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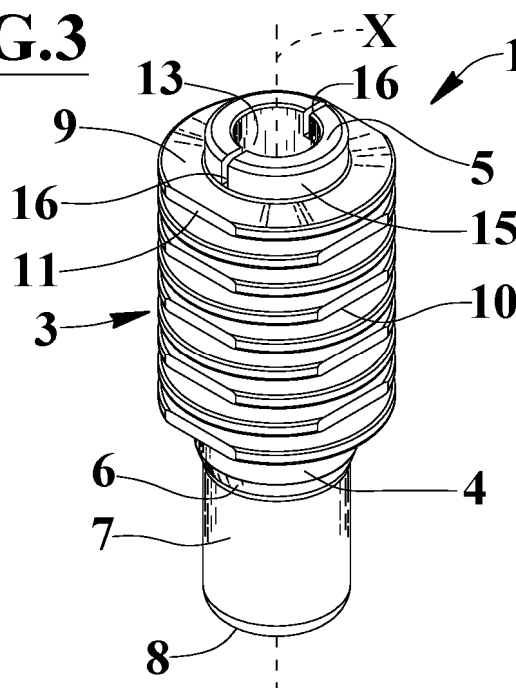
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(54) ELECTRODE WITH IMPROVED HEAT DISSIPATION FOR A PLASMA TORCH

(57) An electrode with improved heat dissipation for a plasma torch extends along a longitudinal axis (X) thereof and comprises a proximal portion (3), having a proximal end (5) assigned for electrical connection to an electrical power source for the torch, a distal portion (7) integral with the proximal portion (3) and a plurality of parallel fins (9), protruding transversely from the

proximal portion (3) and spaced by respective grooves (10). Each fin (9) has at least one passage (11) which puts the grooves (10) adjacent to it in fluid communication, where the passages (11) of a fin (9) are staggered with respect to the passages (11) of the fins (9) adjacent to it.

FIG.3



Description

TECHNICAL FIELD

[0001] The present invention relates to plasma cutting torches and specifically relates to an electrode with improved heat dissipation for a plasma torch.

PRIOR ART

[0002] A known electrode for a plasma torch has an elongated body with a proximal portion, or section, and an opposing distal portion, which is generally constrained and held in place within a tubular swirl ring element associated with a torch tip. The proximal portion is assigned to be placed in electrical contact with a torch power source; the distal portion is assigned to be positioned within a nozzle attached to a corresponding end of the swirl ring element, forming a chamber for plasma ignition. The known electrode is provided with a bracket that protrudes from the electrode body and spirals around the proximal portion, laterally contacting the internal wall of the swirl ring element.

[0003] During torch operation, a pressurized gas is introduced into the chamber through a plurality of holes commonly drilled through the swirl ring element: part of this gas is ionized and exits through the nozzle in the form of plasma, while the remainder acts as a cooling gas and flows along the spiral shelf, wrapping itself around the proximal portion of the electrode to an exhaust outlet, removing and dissipating outside the torch the heat produced by the high electric current flowing through the electrode. In torches with so-called pressure ignition, the gas entering the spiral shelf also causes the electrode to move away from the nozzle, thus triggering a discharge in the plasma chamber.

[0004] A disadvantage of the known electrode is that the flow of the cooling gas along the spiral shelf is nearly uniform and laminar, and consequently, convective heat transfer from the electrode to the cooling gas is relatively inefficient. In fact, the layers of the flow closest to the electrode are slower and absorb most of the total absorbed heat, while the layers that travel further inside the spiral are faster and remain virtually independent in respect of the slower and cooler layers of such.

[0005] Another disadvantage of the known electrode is that the gas flow along the spiral shelf can cause the electrode to rotate undesirably around its axis, causing the electrode to rub against the diffuser element and the power source, resulting in wear on the various components.

[0006] Another disadvantage of the known electrode is that to improve its cooling, it is useful to increase the length of the spiral shelf and, consequently, the number of turns. However, this also leads to a progressive increase in the pressure of the cooling gas flowing along the spiral, with the consequent opposite effect of slow-

ing the flow and reducing the cooling efficiency.

[0007] Another disadvantage of the known electrode is that, due to the high temperatures reached during use and the mass and material of the electrode itself, its cooling by gas flow is minimal and often insufficient to reduce electrode wear due to overheating.

DISCLOSURE OF THE INVENTION

[0008] An object of the present invention is to propose an electrode with improved heat dissipation for a plasma torch, shaped in such a way as to cause a turbulent flow of the cooling gas along the electrode itself, thus increasing the efficiency of heat transfer from the electrode to the gas.

[0009] Another object of the present invention is to propose an electrode that causes a nearly random flow of the cooling gas, to avoid the onset of unwanted rotations.

[0010] Another object of the present invention is to propose a low-mass electrode that is easier to cool by a flow of cooling gas.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] The characteristics of the invention are highlighted below with particular reference to the accompanying drawings, in which:

- Figure 1 illustrates a partial sectional view along a median plane of the electrode with improved heat dissipation of the present invention, assembled into a plasma torch, in which some parts have been removed to better highlight others;
- Figure 2 illustrates a side view of the electrode of Figure 1 housed into a plasma torch shown in partial section, in which some parts have been removed to better highlight others;
- Figure 3 illustrates an axonometric view of the electrode of Figure 1;
- Figure 4 illustrates a side view of the electrode of Figure 1;
- Figure 5 illustrates a sectional view along the V-V plane of the electrode of Figure 4, in which some parts have been removed to better highlight others;
- Figure 6 illustrates a cross-sectional view along the VI-VI plane of the electrode of Figure 5, in which some parts have been removed to better highlight others;
- Figure 7 illustrates a cross-sectional view along a median plane of the electrode of Figure 1;

- Figure 8 illustrates a cross-sectional view along a median plane of a variant of the electrode of Figure 1;
- Figures 9-18 illustrate cross-sectional views of respective variants of a fin of the electrode of Figure 4, in which some parts have been removed to better highlight others.

BEST MODE TO CARRY OUT THE INVENTION

[0012] With reference to Figures 1-8, numeral 1 indicates the electrode with improved heat dissipation of the present invention, assigned in its operating condition to be mounted into a tip or cartridge 100 of a plasma torch.

[0013] In the preferred embodiment of the invention, the electrode 1 has a body that defines and extends along its own longitudinal axis X and comprises a proximal portion 3 (or proximal section 3) and a distal portion 7 integral with each other. The body of the electrode 1 is made of metallic material, typically copper or a copper-based alloy.

[0014] The proximal portion 3 has a nearly cylindrical side surface 4 centered on the longitudinal axis X, and has one end joined in a single body or otherwise coupled to the distal portion 7 and an opposite proximal end 5 that in the operating condition is assigned to make electrical contact with a conductive terminal P of a power source of the plasma torch, placing the electrode 1 in electrical connection with the source. This electrical contact may be indirect and mediated and/or aided by other conductive elements placed between the proximal end 5 and the conductive terminal P and/or associated with the proximal end 5 or other parts of the proximal portion 3.

[0015] The distal portion 7 is also almost cylindrical and, as usual, has an insert of hafnium or other material or alloy at the center of its bottom at its distal end 8.

[0016] Unlike known electrodes, the electrode 1 comprises a plurality of fins 9 parallel to each other and substantially flat in shape, that is, plate-like or washer-like, protruding transversely from the side surface 4 of the proximal portion 3, that is, extending mainly in a direction perpendicular to the longitudinal axis X. The fins 9, assigned to dissipate the heat of the electrode 1 in a flow of cooling gas, are preferably spaced from the ends of the proximal portion 3, leaving their extreme sections exposed for predetermined respective lengths.

