This invention relates to torches and, more particularly, to improvements therein.

Direct-current plasma torches which are used for cutting, for welding, or for flame spraying are not suitable for tasks involving fine or delicate work which requires a noncontaminated, high-temperature gas. The flame is either large or contains contaminants which limit its range of usefulness. Flame spraying is the process of depositing molten materials onto surfaces.

The situation arises wherein, after a grinding or cutting operation or ceramic has occurred, it is found that too much material has been taken away. Or, sometimes it is just desired to add metal or ceramic to a specific location. Where the amount of metal or ceramic to be added is sizable, or where the location is sizable, then it is a simple matter to deposit the solid metal and melt it in place or to sinter the ceramic, using well-established methods. Where it is desired to add only small amounts of metal or ceramic, or where it is desired to add small amounts under controlled conditions so that refinishing is kept to a minimum, as for example, in dental practice in working with teeth inlays and the like, the use of available torches for the purpose is difficult or impossible.

An object of this invention is the provision of a novel, unique, and useful torch.

Yet another object of this invention is the provision of a torch for fine or delicate operations which cannot be accomplished with known torches.

Another object of the present invention is the provision of a simple torch which permits the addition of metal or ceramic to a desired location in a manner of which other torches are not capable.

Still another object of the present invention is the provision of a novel, simple, and unique torch employing noncontaminated plasma, i.e., a hot, noncontaminated ionized gas.

These and other objects of the invention may be achieved in an arrangement wherein a gas which is ionized to form a plasma is applied to one end of a tube wherein the other end constricts to an opening whose size determines the size of the flame of the plasma torch. The tube is surrounded by turns of wire which, if desired, may be water-cooled tubing forming a helical coil near the end having the small opening. Radiofrequency power is applied to the coil, and the gas in the region enclosed by the turns of wire is ionized to form a plasma. Under the pressure of the incoming gas, this plasma extends through the constricted opening to provide a flame having an extremely small cross-sectional area. The flame may be gentle or highly turbulent, depending upon the pressure of the incoming gas. The heat content of this plasma flame is sufficient for melting metal and/or ceramics. The tube is not appreciably heated, even though it contains the plasma. If it is desired to deposit metal or ceramic instead of cutting metal, metal or ceramic powder may be injected into the tube, along with the gas. The molten material will then flow out of the small orifice of the tube, and the plasma torch may literally be used for forging with molten metal or ceramic in a desired location. Because of the nature of this torch, the plasma is not accompanied by contaminants which accompany torches employing a chemical flame or a direct-current arc. Thus, this torch may be employed for materials where chemical flame or direct-current arc torches are not suitable, such as in dental work where it is desired to add metal to cracks or cavities in bridgework.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation, as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a drawing of an embodiment of the invention;
FIGURE 2 is a drawing of another embodiment of the invention;
FIGURE 3 is a sectional view along the lines 3-3 of FIGURE 2;
FIGURE 4 illustrates still another embodiment of the invention; and
FIGURE 5 is a drawing in section of a powder-feeding arrangement which may be employed with this invention.

It has long been known that when a suitable potential, either A.C., D.C., or RF, is applied to a collection of gas, that the gas will ionize to form a plasma. Such ionization will continue as long as the potential is applied thereacross. At gas pressures near atmospheric, the plasma is at high temperature, on the order of several thousand degrees. This invention takes advantage of the high temperature of the plasma gas and utilizes it in a manner to constitute a usable torch.

Referring now to FIGURE 1, there may be seen a drawing of a radiofrequency plasma torch in accordance with this invention. This includes a source of a gas, or a gas powder mixture. The meaning of the "gas powder" mixture will become more clear as this explanation progresses. Assume now that the source provides an ionizable gas, such as argon or oxygen, to a tube at a pressure which is just slightly above the atmospheric pressure. The tube has one end which can communicate with the source through a tube leading therefrom to the tube. The opposite end of the tube gradually tapers until it terminates in a nozzle opening. The portion of the tube which is adjacent the nozzle opening is surrounded by a number of turns of wire which constitutes a coil. This wire coil is connected to a radiofrequency generator. If desirable, for achieving additional cooling, the wire coil may be hollow for the purpose of carrying a coolant.

