

July 3, 1962

H. K. ORBACH
METHOD AND APPARATUS FOR EFFECTING GAS-STABILIZED
ELECTRIC ARC REACTIONS
Filed April 4, 1960

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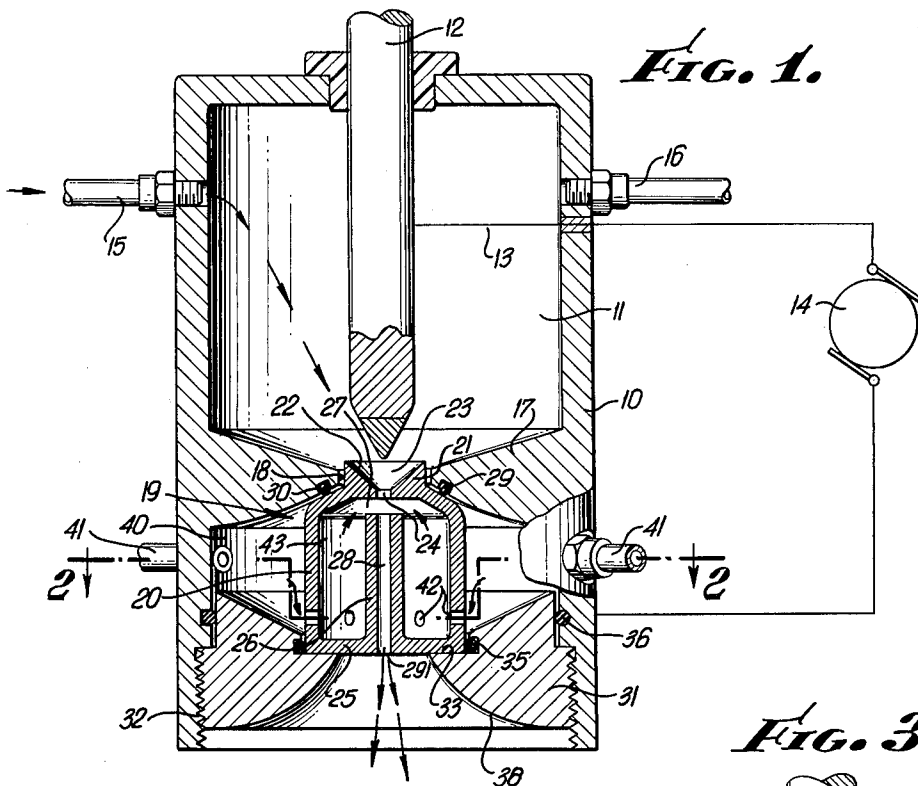


FIG. 1.

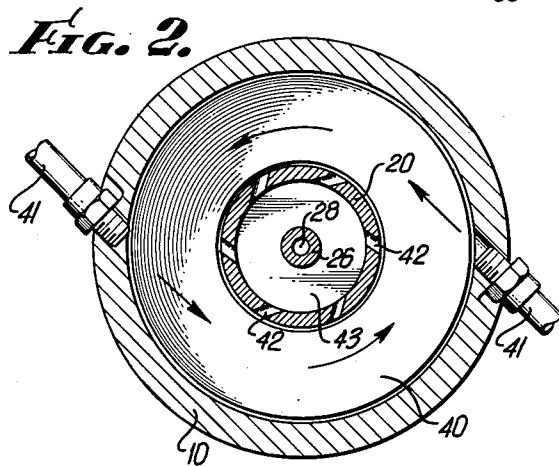


FIG. 2.

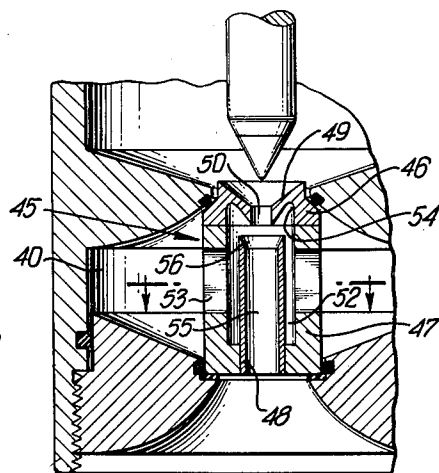


FIG. 3.