[0017] The fins 9 are spaced in pairs by a respective annular groove 10, which runs between two adjacent fins 9 and separates two adjacent faces of these. Each groove 10 is therefore laterally delimited by the faces of the two adjacent fins 9, ends in a bottom in the direction of the longitudinal axis X, and is open in the opposite direction. The bottom of the grooves 10 may coincide with the side surface 4 of the proximal portion 3, or be at a smaller or larger radius from the longitudinal axis X

than the side surface 4.

[0018] The thickness of a fin 9, that is its dimension in the longitudinal direction, is variable depending on parameters such as the overall dimensions of the electrode 1, the number of fins 9 and the nominal operating current. It has been surprisingly observed that the efficiency or rate of heat dissipation improves significantly when the ratio between the longitudinal width of a groove 10 (that is the distance between two consecutive fins 9) and the thickness of a fin 9 is between about 0.6 and 2, preferably between about 0.8 and 1.8, or between about 0.9 and 1.7, or between about 0.95 and 1.6, and more preferably between about 1 and 1.5 within which excellent results are observed, with the specification that in this document the extremes of the ranges indicated are understood to be included in the ranges themselves, and that "about" means, for example, a standard rounding to the least significant figure, unless otherwise specified. The improvement referred to refers to a known electrode with a spiral shelf of the same or similar diameter and length (for example, within 10% of the difference) as electrode 1, and of a nominal operating current and number of turns equal to the nominal operating current and number of fins 9 of electrode 1.

[0019] Each fin 9 has a peripheral edge that is preferably chamfered or rounded, primarily to facilitate the insertion of electrode 1 into a swirl ring element 101 of the tip or cartridge 100 of a plasma torch, where in the operating condition, such peripheral edge of the fins 9 is in contact in at least some sections with the inside of a side wall 102 of said swirl ring element 101.

[0020] Variants of the electrode 1 provide for the entire profile or cross-section of the fins 9 to be thinned in a radial outward direction. In these cases, the thickness of a fin 9 can be understood as its minimum, average, or maximum thickness.

[0021] Each fin 9 has at least one passage 11 or opening that passes through its thickness and provides fluid communication between the adjacent grooves 10, that is, the sides of the fin 9 itself.

[0022] The passage 11 or passages 11 of a fin 9 are staggered along a direction parallel to the longitudinal axis X with respect to the passages 11 of the fins 9 adjacent to it.

[0023] Preferably, the fins 9 are centered along the longitudinal axis X of the electrode 1, and extend around the proximal portion 3 with radial symmetry, possibly excluding or disregarding the passages 11. Each passage 11 preferably consists of a section of the perimeter edge of the respective fin 9 recessed with respect to the maximum protrusion or maximum radius of the fin 9 itself. Mostly, the portions of the edge of a fin 9 corresponding to respective passages 11 therefore do not come into contact with the side wall 102 of the swirl ring element 101.

[0024] More precisely, each fin 9 preferably has an edge of circular or approximately circular shape or with

portions of circular shape or oval, or polygonal with rounded sides, or of another shape.

[0025] Each passage 11 consists of a recessed section of the perimeter edge of the fin 9, chamfered, milled, cut, shaped, or otherwise reduced with respect to the maximum radius of the fin 9. The passages 11 of a fin 9 preferably coincide with respective sides or sections of a triangle, a square, a rectangle, another polygon, or an ellipse, or follow another or other linear, broken, or curved profile.

[0026] In any case, it can therefore be said that a fin 9 has an approximately circular shape, where the passages 11 deviate some sections or portion of the edge of the fin 9 from a perfect circumference, or it can be said indifferently and equivalently that a fin 9 has a polygonal or sectionally polygonal, elliptical shape, and so on, where such a shape is in any case inscribable in a geometric circle, that is ideally traceable.

[0027] In fact, it always turns out that each fin 9 can be inscribed in a geometric circle, where the presence of the passages 11 reduces the maximum area, equal to the area of said geometric circle, that the fin 9 would have if it were without passages 11. The circumference T of said geometric circle is indicated by a dotted line in Figures 5 and 6.

[0028] Alternatively or in addition, each passage 11 consists of a slot or hole made through the thickness of the respective fin 9. In this case, the perimeter edge of the fin 9 describes a complete circumference coinciding everywhere with that of said geometric circle, with the passages 11 lying within it.

[0029] The total area of the passages 11 of a fin 9 is generally between approximately 0.5% and 50% of the area of said geometric circle, preferably between approximately 1% and 30% of the area of said circle, or between approximately 2% and 20%, or between approximately 2.5% and 10%, more preferably between approximately 3% and 6%, or even more preferably between approximately 3.2% and 5.5% of the area of said geometric circle. The ratio between the total area of the passages 11 and the area of the geometric circle circumscribed to a fin 9 is also conveniently determined on the basis of the number of fins 9, as better explained below.

[0030] Alternatively but equivalently, by removing the cross-sectional area of the proximal portion 3 and therefore limiting the ratio to the maximum area that fins 9 with a circular crown shape without passages 11 would have (that is for which the external circumference coincides with the circumference T of the already introduced geometric circle), the area of the passages 11 of a fin 9 is generally between approximately 0.6% and 55% of the area of said circular crown, preferably between approximately 2% and 35% of the area of said circular crown, or between approximately 3% and 27%, or between approximately 3.5% and 15%, more preferably between approximately 3.6% and 7.5%, or even more preferably between approximately 3.7% and

6.5% of the area of said circular crown.

[0031] In the embodiment of the electrode illustrated in Figures 1-8, the ratio between the areas of the passages 11 and the area of the circle in which the fin 9 is inscribed is approximately 3.3%; equivalently, the ratio between the areas of the passages 11 and the area of the circular crown of the fin 9 if no passages 11 are present is approximately 3.8%.

[0032] Preferably, each fin 9 has at least two radially symmetrical passages 11, that is, they are angularly equispaced with respect to the longitudinal axis X. Consequently, the passages 11 of a fin 9 are staggered, that is, offset by a predetermined angle with respect to the passages 11 of the fins 9 adjacent to it, taking as a reference, for example, the midpoint of each passage 11.

[0033] For example, with particular reference to Figures 4-6, the fins 9 each have two passages 11 consisting of linear millings, where each milling involves a portion of approximately 50° of the circular edge of the fin 9 recessed with respect to the edge itself, making this edge approximately circular. The two passages 11 are radially mirrored, that is, their centers are angularly spaced by 180° with respect to the longitudinal axis X. As can be seen from a comparison between Figures 5 and 6, fin 9 in Figure 6 has two passages 11 identical to those of fin 9 in Figure 5, but one is out of phase with respect to the other by 90°, thus resulting in a staggered pattern.

[0034] If the fins 9 are identical and the out of phase angle, in other words the offset angle, between adjacent fins 9 is constant, the fins 9 of the electrode 1 will provide a given periodic pattern. In the embodiment illustrated in Figures 1-8, this pattern is repeated every two fins 9.

