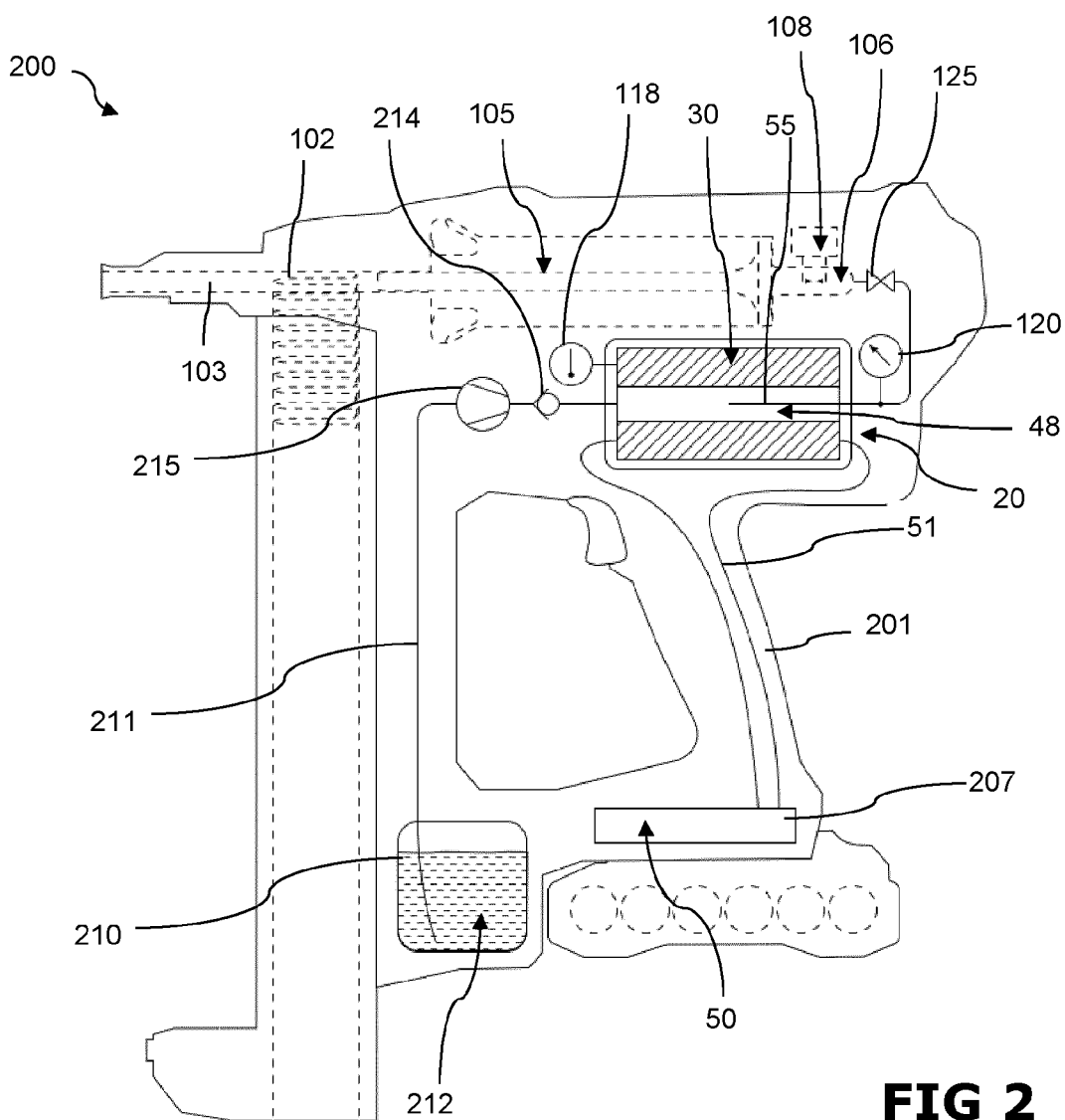


FIG 2

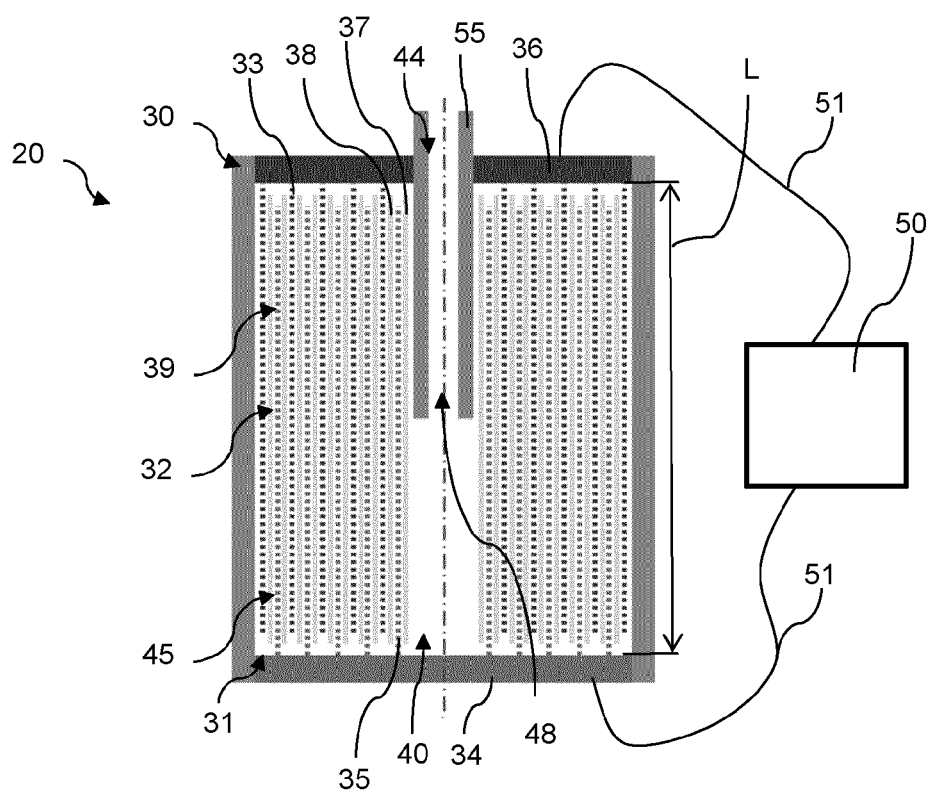


FIG 3

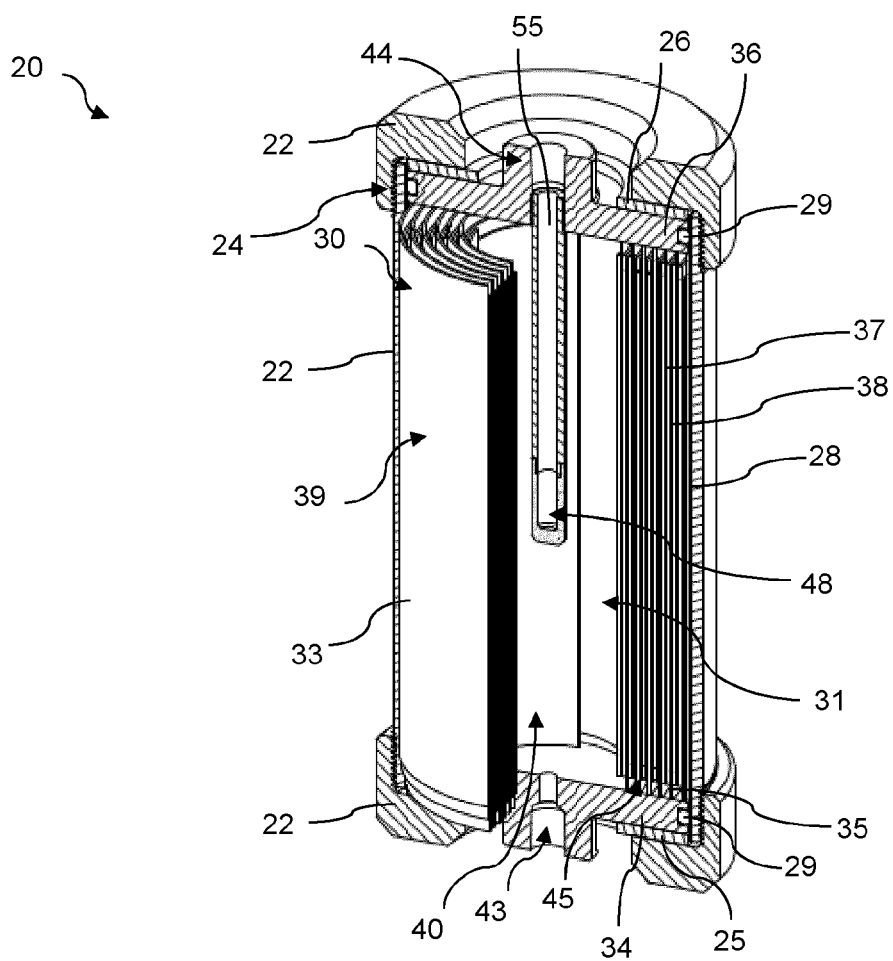


FIG 4