In operation, gas is provided from the source and flows through the tube, out through the opening. When power is applied from the RF generator to the coil, the gas in the region within the coil ionizes. Because of the pressure of gas provided by the source, a portion of the ionized gas extends out of the nozzle. The appearance of the plasma which is created is indicated generally by the dotted lines. By way of illustration of a working arrangement for the invention, but not to be construed as a limitation, the tubing was made of a high-temperature resistant dielectric material, such as quartz or Vitro Vycor. Vycor is a trade name for a glass manufactured by Corning Glass Works. The inside diameter of the tube was approximately one inch, and the nozzle-opening diameter was on the order of 0.12". The frequency of the radiofrequency generator which was applied to the coil was on the order of 5.5 megacycles per second. The flow rate of the argon was on the order of 0.2 gram per second. It was found that the size of the nozzle diameter was not critical, this being determined merely by the size of the flame desired.
The frequency range of the RF generator was 5 to 15 mc. The RF generator need only provide enough power to initiate the plasma arc and to maintain it thereafter. The location of the coil and the number of the turns is not critical, either. The hot plasma does not heat up the walls of the tube 12, since it is contained by a surrounding cool gas layer. The torch shown may be provided with flexible leads, and the portion of the tube 12A can be made flexible so that the torch can be moved and handled easily and can be used to accurately cut through metal or to melt metal in locations where the other known types of torches cannot be employed. The small size of the flame emitted from the nozzle enables extremely fine and precise cutting, burning, or flame spraying to be achieved.

When it is desired to add to the metal or ceramic material already present or to lay down metal or ceramic material in very small amounts, the embodiment of the invention shown in FIGURE 1 can be used for that purpose by introducing, instead of pure gas, a mixture of gas and metal or ceramic powder into the tube 12. The gas ionizes exactly as has been described, and, then, because of the powder, serves to carry metal particles. These melted particles are emitted with the flame from the torch and are deposited out from the tip of the jet.

It has been found that when the gas which is introduced into the tube 12 is given a swirling motion, the flame which is emitted from the nozzle has a finer and more definitely shaped point than when gas is fed straight through from one end of the tube 12 through the nozzle, FIGURE 3, which is a cross section along the lines 3—3 of FIGURE 2, illustrates an embodiment of this invention for achieving the swirling of the gas. The flame obtained by swirling lends itself better to the purpose of cutting or drilling of metal or other material by the hot gas stream. Tube 12, having a nozzle 12B, RF generator 16, and RF coil 14 may be employed as was described in connection with FIGURE 1. Also, the source of gas 10 may be the same.

The gas is fed from the source into an arrangement as shown in cross section in FIGURE 3. This merely consists of a circular block 20. This circular block has a passage 22 drilled therein to receive the tube 12. A circular chamber 24 is coaxial with the opening 22 and opens therein. Another passage 26 is drilled through the block 20 to provide access for gas from the source 10 through a tube 28 into the chamber 24. The passage 26 is drilled into the block 20, to be off-center with respect to the access of the chamber 24.

Gas from the source 10 is introduced through the tube 28 into the chamber 24. Because of its off-center introduction into that chamber, the gas is given a swirling motion. It proceeds from the chamber 24 into the tube 12 and maintains this swirling motion even when it is formed into the plasma and emitted from the nozzle 12B.

Reference is now made to FIGURE 4, which shows a preferred arrangement for the plasma torch for flame spraying. As before, there is employed a tube 12 of a suitable dielectric material which is shaped at one end to provide a nozzle 12B. An RF generator 16 supplies suitable radiofrequency power to the coil 14 in order to ionize gas within the region created by the coil in the plasma. Gas is introduced from a suitable source 30 through a pipe 32 into a circular block 34 having suitable openings drilled therein to permit the gas to be admitted into the tube 12.

This block 34 has an annular chamber 36, which is concentric with a central opening 38 into which the tube 12 may be inserted. An opening 41 communicates from the pipe 32 to the annular chamber 36. Another tube 40 of a dielectric material is fitted into an opening 42 to be supported concentrically with the tube 12 and the opening 40 extends axially into the tube 12 over a distance which is not critical.

There is an opening or passage 44 provided which ex-23,508 tends between the annular chamber 36 and the space 46, which exists between the outer diameter of the tube 40 and the inner diameter of the tube 12. Accordingly, gas which is introduced from the source 30 flows through the pipe 32 and opening 41 into the annular chamber 36. This gas then flows through the passage 44 and axially along the opening 46 into the region defined by the RF coil 14, where it is ionized.

Another passageway is provided in the block 34, which is the passageway 48 extending from the end of the opening 42 into which the tube 40 extends to the end of the block 34 in order to accommodate a pipe 50. This pipe communicates with a source of gas and powder 52. The gas and powder mixture is introduced into the pipe 50 and flows centrally into the plasma, where it, together with the gas from source 30, is ionized, and the powder is melted.

Thus, there will extend from the nozzle opening 12B a sharply tipped plasma flame which can deposit a fine, thin, liquid metal stream.