[0035] Variants of the fins 9 with different numbers and/or shapes of passages 11 are illustrated, by way of example, in Figures 9-18 with the corresponding circumscribed geometric circle T, and in particular:

- Figure 9 illustrates a fin 9 with two diametrically opposed passages 11, where the shape of each passage 11 follows a segment of an ellipse whose center is external to the fin 9, for example with its center on the circle T at the midpoint of the sector corresponding to the passage 11 and with its major axis equal to the radius of the circle T;
- Figure 10 illustrates a fin 9 with two straight passages 11, similar to those of the fins 9 in Figures 5 and 6, but with a larger area of the passages 11;
- Figure 11 illustrates a fin 9 with two passages 11 whose shape follows respective opposing segment of an ellipse whose center coincides with that of the circumference T and whose major axis is greater than its radius;
- Figure 12 illustrates a fin 9 of elliptical shape, coaxial with the longitudinal axis X and with its major axis equal to the radius of the circumference T,

where each passage 11 therefore corresponds to a respective half of the ellipse;

- Figure 13 illustrates a fin 9 with an edge in the shape of an equilateral triangle inscribed in the circumference T, and consequently having three passages 11 angularly equally spaced at 120°;
- Figure 14 illustrates a fin 9 with three equally spaced 120° angular passages 11 that belong to an equilateral triangle centered at the center of the circumference T and intersected by it;
- Figure 15 illustrates a fin 9 with two diametrically opposed passages 11, each shaped like a circular segment centered on the circumference T and with a radius equal to the maximum radius of a cavity 13 of the electrode 1, which will be presented in more detail below;
- Figure 16 illustrates a fin 9 with a perfectly circular edge and two passages 11 formed by opposing slots, each occupying a sector of approximately 90° concentric with the circumference T;
- Figure 17 illustrates a fin 9 with four passages 11, spaced 90° apart as they belong to a square centered at the center of the circumference T and with a diagonal greater than its diameter;
- Figure 18 illustrates a fin 9 with a single linear passage 11.

[0036] The number of fins 9 is variable and is chosen based on at least one parameter such as the length of the proximal portion 3, the overall length of the electrode 1, the diameter of the electrode 1, its maximum nominal operating current, or others. As the current increases, and consequently the temperature of electrode 1 rises, it is preferable to provide a greater number of fins 9 to increase the rate of heat dissipation. On the other hand, the greater the number of fins 9, the greater the aerodynamic resistance they offer to a flow of cooling gas directed towards the proximal end 5, slowing it down, with a consequent reduction in cooling effectiveness. Conveniently, the electrode 1 according to the invention allows the number of fins 9 to be increased at will to improve cooling: the flow of cooling gas is thus balanced and maintained at sufficiently high values by increasing the overall area of the passages 11 of a fin 9 as the number of fins 9 increases, to prevent a large number of fins 9 from causing backpressure with a flow-retarding effect, as instead occurs with an excessively high number of turns in known electrodes.

[0037] For example, for electrodes 1 operating with typical currents between approximately 20 A and 150 A, the number of fins 9 of electrode 1 is preferably between 5 and 20, and more preferably between 6 and 15, for example 7, 8, 9, 10, 11, or 12. The indicated ranges provide an optimal compromise for maximizing heat dissipation at these operating currents.

[0038] The electrode 1 preferably also comprises a cavity 13 having an open access 15 at the proximal

end 5 of the proximal portion 3, extending along the longitudinal axis X within at least one part or longitudinal section of the proximal portion 3, and terminating in a closed bottom 17 within the body of the electrode 1.

[0039] The bottom 17 is flat or of another shape, for example conical or hemispherical, typically determined by the tool used for milling or boring the cavity 13, such as a cutter with a 118° tip. The bottom 17 borders the internal wall of the cavity 13 via a sharp, chamfered, or rounded edge.

[0040] The cavity 13 preferably has radial symmetry around the longitudinal axis X, and more preferably is of circular cross-section and is therefore cylindrical, conical, or truncated conical in shape, or cylindrical and/or conical or truncated conical in sections.

[0041] The access 15, therefore, has the shape of a hollow cylindrical wall, delimited internally by the side wall of the cavity 13, externally by the side surface 4 of the proximal portion 3, and ultimately by the proximal end 5. The access 15 is preferably provided with one or more slots 16 at the proximal end 5, so as to facilitate the circulation of the cooling gas into and out of the cavity 13 even when it contacts the conductive terminal P of the torch's electrical power source.

[0042] In some unillustrated variants of the cavity 13, the access 15 does not directly face the proximal end 5, but consists of one or more through holes made radially through the thickness of the side wall of the cavity 13 near the closed proximal end 5. The through holes are preferably at least two and are angularly equally spaced around the longitudinal axis X.

[0043] However, possible embodiments of the electrode 1 are without the cavity 13 or is solid.

[0044] To better illustrate the preferred ratios between the dimensions of different parts of the electrode 1, it is convenient to define the following measurements, also with reference to the figures:

- F indicates the maximum width or maximum diameter of the cavity 13, if present, measured without taking into account any chamfers or recesses made at the access 15 of the cavity 13 itself;
- E indicates the external thickness or diameter of the proximal portion 3 measured at the bottom of the grooves 10;
- A indicates the external thickness or diameter of the proximal portion 3 measured at the access 15 of the cavity 13, that is at the proximal end 5, from which it follows that the thickness of the cylindrical wall of the proximal portion 3 to the access 15 is equal to $(A-F)/2$;
- C indicates the external thickness or diameter of the proximal portion 3 measured on the side surface 4 of the extreme section bordering the distal portion 7;
- D indicates the thickness or diameter of the distal portion 7, which is essentially cylindrical, that is, approximated by a cylinder, excluding any cham-

fers, connections, or other elements attached to its side surface;

- S indicates the distance between the distal end 8 of the distal portion 7 and the bottom 17 of the cavity 13, where the measuring point of the bottom 17 is either the deepest point within the body of the electrode 1 or the edge or connection with the internal wall of the cavity 13, as applicable;
- L indicates the length of the cavity 13 measured along the longitudinal axis X, where, as applicable, this measurement stops at the deepest point of the bottom 17 or at the edge or connection with the internal wall of the cavity 13; from which it is evident that the overall length of electrode 1 is equal to the sum of L+S.

[0045] The maximum width F of cavity 13 is preferably greater than or equal to one-third, and more preferably half, of the diameter E of proximal portion 3 measured at the bottom of the grooves 10, that is, $F \geq E/3$ or $F \geq 0.5 E$, for example, $F = 0.6 E$. This is to ensure, as better explained below, a sufficient thinning of the cylindrical wall thickness of proximal portion 3 and, marginally, a larger surface area exposed to ventilation to dissipate heat from inside electrode 1. At the same time, to ensure that proximal portion 3 maintains sufficient structural strength and does not deform significantly as the temperature of electrode 1 increases, the maximum width F of cavity 13 is preferably less than or equal to 75% of the diameter E of proximal portion 3, that is, $F \leq 0.75 E$.

[0046] Furthermore, to allow adequate electrical conductivity for even the high currents that, as is known, pass through an electrode of a plasma cutting torch, the thickness of the cylindrical wall of access 15 varies depending on the maximum nominal operating current of electrode 1. In general, however, this thickness is preferably greater than or equal to half the maximum width F of cavity 13, that is, $(A-F)/2 \geq 0.5 F$, and more preferably $0.6 F \leq (A-F)/2 \leq 0.7 F$; for example, $(A-F)/2 \approx 0.64 F$ represents an excellent compromise between electrical conductivity, structural robustness, and heat conduction efficiency towards access 15.

[0047] It is preferable that the diameter of the proximal portion 3 be slightly larger between the fins 9, that is, measured at the bottom of the grooves 10 (diameter E), than the diameter of the same proximal portion 3 measured at access 15 (diameter A) and the section adjacent to the distal portion 7 (diameter C); in formulas, preferably $E > A$ and $E > C$. A slightly increased diameter E provides a more robust anchorage and more effective heat transfer between the proximal portion 3 and the fins 9.

[0048] These constraints ensure that electrode 1 has a minimum cross-section of conductive material throughout, sufficient to allow the passage of the maximum rated operating current; this cross-section, at least as a first approximation, is empirically determined

to be at least 1 mm^2 for every 10 A of current.

