Oct. 23, 1956 A. RAVA 2,768,279

ELECTRIC ARC TORCH APPARATUS

Filed Jan. 18, 1955 3 Sheets-Sheet 1

Fig. 1.

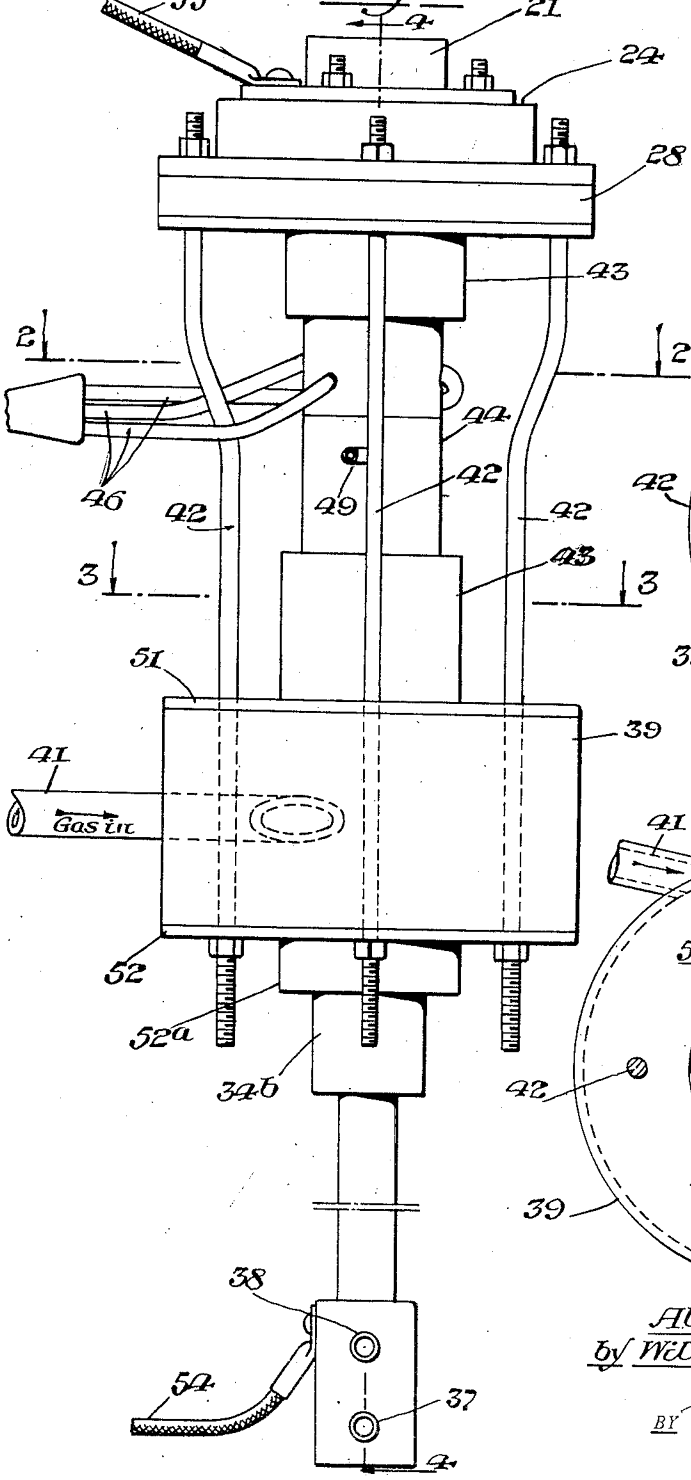

Fig. 2.

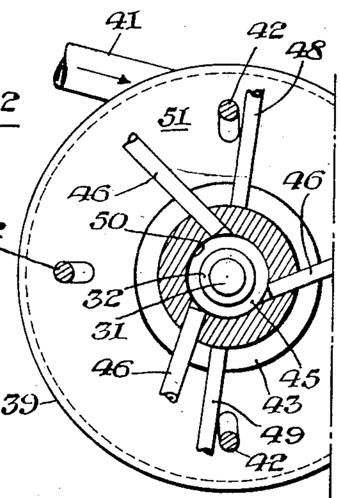

Fig. 3.