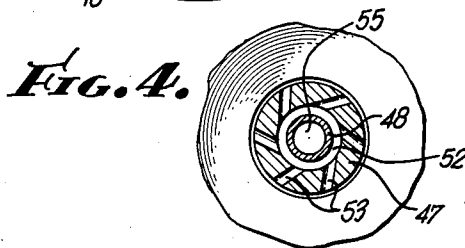


FIG. 4.

INVENTOR.
HARRY K. ORBACH
BY *White and Harpiger*
ATTORNEYS.

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METHOD AND APPARATUS FOR EFFECTING GAS-STABILIZED ELECTRIC ARC REACTIONS**Harry K. Orbach, Whittier, Calif., assignor, by mesne assignments, to MHD Research, Inc., Newport Beach, Calif., a corporation of California****Filed Apr. 4, 1960, Ser. No. 19,628,
11 Claims. (Cl. 313—231)**

This invention relates generally to improvements in gas stabilized electric arcing apparatus of the so-called "plasma jet" type which operates to arc-ionize a gas and create a high velocity, high temperature gaseous discharge of the gas and other materials passed through the arc. Generally such devices have comprised a body containing a cathode and anode spaced to arc-ionize a gas fed into the body. The impingement of the plasma upon the electrodes has necessitated cooling the electrodes, particularly the anode, by methods generally employing a high velocity, high pressure stream of water contacting the outer surfaces. Upwards of fifty percent of the electrical energy fed to the arc is removed by the water, and consequently is wasted.

My general object is to improve the efficiencies of such devices by employing as an electrode coolant, a portion of the gases to be heated by the arc, and in this manner conserve essentially all of the input energy for heating of the gases fed to the device. Experience has shown that the present device, employing part of the input gas or gases as the electrode coolant, will operate for extended periods without other cooling and with no damage to the electrodes beyond the normally expected fused spot on the cathode. Efficiency therefore is maximized.

An unexpected result of the invention which can be used to advantage in chemical processing, is that the arc characteristics, i.e. voltage and amperage, are a function of the type of gas passing the cathode and are not appreciably affected by the type of gas entering the arc region through the anode. The former will be termed "arc gas" and the latter "coolant gas." Normally in devices of this general type, where all the gas passes the cathode, different physical configurations and different voltages are needed for different gas compositions, and often several hundred volts are required to maintain the arc. The present invention permits use of many different reactants as coolant gases without altering the equipment or materially affecting the amperage or voltage as established by the arc.

In addition to increased efficiency and flexibility in voltage choice, the invention affords various additional unique features: Lower operating temperatures are allowed by using large quantities of coolant gas. This feature may be used to advantage in chemical synthesis in that optimum temperatures may be selected for each reaction and composition. These temperatures often fall below the minimum maintainable with existing arc equipment in which the arc is extinguishable by high gas flows. Gases which are normally corrosive to a tungsten cathode or cause deposits upon it may be used as the coolant gas since the latter does not contact the cathode. Solids may be carried into the arc in a now efficient and symmetrical manner by the coolant gas, for such purposes as direct reduction of ores. Similar advantages apply to use of the apparatus for the spraying of metal or refractory coatings, which currently is a major use for plasma jet-type devices.

Structurally, the invention contemplates an improved assembly comprising a body forming a chamber containing an electrode, e.g. the cathode, and containing a tubular anode having a gas mixing passage and arc-gap

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spacing from the cathode at the inlet end of the passage, means for admitting gas to the chamber for ionization in the arc, and means for feeding coolant gas about the anode and for then passing the gas into that part of the arc region furthest from the cathode.

The invention will be further understood from the following detailed description of an illustrative embodiment shown by the accompanying drawing, in which:

FIG. 1 is a view showing the apparatus in longitudinal section;

FIG. 2 is a broken cross section on line 2—2 of FIG. 1;

FIG. 3 is a fragmentary view showing a variational form of the gas-cooled electrode, and

FIG. 4 is a cross section on line 4—4 of FIG. 3.

Referring to the drawing, the apparatus is shown to comprise a conductive metal body 10 containing a chamber 11 which accommodates the conventional illustrated electrode 12 which, typically, may be a tungsten-tipped copper or brass cathode receiving current in any suitable or conventional manner, of which conductor 13 leading from direct current generator 14 is illustrative. A gas to be ionized is fed to chamber 11 through line 15, and if desired, provision may be made for admitting to the chamber a second gas through line 16. The chamber is defined at its inner end by annular projection or shoulder 17 having a central opening 18 for accommodation of the anode generally indicated at 19.