[0049] Some variants of the invention may, however, provide that $E \leq C, A$.

[0050] The size of diameter A relative to diameters E and C does not significantly affect the operation and cooling of electrode 1, and may rather be determined by the shapes and dimensions of other parts of the tip or cartridge 100 or the plasma torch for which electrode 1 is assigned.

[0051] The distance S between the distal end 8 of the distal portion 7 and the bottom 17 of the cavity 13 is preferably between 1 and 2 times the diameter D of the distal portion 7, that is $D \leq S \leq 2 D$. Furthermore, the distal portion 7 has a length preferably greater than its diameter D, where this length is measured between the distal end 8 and the interface between the distal portion 7 and the proximal portion 3. The constraint $S \geq D$ ensures that the distal portion 7 has a quantity of copper or other conductive material near the distal end 8 sufficient to withstand the heat developed by the plasma arc without melting; The constraint $S \leq 2 D$ ensures that the thickness of the cavity 13 wall, reduced compared to the thickness of a solid electrode 1, extends to the electrode 1 up to a sufficiently close distance to the distal end 8 to induce better heat transfer from the latter to the proximal end 5.

[0052] The plasma jet generated during the use of a plasma torch is more confined and therefore allows for more precise cutting when the gas, which flows between the electrode and the nozzle through holes 103 made in a side wall 102 of a swirl ring element 101 of the torch itself, is rotated around the electrode itself. The gas passing through the holes 103 must, however, be appropriately distributed between a flow directed to form the plasma jet and a cooling flow in the opposite direction. In the electrode 1 of the invention, the separation of the gas into these two flows is conveniently obtained by means of a longitudinal connection portion 6 of a truncated cone or other tapered shape at the interface between the proximal portion 3 and the distal portion 7. The length of the connection portion 6 is preferably less than 10% of the overall length of the electrode 1, more preferably less than 5% of the overall length. A subset of the holes 103 facing the proximal portion 3, and/or the connection portion 6 in proximity to the proximal portion 3, supplies the gas that will proceed in the cooling flow; a subset of the remaining holes 103 facing the distal portion 7 and/or on the connection portion 6 in proximity to the latter supply the gas for the plasma jet. In particular, the rotation or so-called vortex effect is obtained through a particular orientation of all or part of the holes 103 in a direction that is not perfectly radial, that is, slightly offset from the longitudinal axis X.

[0053] With particular reference to Figure 2, the gas that, in an operating condition of the torch in which the electrode 1 is inserted, enters through the holes 103 of the swirl ring element 101 at the connection portion 6

undergoes acceleration and a simultaneous vortex wrapping around the distal portion 7 towards the distal end 8 and an exit hole 105 of a nozzle 104 of the torch. It has been experimentally verified that, surprisingly, gas acceleration and wrapping are best suited to generate a thin and precise plasma jet when the ratio between the diameter D of the distal portion 7 and the diameter C of the proximal portion 3 measured on the side surface 4 in the vicinity of the distal portion 7 is between about 0.75 and 1, preferably between about 0.85 and 0.95, more preferably between about 0.87 and 0.93, even more preferably and as illustrated when D/C is equal to or about 0.9.

[0054] The operation of the electrode 1 requires that, in its operating conditions, it is assembled into a tip or cartridge 100 of a plasma cutting torch, as shown for example in Figures 1 and 2. More precisely, the electrode 1 is inserted in a hollow cylindrical swirl ring element 101, centred along the longitudinal axis X and fitted onto the electrode 1 with the edges of the fins 9 almost in contact with the inside of a side wall 102 of the swirl ring element 101 and with the passages 11 of the fins 9 recessed with respect to the maximum diameter of the edge of the fins 9 and therefore spaced from such side wall 102. In the cartridge 100, a conductive nozzle 104 is fixed to a distal end of the swirl ring element 101 and is provided with an exit hole 105 for the plasma; the nozzle 104 surrounds the distal end 8 and at least part of the distal portion 7 of the electrode 1, from which it remains spaced by a thin separation space in which the plasma gas flow will flow. The swirl ring element 101 is provided with a plurality of holes 103 made through its side wall in directions staggered with respect to the longitudinal axis X and arranged in two rows facing or near the connecting section 6 between the proximal portions 3 and distal portions 7 of the electrode 1.

[0055] In the operating condition of a contact-ignition type torch, the distal end 8 of the electrode 1 is initially in contact with the nozzle 104 and a high electric current flows through this contact. A flow of compressed gas passes through the holes 103 of the swirl ring element 101, then fills and compresses in the separation space between the distal portion 7 and the nozzle 104. From this separation space, the gas partly insinuates itself through the passage or passages 11 of the first fin 9 closest to the distal portion 7, and partly presses against the surface of said fin 9. Once it reaches the first groove 10 between the first fin 9 and the subsequent second fin 9, the gas is forced to travel at least a portion of said first groove 10 along a trajectory mainly tangential to the longitudinal axis X up to the passages 11 of the second fin 9, and in doing so, presses against the surface of the second fin 9.

[0056] In this way, the gas insinuates itself through the passages 11 of all the fins 9 with a turbulent flow that follows tortuous and non-linear paths, preferably random, and presses against the fins 9 with a resultant

force net along the longitudinal axis X directed towards the proximal end 5. This force opposes and overcomes an opposing force, for example the elastic force of a spring (not shown) placed between the proximal portion 3 and the electrical power source, and moves the electrode 1 causing it to detach from contact with the nozzle 104, during which an arc discharge is generated between the two conductors, that is the plasma. Part of the pressurized gas in the separation space inside the nozzle 104 is spun in a vortex manner and is accelerated by the connecting section 6 and flows at high speed through the exit hole 105, dragging the plasma out in the form of a jet which is used for cutting.

[0057] The swirl ring element 101 keeps the electrode 1 centered and allows it to flow only along the longitudinal axis X, and laterally closes the grooves 10, so that the only path the cooling gas can follow to reach the proximal end 5 is through the passages 11 (except for any negligible leaks between the outer edge of the fins 9 and the side wall 102 of the swirl ring element 101).

[0058] The high electric current continues to flow through the electrode 1, sustaining the arc discharge and consequently causing rapid heating of the electrode 1 itself starting from the distal end 8. The gas flowing through the fins 9 and the grooves 10, therefore, in addition to providing the thrust to initiate the arc discharge, also acts as a cooling gas.

[0059] Advantageously, the turbulent flow of the cooling gas contacts the entire surface of the fins 9 and the grooves 10, promoting the transfer of heat from the electrode 1 to the gas itself, which exits heated through the torch's exhaust ducts. Furthermore, the cross-section of the electrode 1 affected by the cavity 13 is smaller than the cross-section of an identical solid electrode 1: this reduction provides the unexpected but experimentally verified advantage that the heat developed at the distal end 8 is more quickly drawn towards the proximal end 5 and the fins 9 and, therefore, more quickly dissipated in the turbulent flow of the cooling gas.

[0060] It should be noted that the flow of cooling gas does not affect cavity 13 at all, or affects it only marginally, the main purpose of which is said to reduce the cross-section of conductive material towards the proximal end 5. However, the air or gas inside cavity 13 heats up to temperatures higher than the cooling gas. This air or gas tends to exit from the access 15 either by convection due to the temperature gradient or by being attracted by the depression caused outside the access 15 by the flow of cooling gas. This further increases heat removal from inside the electrode 1.