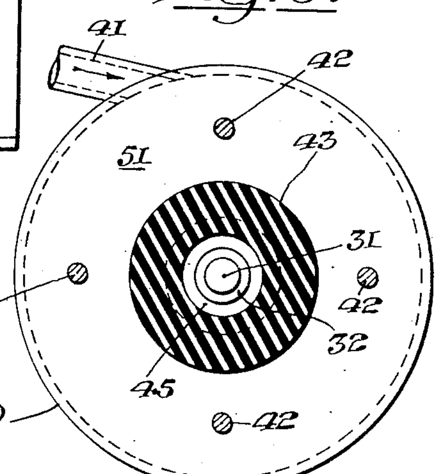

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Fig. 4.

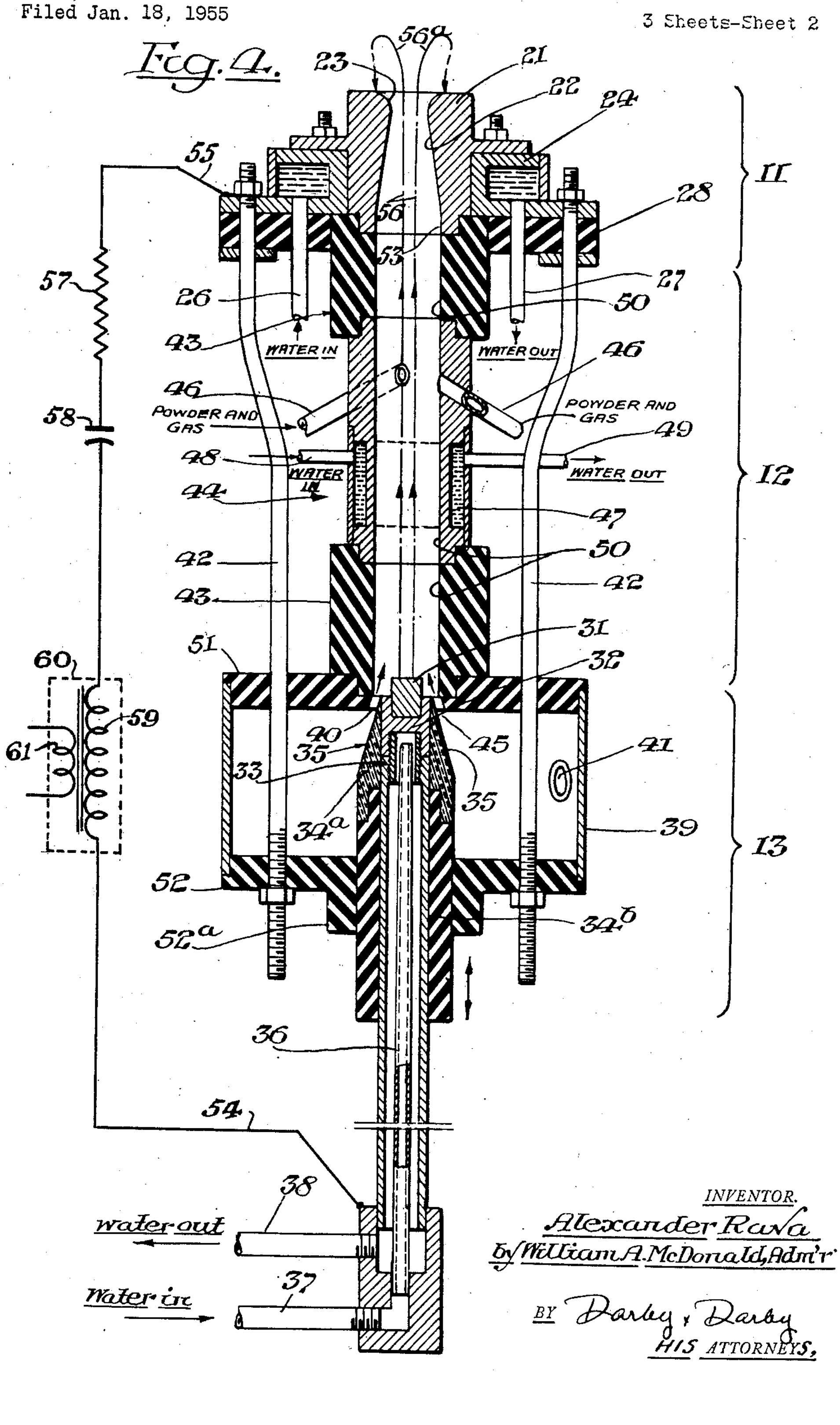

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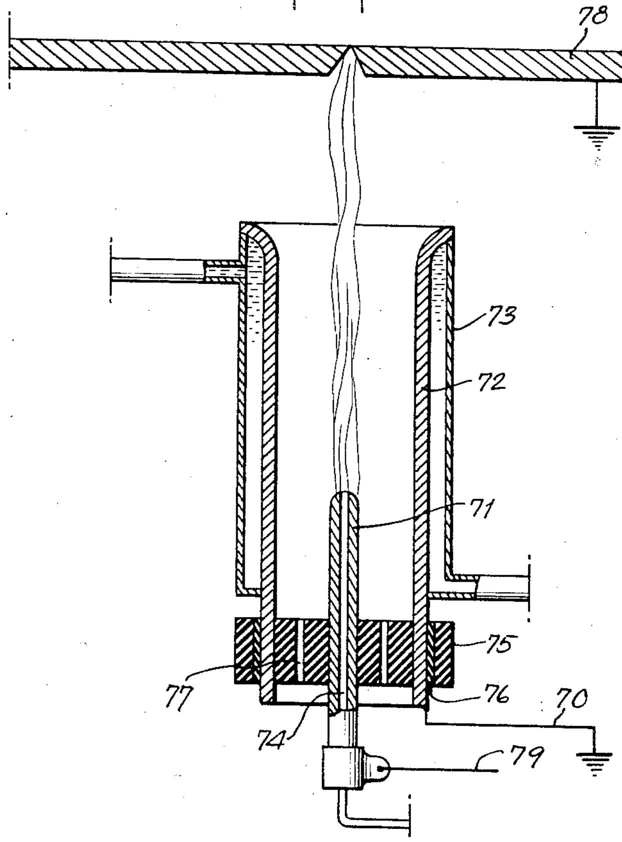
Fig. 5.



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ELECTRIC ARC TORCH APPARATUS

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Application January 18, 1955, Serial No. 482,513

20 Claims. (Cl. 219—75)

The present invention relates to the art including electric arc torches, and is more particularly concerned with the provision of features for permitting extended high temperature operation of such torches.

In the production of high temperatures for a variety of purposes, attention has long been directed to the electric arc produced by applying a proper voltage between a pair of electrodes to ionize the air or other gas therebetween, the consequent flow of high values of current producing elevated temperatures in the gas. Such electric arcs have been utilized for welding, for fusing materials supplied to the arc, for accomplishing chemical processes under high temperature conditions, and the like.

However, in conventional systems utilizing electric arcs, difficulty is experienced in the design and construction of suitable apparatus because of the necessity of providing means for supplying materials to be acted upon by the arc and for readily deriving from the arc the materials previously acted upon by the arc. As a consequence, elaborate and complex mechanisms have been suggested and utilized for conveying powdered, gaseous or solid materials to the arc either internally of a hollow electrode and hence in an axial direction along the axis of the arc, or else transversely of the arc. Such methods may be suitable where the products formed by the arc are of a gaseous type which can be readily conducted away from the arc by exhaust systems, or where the products acted upon by the arc can be readily moved out of the zone of interaction with the arc.