By way of illustration, there is shown in FIGURE 5 a cross-sectional view of an arrangement for mixing powder with gas to be fed into the plasma torch. This can comprise a metal or ceramic tube 60, which is supported in a block 62 of any suitable friable material. The bottom of the tube 60 lies in a central cavity 64 therein. A motor 66 drives a shaft 68, which has a screw-shaped portion 70 extending in the central cavity 64. The shaft 68 is journaled at one end in a bearing 72, which also serves to close up the one end of the cavity 64. The other end of the shaft 68 bears against the bearing 74. Powder from the tube 60 drops onto the screw 70, which is rotated by the motor to move the powder over to another passageway 76 in the block. The passageway 76 extends from the outer diameter of another opening 78 into the passage 80, into which there is mounted a tube 82, closing up the end of the opening 78, which communicates to the outside. The passage 76 and the tube 82 are aligned with each other.

Gas from a source of gas 84 is fed through a pipe 86 into the opening 78. This gas can pass through the space 88 between the plug 80 and the bottom of the opening 78 to break up powder agglomerates and entrain the powder which is dropped into the opening 76 and can carry it along the tube 82 into the tube 50, by way of example shown in FIGURE 4. Effectively, the manner of introduction of gas from the source 84 into the tube 82 provides an axial motion to the gas, as a result of which the powder and gas are thoroughly mixed by the time they reach the tube 40, shown in FIGURE 4.

There has been described hereinabove a novel, useful, and simple arrangement for the making of a metal plasma. In addition to the normal uses of a torch, metal or ceramic powder may be introduced into the plasma in accordance with this invention for affording a better way of depositing liquid metal or ceramic at a desired location than heretofore available. Although the advantages of the plasma torch over presently known arrangements have been explained in terms of the small-flame size and its utility for confining the working area to small spaces, this should not be construed as a limitation upon the invention, since it will be apparent to those skilled in the art how to enlarge the size of the flame to use it in the manner in which any torch may be used.

Another use for the plasma torch which constitutes the invention herein is for the purpose of propulsion of a vehicle. It is well known that once a vehicle has been boosted from the earth into outer space, the force required for the propulsion thereof is too small. A plasma torch described herein may be supported at the tail of such vehicle. It can be energized as described once outer space is reached. The reaction to the emission of plasma from the nozzle provides the required force to propel the space vehicle.

We claim:

1. A radiofrequency plasma torch comprising a first
tube having an admitting opening at one end and an emitting opening at the other end, a second tube having a diameter smaller than said first tube, means for supporting said second tube coaxially with said first tube, and partially extending thereinto through said admitting opening thereof, a source of ionizable gas, means for applying gas from said source into said first tube through the space between the walls of said first and second tube to give said gas a straight, axial velocity as it passes along said first tube toward said emitting opening, means for introducing into the end of said second tube extending from said first tube a mixture of gas and a powder under a sufficient pressure to cause them to travel toward the emitting opening of said first tube, and means for ionizing gas which is at the region of said first tube near its emitting opening for emitting from said opening a plasma containing melted powder.

2. A radiofrequency plasma torch as recited in claim 1 where the end of said first tube terminating in an emitting opening is given a nozzle shape to form said plasma into a jet.

3. A radiofrequency plasma torch as recited in claim 1 wherein said means for providing a mixture of a gas and powder comprises a chamber, a screw extending along the length of said chamber, means for rotatably supporting said screw within said chamber, means for dropping powder near one end of said chamber upon said screw, means for rotating said screw for moving said powder toward the other end of said chamber, an escape opening for said powder at the other end of said chamber, a circumferential slit communicating with said powder-escape opening, into which said powder is forced by a motion of said screw, and means for introducing gas into said circumferential slit to be mixed with said powder.

References Cited by the Examiner

UNITED STATES PATENTS

2,587,331 2/1952 Jordan 43—44.93
2,768,279 10/1956 Rava 219—121
2,826,708 3/1958 Foster 313—231.5
2,906,858 9/1959 Morton 219—121
2,919,370 12/1959 Giannini et al. 313—231.5
2,922,869 1/1960 Giannini 219—121
2,944,140 7/1960 Giannini 219—121
2,945,119 7/1960 Blackman 313—231
3,015,745 1/1962 Klein 313—231.5
3,046,736 8/1962 Emmerich
3,071,678 1/1963 Neeley 219—121
3,073,984 1/1963 Eschenbach 219—121
3,083,289 3/1963 Munro 219—121
3,089,983 5/1963 Hadencourt et al. 313—231.5

DAVID J. GALVIN, Primary Examiner.

ARTHUR GAUSS, GEORGE WESTBY, Examiners.

C. R. CAMPBELL, K. CROSSON, S. SCHLOSSER, Assistant Examiners.