[0061] The hot air or gas inside the cavity 13, however, increases in pressure as its temperature increases: the slots 16 at the proximal end 5, or the radially drilled through holes as described for some variants, allow the air or gas to escape outside the cavity 13. This prevents the formation of a gas cushion in the

cavity 13 which, if it reaches sufficiently high pressures, could push the electrode 1 towards the nozzle 104, interrupting the contact and electrical connection of the proximal end 5 with the conductive terminal P and therefore interrupting the plasma generation.

[0062] As the ratio between the total area of the passages 11 of a fin 9 and the area of the geometric circle or circular crown corresponding to an identical fin 9 without passages 11 increases, on the one hand, the speed of the cooling gas flow increases and, at least up to a certain threshold, the effectiveness of the cooling effect on the electrode 1, but on the other hand, the aerodynamic resistance opposed by the fins 9 to the cooling gas decreases; this resistance must remain above a minimum threshold necessary to overcome the elastic force of said spring and cause the separation of the electrode 1 from the nozzle 104 and the ignition of the plasma.

[0063] The temperature of the plasma arc, which can be approximately identified with the average temperature of the electrons in the plasma, varies at least as a function of the voltage and current supplied to electrode 1, and of the gas type, pressure and velocity. Since the arc originates almost entirely at the insert at the distal end 8, it is clear that the temperature of the electrode 1 during torch operation is maximum at the distal end and the heat is distributed from there towards the proximal end 5. Regardless of the value of the absolute temperature reached by the electrode 1, it has been experimentally verified that the electrode 1 made according to the invention and provided with cavity 13 transports the heat produced at the distal end 8 towards the proximal end 5 and the fins 9 and dissipates it in the cooling gas with a speed or efficiency advantageously higher by between 20% and 50% compared to an equivalent known electrode with a spiral shelf, with the same dimensions, gas parameters and operating current; the dissipation efficiency is reduced for a full electrode 1 that is without cavity 13, but still remains between 10% and 25% higher than the known electrode. This evidently translates into a longer operating life for electrode 1 compared to that of known electrodes.

[0064] This improvement can be appreciated by a simple visual comparison between electrode 1 and a known electrode, both copper-made or copper-based, after having subjected them to the same duty cycle. Using air as the gas, a layer of copper oxide (CuO) forms on the electrode surface, starting from the distal end and becoming more visible the more the electrode is heated. In the known electrode, this oxidized layer covers the entire distal portion, reaching the first turns of the shelf. In contrast, in electrode 1 made according to the invention, the oxidized layer is limited to a short longitudinal section near the distal end 8 and is less pronounced.

[0065] Since the thermal conductivity of copper oxide is significantly lower than that of copper, it is clear that the electrode 1 of the invention continues to dissipate

heat more efficiently than a known electrode, which, as it rapidly oxidizes, rapidly reduces its ability to transfer heat to the cooling gas, exponentially accelerating its wear. Consequently, the electrode 1 is extremely durable.

[0066] Similar conclusions also apply to electrodes made of other materials.

[0067] In some variants of the electrode 1 provided with the cavity 13, the cavity narrows from the access 15 to the bottom 17, so that the wall thickness of the proximal portion 3 decreases in the opposite direction from the bottom 17 to the proximal end 5.

[0068] Some of these variants of cavity 13, not illustrated, provide for cavity 13 to have a conical or truncated cone shape that tapers continuously from access 15 to the bottom 17.

[0069] In another of these variants, cavity 13 comprises, or is composed of or divided into, a plurality of longitudinal sectors, each cylindrical or truncated cone-shaped, with a diameter progressively smaller from access 15 to the bottom 17. Compared to a cavity 13 that tapers into a cone, machining to create progressively narrower sectors is conveniently easier.

[0070] For example, in the variant illustrated in particular in Figure 8, cavity 13 preferably comprises, arranged in order from access 15 to the bottom 17, a first sector 21, a second sector 22, and a third sector 23, each cylindrical or approximately cylindrical in shape.

[0071] The length of a sector is preferably equal to or differs by no more than approximately 20% from the length of the other sectors. Furthermore, the length of the first sector 21 is preferably equal to or close to one-third of the overall length L of the cavity 13.

[0072] The internal diameter of the first sector 21 coincides with the maximum diameter F of the cavity 13. The internal diameter of the second sector 22 is between approximately 0.7 and 0.9 times, that is, approximately 0.8 times, the diameter of the first sector 21. The internal diameter of the third sector 23 is between approximately 0.5 and 0.7 times, that is, approximately 0.6 times, the diameter of the first sector 21. The different sectors of different diameters are connected by short chamfers or truncated cone-shaped junctions.

[0073] Naturally, the number of sectors can be different from three, for example, two, four, five, six, and so on.

[0074] These variants are particularly advantageous for creating a cavity 13 that extends deeper along the body of the electrode 1, even inside the distal portion 7, since, when the distance S between the distal end 8 and the bottom 17 is minimal, that is equal to the diameter D of the distal portion 7, it is convenient for the diameter of the cavity 13 to be reduced towards the bottom 17. This bottom 17 is in fact located in the distal portion 7 of the electrode 1, which is the portion most subject to overheating during use. To leave a sufficient quantity of material in the body of the electrode 1 in the proximal portion 7 so that, even when overheated, it

maintains solidity and structural integrity, the most advanced sectors of the cavity 13 are narrowed as mentioned. At the same time, with this solution, the heat gradient tends more rapidly toward the proximal end 5, further improving the cooling efficiency of the electrode 1.

[0075] It is provided by the invention that the characteristics described for different variants and embodiments described for the electrode 1 can be selected and combined independently.

[0076] The present invention also provides a cartridge 100 for, or tip of, a plasma torch comprising an electrode 1 as described above, in all its possible forms or variations. The tip or cartridge 100 is removable and interchangeable or replaceable, provided with a special attachment, or is integral with the torch.

[0077] The cartridge 100 extends along its own longitudinal axis X and comprises an electrode 1 centered along the same longitudinal axis X.

[0078] This electrode 1 in turn comprises a proximal portion 3, having a proximal end 5 assigned for direct or indirect electrical connection to a conductive terminal P of a torch power source, and a distal portion 7 integrally connected to the proximal portion 3 at a connecting section 6 whose cross-section reduces from the proximal portion 3 to the distal portion 7.

[0079] The electrode 1 of the cartridge 100 also comprises a plurality of fins 9 parallel to each other, protruding transversely from the proximal portion 3 mainly on planes perpendicular to the longitudinal axis X and mutually spaced by respective grooves 10. Each fin 9 has at least one passage 11 that passes through its thickness and places the grooves 10 adjacent to the sides of the fin 9 itself in fluid communication, where the passages 11 of a fin 9 are staggered with respect to the passages 11 of the fins 9 adjacent to it, thus establishing a turbulent flow of a cooling gas in an operating condition of the plasma torch on which the cartridge 100 is mounted.

[0080] The cartridge 100 preferably also comprises a hollow, nearly cylindrical swirl ring element 101, as described above, made of dielectric material, centered along the longitudinal axis X and fitted onto the electrode 1 at least at the proximal portion 3 thereof, with the perimeter edges of the fins 9 in nearly contact - not necessarily, but possibly airtight - with a side wall 102 of the swirl ring element 101 itself and with the passages 11 of the fins 9 that are spaced from this side wall 102.

[0081] A nozzle 104 provided with an exit hole 105 for the plasma is attached to a distal end of the swirl ring element 101. Optionally, the cartridge 100 comprises other elements such as a screen 106 that covers the nozzle 104 and a support and thermal insulation bushing 107.

[0082] The swirl ring element 101 is provided with a plurality of holes 103 formed through its side wall 102 in directions slightly offset or deviated from the longi-

nal axis X, or oriented in a non-perfectly radial direction. This offset is preferably between 1° and 60°, more preferably between 2° and 45°, and even more preferably between 3° and 35°.