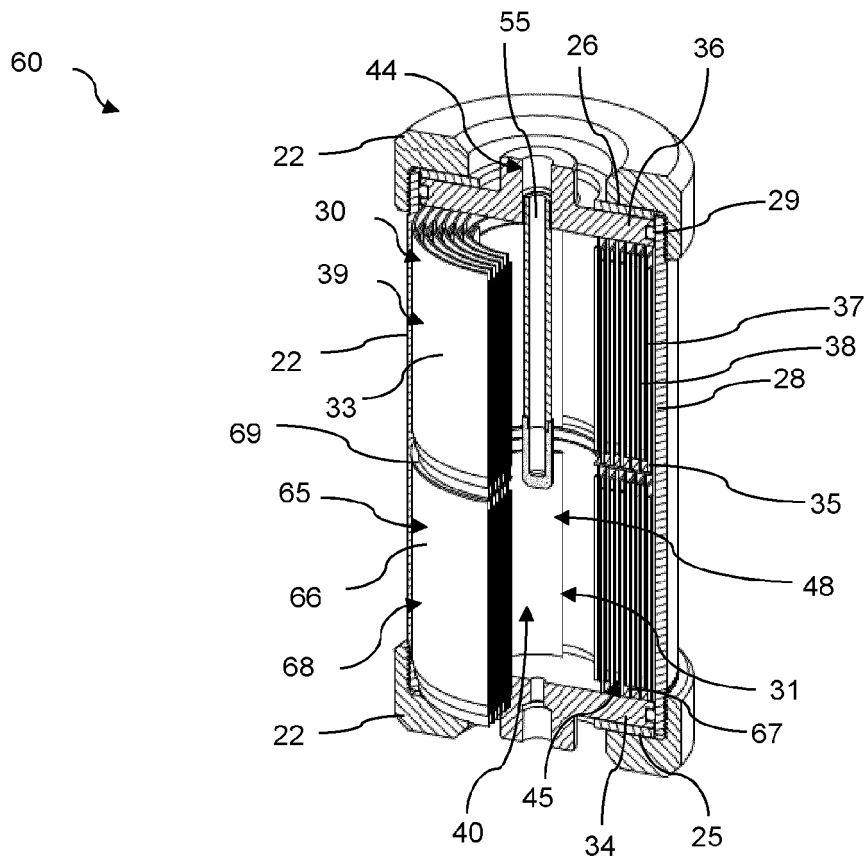


FIG 5

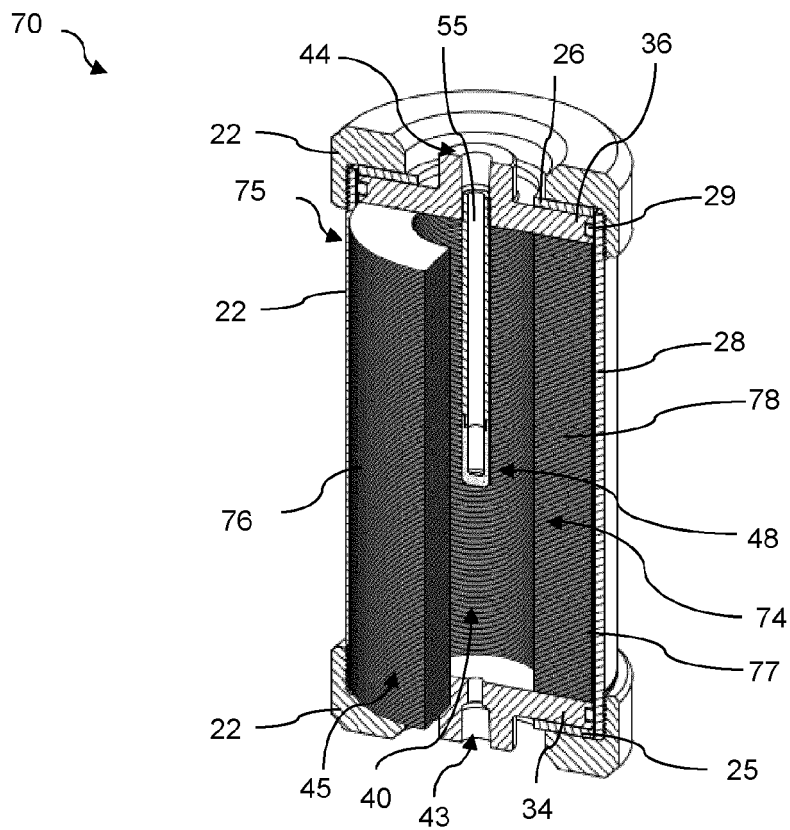


FIG 6

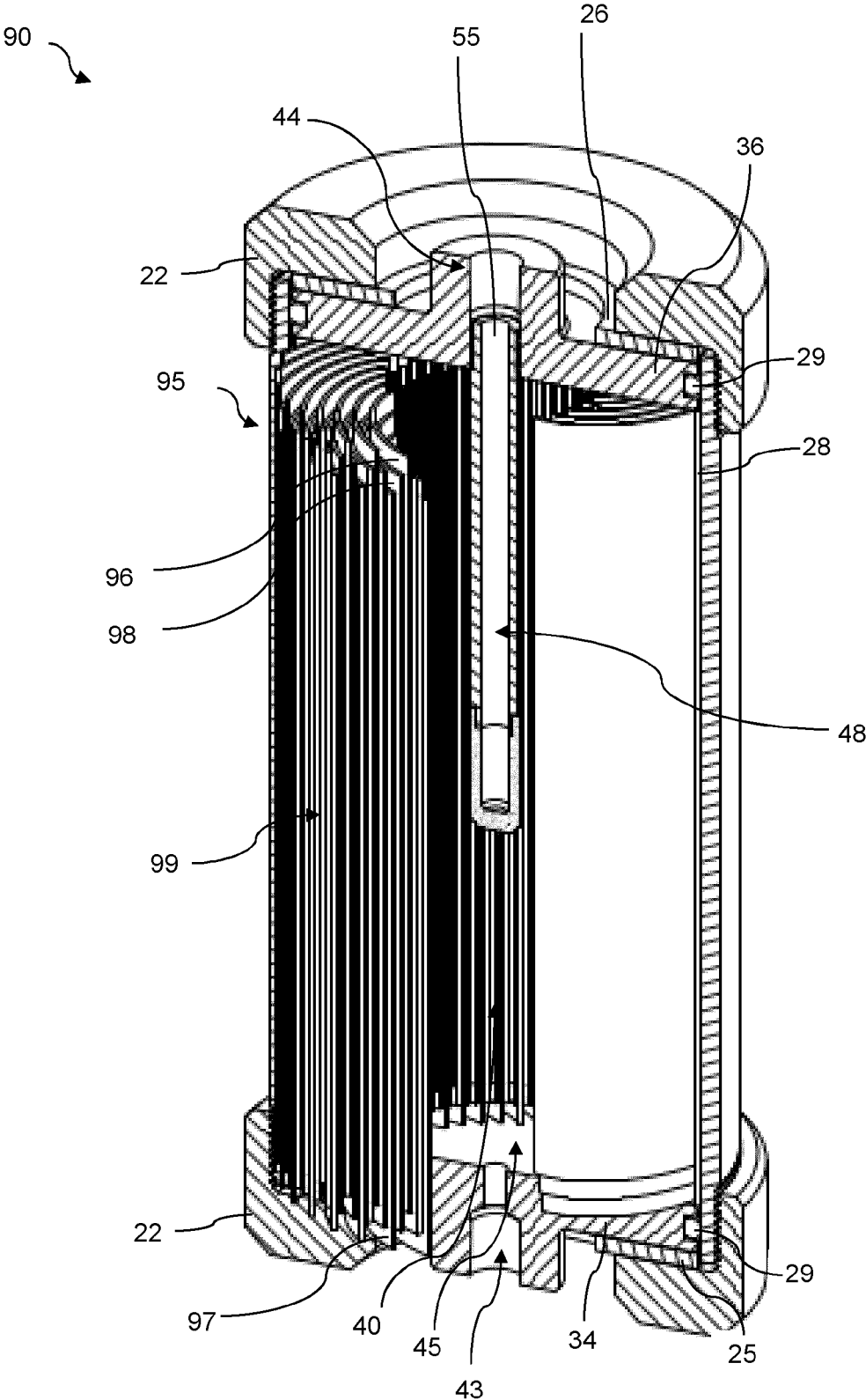


FIG 7



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Application Number

EP 23 17 4618

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Place of search		Date of completion of the search	Examiner
The Hague		27 October 2023	D'Andrea, Angela
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