As illustrated in FIGS. 1 and 2, the anode 19, made typically of copper, is generally tubular for the passage of gas therethrough, and has the form of an annularly hollow body 20 including a reduced neck portion 21 received within opening 18 and presenting a recessed mouth 22 exposed to the arc gap at 23 and receiving the ionized gas for passage through aperture 24 into the anode. The latter has a forward closed end 25 and a central tubular portion 26 spaced at 27 from the aperture 24 and forming a mixing passage 28 through which the heated gases are discharged at 29 in a high velocity, high temperature stream or jet. The electrode 19 is releasably contained within the body 10 by engagement with a seal ring 29 contained within the shoulder recess 30, and against which the electrode is held by a ring 31 threaded at 32 into the end of the body and having a shoulder 33 which supports the end face of the electrode. Rings 35 and 36 seal, respectively, between the electrode and ring 31, and between the latter and body 10. As illustrated, the ring 31 may have a mouth 38 flaring away from the projected gas jet.

One or more coolant gases may be introduced to space 40 surrounding the anode 19, by way of inlets 41 which preferably are positioned to direct the gas tangentially into the space, thereby creating a swirling flow of the gas which extends its cooling time of contact with the exterior of the anode and can act to maintain entrainment of any solids introduced with the gas. From space 40 the gas flows through circularly distributed and angularly or tangentially directed apertures 42 in the forward wall of the anode into chamber 43, the gas then reversing its flow in cooling contact with the electrode surfaces in passing into space 27 to join and become directly admixed in passage 28 with the gas from passage 24. Thus, as will be observed, the gas introduced to space 40 effectively cools the anode in being caused to contact both its external and internal surface before entering the discharge passage.

FIG. 3 illustrates a variational embodiment of the invention, generally similar to the first described form except for modification of the anode at the arc end, and of the coolant gas-passing apertures. Here the anode 45 may be made in sections 46, 47 and 48, the first presenting a mouth 49 converging to a central opening 50 which may be somewhat larger in relation to opening 24 in the

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FIG. 1 form, to offer less restriction to extension of the arc into space 51. Tube 48 may be formed as a separate piece and carried within the body section 47 in spaced relation at 52 to form a passage receiving the coolant gas through tangential openings 53. Here the openings may be formed as elongated slots to minimize any tendency for solids entrained in the feed gas to separate and collect in the outer space 40. Leaving passage 52, the gas generally reverses its flow in being baffled within the annular head recess 54, and then enters passage 55 through its tapered mouth 56. In this FIG. 3 form, passage 55 is shown to be somewhat larger in diameter than opening 50, an illustrative ratio being about 0.3 to 0.18 inch. As before, mixing of the coolant gas with the arc gas occurs in space 51 at the mouth of passage 55, and within the arc being projected through opening 50.

In considering the operation of the devices, an arc gas such as argon or helium may be fed into chamber 11 through line 15 and subjected to high temperature ionization within the arc created in gap 23 between the electrode 12 and the rear portion of the electrode 19. The high temperature ionized gas flowing through aperture 24 into passage 48, is admixed with the coolant gas that has passed about and through the anode into space 27, as previously described. The arc itself may be blown through opening 24 into space 27 with the inner end of tube 26 acting as the anode surface. Maximum efficiency in terms of utilization of the electrical input energy, is assured since no heat is wasted in electrode cooling but instead is absorbed by the coolant stream and carried into the ionized gas flow. Energy is further extracted from the arc by causing the coolant gas to contact it at nearly a right angle.

The apparatus may be used for carrying out various chemical reactions as typified below, in any of which one of the reactants may serve as the arc gas since each reaction involves a one relatively inert gas. However, it may also be advantageous in any of these reactions to use an inert gas such as argon or helium at the cathode to limit erosion or voltage requirements. Possible arc gases are underlined in the following typical reactions:

- (1) $2C_3H_8 + \underline{4H_2} \rightarrow 3C_2H_2 + 9H_2$ (excess H_2)
- (2) $2C + \underline{N_2} \rightarrow (CN)_2$
- (3) $CaCO_3 + \underline{H_2} \rightarrow Ca + CO_2 + H_2O$
- (4) $LiCO_3 + \underline{CO} \rightarrow Li + 2CO_2$
- (5) $H_2 + \underline{N_2} \rightarrow N_2H_4$
- (6) $O_2 + \underline{N_2} \rightarrow 2NO$
- (7) $2C + \underline{4H_2} \rightarrow C_2H_2 + 3H_2$ (excess H_2)
- (8) $CH_4 + \underline{1/2N_2} \rightarrow HCN + 3/2H_2$