[0083] The holes 103 are evenly distributed in two rows, that is, they are angularly equally spaced along two circumferences centered on the longitudinal axis X and perpendicular to it. When the cartridge 100 is fully assembled, the first-row of holes 103 face the proximal portion 3 and/or the connecting section 6 near the proximal portion 3, for example, between the connecting section 6 and the proximal portion 3, while the second-row of holes 103 face the distal portion 7 and/or the connecting section 6 near the distal portion 7. During operation of the plasma torch, the gas entering the swirl ring element 101 through the first-row holes 103 flows mostly toward the proximal end 5 as a cooling gas, while the gas entering through the second-row holes 103 flows mostly toward the exit hole 105 of the nozzle 104.

[0084] The division of the two flows, as already mentioned, is achieved mainly by the connecting section 6. Optionally, the internal surface of the side wall 102 of the swirl ring element 101 inclines internally into a truncated cone that narrows toward the longitudinal axis X at the second row of holes 103. This truncated cone faces almost parallel to the connecting section 6, which surprisingly results in improved vorticity and precision of the plasma jet.

[0085] Variants of the tip or cartridge 100 comprise a swirl ring element 101 provided with a single row of holes 103, in which the plasma and cooling gas flows are separated due to the high gas inlet pressure and the shape of the connecting section 6.

[0086] A further object of the present invention is a plasma cutting torch comprising an electrode 1 as described above, that is a cartridge 100 as described above and comprising such an electrode 1.

Claims

1. Electrode with improved heat dissipation for a plasma torch, the electrode (1) extending along a longitudinal axis (X) thereof and comprising a proximal portion (3), having a proximal end (5) assigned for electrical connection to an electrical power source for the torch, and a distal portion (7) integral with the proximal portion (3); the electrode (1) being **characterized in that** it comprises a plurality of parallel fins (9), protruding transversely from the proximal portion (3) and spaced by respective grooves (10), each fin (9) having at least one passage (11) which puts the grooves (10) adjacent to it in fluid communication, where the passages (11) of a fin (9) are staggered with respect to the passages (11) of the fins (9) adjacent to it.

2. Electrode according to claim 1 **characterized in that** the fins (9) are centered along the longitudinal axis (X), where each passage (11) consists of a slot made through the thickness of the respective fin (9), or consists of a recessed section of the edge of the fin (9). 5
3. Electrode according to claim 1 or 2 **characterized in that** the edge of each fin (9) is approximately or in portions circular, and each passage (11) consists of a chamfered, milled, cut or shaped portion of the edge, where the passages (11) of a fin (9) coincide with respective sides or portions of a triangle, a square, a rectangle, another polygon, or an ellipse, or follow another linear, broken or curved profile. 10 15
4. Electrode according to claim 2 or 3 **characterized in that** each fin (9) has at least two passages (11) angularly equispaced with respect to the longitudinal axis (X), where the passages (11) of a fin (9) are staggered by a predetermined angle with respect to the passages (11) of the fins (9) adjacent to it. 20
5. Electrode according to any of the preceding claims **characterized in that** each fin (9) is inscribable in a geometric circle, where the area of the passages (11) of the fin (9) is between about 0.5%-50% of the area of said circle, preferably between about 1%-30%, or 2%-20%, or 2.5%-10% of the area of said circle, more preferably between about 3%-6%, or 3.2%-5.5% of the area of said circle. 25 30
6. Electrode according to any of the preceding claims **characterized in that** it comprises a cavity (13) having an access (15) at the proximal end (5), extending along the longitudinal axis (X) inside at least a part of the proximal portion (3), and ending in a closed bottom (17). 35 40
7. Electrode according to claim 6 **characterized in that** the maximum width of the cavity (13) is greater than or equal to half the diameter of the proximal portion (3), and that the distance between the bottom (17) of the cavity (13) and a distal end (8) of the distal portion (7) is between 1-2 times the diameter of the distal portion (7). 45
8. Electrode according to claim 6 or 7 **characterized in that** the cavity (13) narrows from the access (15) to the bottom (17). 50
9. Electrode according to claim 8 **characterized in that** the cavity (13) comprises a plurality of longitudinal cylindrical or truncated conical sectors (21, 22, 23), of progressively reduced diameter from the access (15) to the bottom (17). 55
10. Electrode according to any of the preceding claims **characterized in that** the width of the grooves (10) is between about 0.6-2 times the thickness of the fins (9), preferably between about 0.8-1.8 times, or between about 0.9-1.7 times, or between about 0.95-1.6 times, and more preferably between about 1-1.5 times.
11. Electrode according to any of the preceding claims **characterized in that** the diameter of the distal portion (7) is between about 0.75-1 times a diameter of the proximal portion (3), preferably between about 0.85-0.95 times, or between about 0.87-0.93 times, and more preferably it is about 0.9 times.
12. Cartridge for a plasma torch extending along its own longitudinal axis (X) and comprising an electrode (1) according to any of claims 1-11.
13. Cartridge according to claim 12 **characterized in that** it also comprises a hollow swirl ring element (101), centered along the longitudinal axis (X) and fitted onto the electrode (1) with the edges of the fins (9) almost in contact with a side wall (102) of the swirl ring element (101) and with the passages (11) of the fins (9) spaced from such side wall (102), where the side wall (102) has a plurality of holes (103) a subset of which faces the proximal portion (3) and/or in proximity thereof, and a different subset of which faces the distal portion (7) and/or in proximity thereof.
14. Plasma torch comprising an electrode (1) according to any of claims 1-11.

FIG. 1

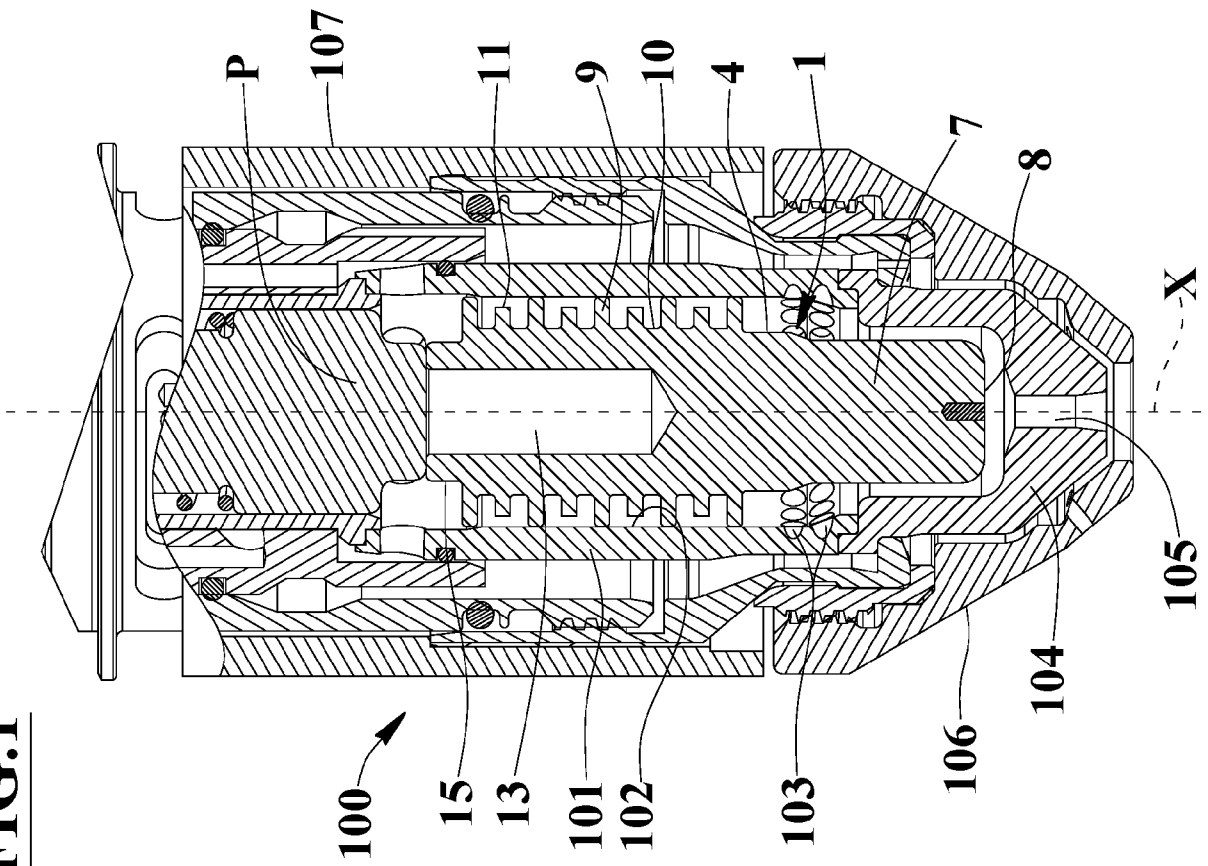


FIG. 2

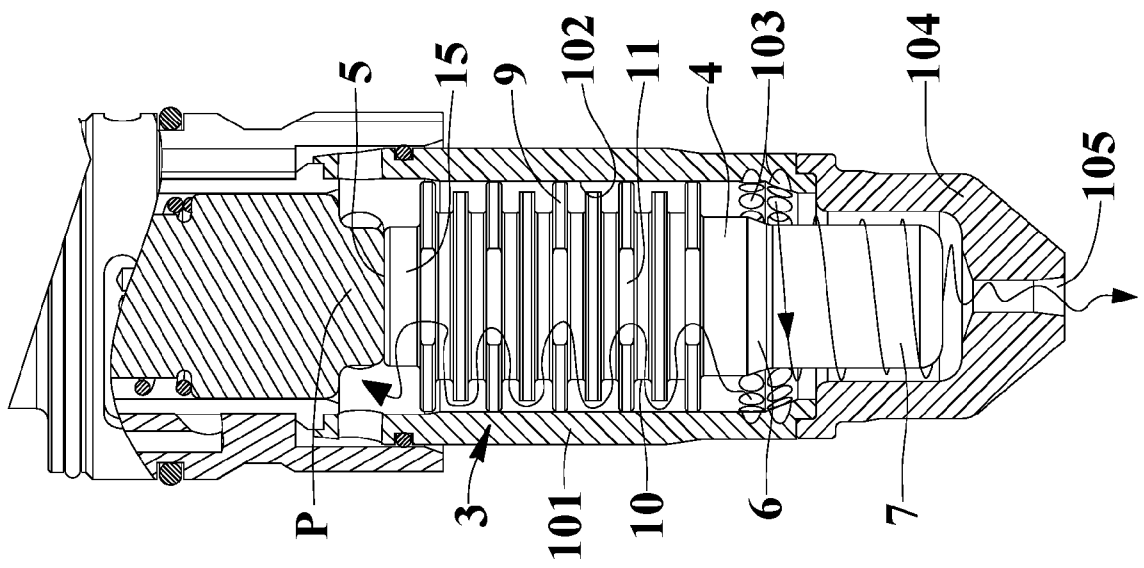


FIG.3

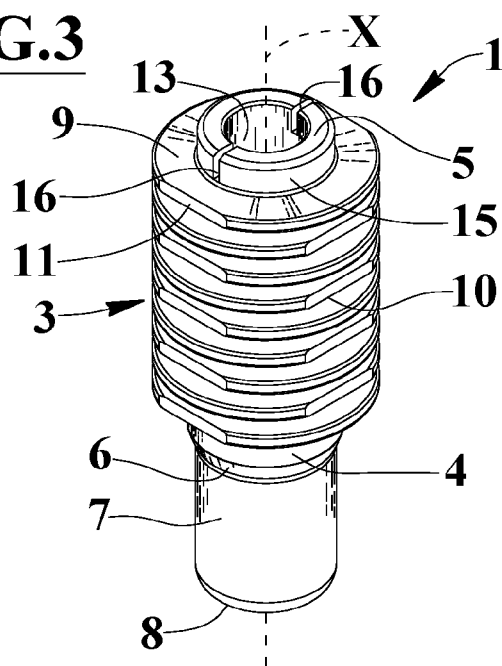


FIG.4

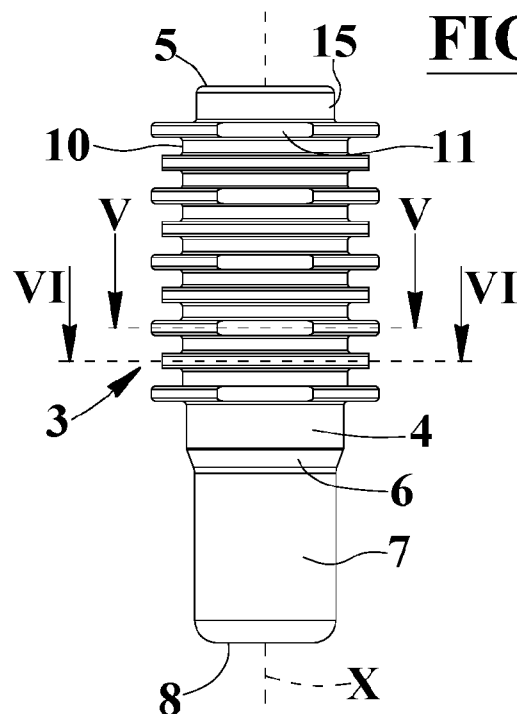


FIG.5

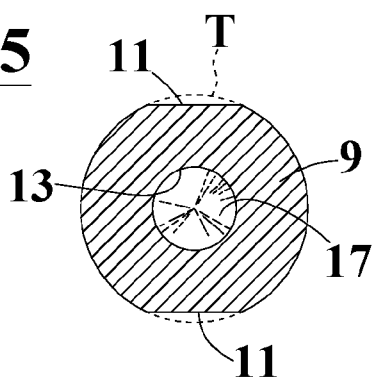


FIG.6

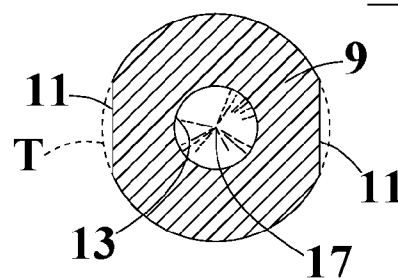


FIG.7

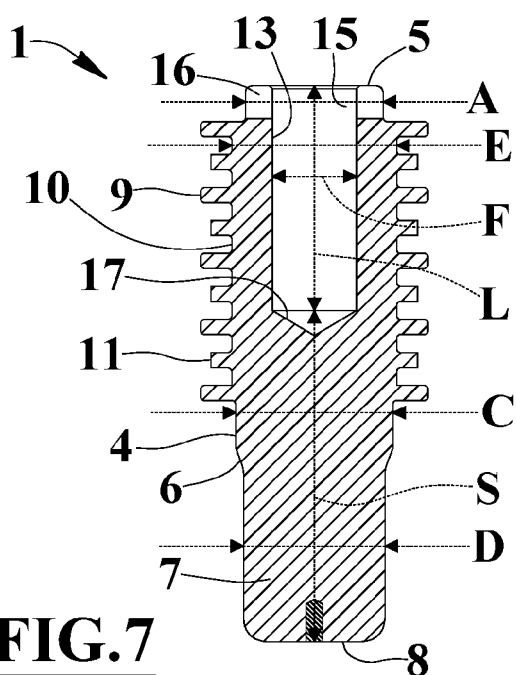


FIG.8

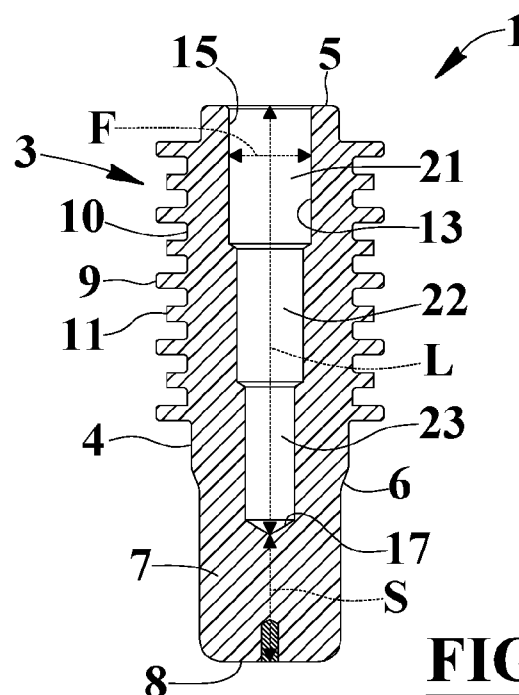


FIG.9

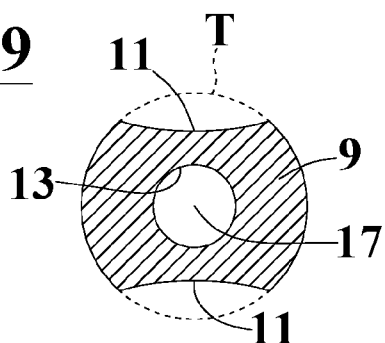


FIG.10

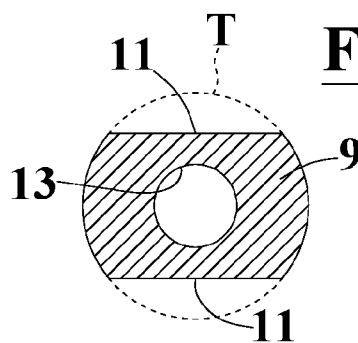


FIG.11

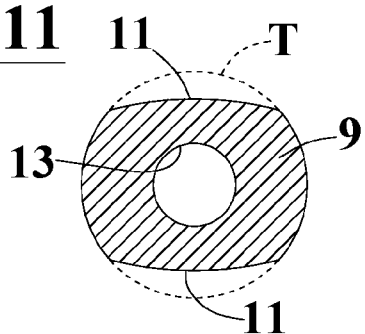


FIG.12

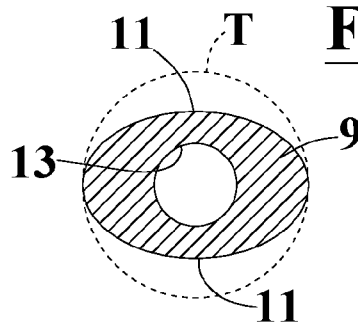


FIG.13

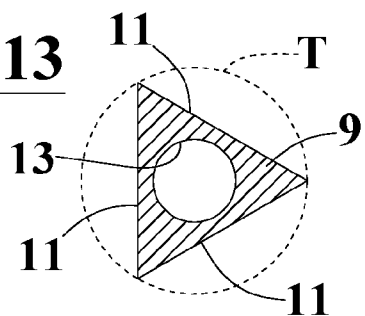


FIG.14

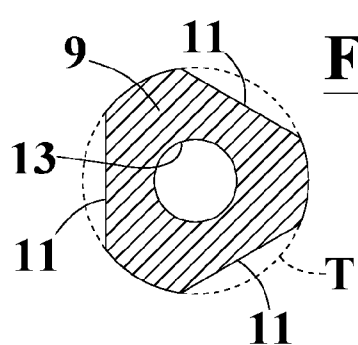


FIG.15

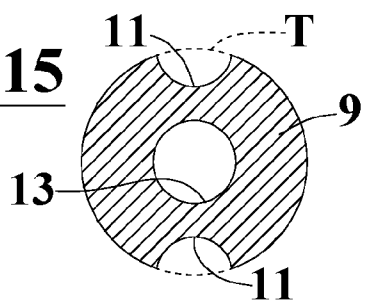


FIG.16

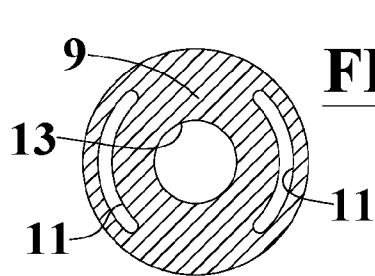


FIG.17

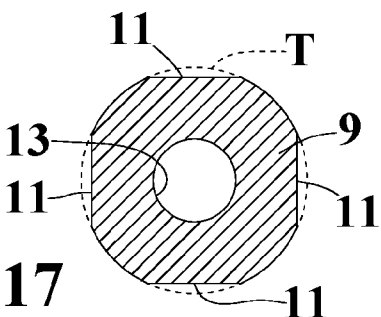
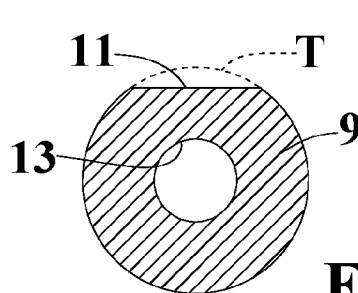


FIG.18





EUROPEAN SEARCH REPORT

Application Number

EP 26 17 0502

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	US 2015/351214 A1 (PATEL SHREYANSH [US] ET AL) 3 December 2015 (2015-12-03) * abstract; figures 2,8,9 * * paragraph [0077] *	1-14	INV. H05H1/28