In carrying out the above reactions, the arc gas may be introduced through line 15 and another or reactant gas supplied as coolant through line or lines 41. Alternatively, and particularly where a solid reactant is involved, a suitable arc gas may be introduced through line 14 and the reactants fed to the cooling zone 40. As a further possibility, one reactant gas may be supplied through lines 41 and a second reactant fed to chamber 11 through line 16.

It will be understood that the drawing is illustrative of a typical embodiment of the invention, and that various changes and modifications may be made without departure from its intended spirit and scope.

I claim:

1. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage,

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means for feeding a second coolant gas into a space about said second electrode and in contact therewith, and means for passing the preheated coolant gas then into the heated gas stream within the arc extent inside the second electrode.

2. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, means for feeding a second coolant gas into a space about said second electrode and in contact therewith, and means for passing the preheated coolant gas then into the heated gas stream within the arc extent inside the second electrode and at a location at the mouth of said mixing passage.

3. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, means for feeding a second coolant gas into a space about said second electrode and in contact therewith, means for passing the preheated coolant gas then into the heated gas stream within the arc extent inside the second electrode, and means for introducing a third gas into said chamber for reaction with one of the other gases.

4. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, means for feeding a second coolant gas into a space about said second electrode and in contact therewith, means for passing the preheated coolant gas then into the heated gas stream within the arc extent inside the second electrode and at a location at the mouth of said mixing passage and means for introducing a third gas into said chamber for reaction with one of the other gases.

5. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, said second electrode containing an annular chamber surrounding said passage, means for feeding a coolant gas into a space about the second electrode and thence into said annular chamber, and means for then passing the preheated coolant gas from the annular chamber into the heated gas stream within the arc extent inside the second electrode.

6. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, said second electrode containing an annular chamber surrounding said passage, means for feeding a coolant gas into a space about the second electrode and thence

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into said annular chamber, means for then passing the preheated coolant gas from the annular chamber into the heated gas stream within the arc extent inside the second electrode, and means for introducing a third gas into the first mentioned chamber for reaction with one of the other gases.

7. Gas ionizing apparatus of the character described, comprising a body forming a chamber and containing an annular shoulder at the inner end of the chamber, an electrode within said chamber at one side of said shoulder, a second tubular electrode within the body at the opposite side of said shoulder and having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage so that the arc enters the second electrode, releasable means engaging the outer end of said second electrode and holding it against said shoulder, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, means for feeding a second coolant gas into a space about said second electrode, and means for passing the coolant gas then into the heated gas stream within the arc extent inside the second electrode.

8. Gas ionizing apparatus of the character described, comprising a body forming a chamber and containing an annular shoulder at the inner end of the chamber, an electrode within said chamber at one side of said shoulder, a second tubular electrode within the body at the opposite side of said shoulder and having an internal gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage, releasable means engaging the outer end of said second electrode and holding it against said shoulder, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, said second electrode containing an annular chamber surrounding said passage,

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means for feeding a coolant gas into a space about the second electrode and thence into said annular chamber, and means for then passing the coolant gas from the annular chamber into the heated gas stream within the arc extent inside the second electrode.

9. Gas ionizing apparatus of the character described, comprising a body forming a chamber, a first electrode within said chamber, a second tubular electrode in said body having a gas mixing passage and arc gap spacing from said first electrode beyond the inlet end of said passage, means for admitting to said chamber a first gas to be heated in said gap and discharged through said passage, said second electrode having an apertured end exposed to said arc and an annular internal chamber surrounding a central tubular portion spaced from said apertured end and forming said mixing passage, means for introducing a coolant gas into an annular space within the body surrounding said second electrode, the gas thence flowing through apertures in the electrode into said internal chamber and thence into the heated gas stream entering said passage.

10. Apparatus according to claim 9, in which said coolant gas is directed tangentially into said space and said apertures are circularly distributed about said internal chamber.

11. Apparatus according to claim 10, in which the coolant gas is directed tangentially into said annular internal chamber.

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