A	EP 3 182 810 A1 (TEC MO S R L [IT]) 21 June 2017 (2017-06-21) * figures 1-5 *	1-14	
A	CN 107 018 618 A (KJELLBERG FINSTERWALDE PLASMA & MASCHINEN GMBH) 4 August 2017 (2017-08-04) * figures 7,9,10 *	1-14	
A	US 6 403 915 B1 (COOK DAVID J [US] ET AL) 11 June 2002 (2002-06-11) * figures 1-4 *	1-14	
			TECHNICAL FIELDS SEARCHED (IPC)
			H05H
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
The Hague		27 August 2026	Crescenti, Massimo
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 26 17 0502

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
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27-08-2026

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2015351214 A1	03-12-2015	US 2015351214 A1	03-12-2015
		US 2018235066 A1	16-08-2018
EP 3182810 A1	21-06-2017	NONE	
CN 107018618 A	04-08-2017	BR PI1016021 A2	26-04-2016
		CN 102388681 A	21-03-2012
		CN 107018618 A	04-08-2017
		DE 102009016932 A1	21-10-2010
		EP 2417840 A2	15-02-2012
		ES 2669644 T3	28-05-2018
		JP 2012523651 A	04-10-2012
		KR 20110136852 A	21-12-2011
		PL 2417840 T3	31-07-2018
		RU 2011145039 A	20-05-2013
		SI 2417840 T1	30-04-2018
		US 2012132626 A1	31-05-2012
		US 2015083695 A1	26-03-2015
		WO 2010115397 A2	14-10-2010
US 6403915 B1	11-06-2002	NONE	