One particularly important use for high temperatures is in the vaporization or atomization of solid materials for the purpose of spraying them upon surfaces or backings to provide densely adherent coatings. A particularly important application of such methods is in the protection of conventional materials from the effects of high temperatures which they may encounter in use; for example, in combustion engines or jet engines extremely high temperatures are encountered and are desired for increase in efficiency. Heretofore the temperatures utilizable in the operation of such devices have been severely limited by the materials of which these devices are made, since high temperature failure of the materials forms a limitation upon the efficiencies and effective lives of such devices. A highly desirable apparatus would be one which could coat conventional materials with refractory and temperature-resistant materials so as to provide a surface coating which can preserve such conventional materials against the effects of elevated temperatures at which they may be operated. Necessarily, the proper handling of such refractory materials requires extremely high temperatures.

The present invention provides means for accomplishing these and other desirable results in a convenient and simple form. According to one aspect of the present invention, an electric arc device is provided in which the arc is axially extended. That is, the arc extends beyond the space between the electrodes, such extension being along the axis of the electrodes, producing what may be termed an "arc torch" having a flame with a temperature determined by the amount of electrical energy supplied thereto. The present invention further provides means for maintaining such an arc and for supplying to such arc materials to be vaporized therein and in such manner that these materials are projected along the axis of the arc, to be heated thereby, and then beyond the arc to impinge upon any material which it is desired to coat by such materials.

The present invention is further concerned with particular features of advantage in such a system for permitting its efficient operation under a wide variety of conditions of arc temperature and of coating material, providing a versatility of operation or operation with many types of material, refractory or otherwise, and under widely varying conditions of temperature.

These and other features and advantages of the present invention will become more fully apparent from consideration of the following description of a preferred embodiment thereof taken in conjunction with the appended drawings, in which:

Figure 1 shows an elevational view of one form of the invention;

Figure 2 shows a transverse cross-sectional view of the device of Figure 1 taken along line 2—2 thereof;

Figure 3 is a further transverse cross-sectional view of the device of Figure 1 taken along line 3—3 thereof;

Figure 4 is a longitudinal cross-sectional view of the device of Figure 1 taken at right angles thereto, illustrating its internal construction, and showing the manner of its connection to the electrical equipment with which it forms the arc circuit; and

Figure 5 is a longitudinal cross-sectional view of a modification of the device of Figures 1–4.

Referring to the drawings, the present device has three general sub-divisions, namely, an upper electrode portion **11**, a column portion **12** and a lower electrode portion **13**. The upper electrode portion **11** comprises a hollow annular conductive electrode **21** having an inwardly tapered bore portion **22** and an outwardly flaring bore portion **23**. This electrode **21** is surrounded by a water jacket **24** having a water inlet pipe **26** and a water outlet pipe **27** supported on an insulating electrode holder plate **28**.

The lower electrode portion comprises a solid conductive electrode **31** preferably formed of refractory material, such as tungsten, tantalum, or the like, which is preferably a cylindrical, rectangular or polyhedral block. This electrode block **31** is supported in a heat-conductive electrode holder **32** joined to a hollow cylinder **33** forming the exterior jacket of a water-cooling arrangement. The electrode holder **32** and jacket cylinder **33** are mounted in an insulating outer sleeve **34***a*, **34***b*, secured thereto. Centrally located within the jacket cylinder **33** is a pipe **36** connected at one end to the water inlet **37**. Water outlet **38** communicates with the cylinder **33**, whereby cooling water or other coolant may be supplied through inlet **37** and pipe **36** to the lower face of the electrode holder **32** to extract heat from the electrode **31**. Such heated water then flows to the water outlet **38** through the cylinder **33**.

The lower electrode **31** and its supporting and cooling arrangement just described are surrounded by a gas inlet housing **39** having a cylindrical wall with a gas inlet pipe **41** communicating therewith. The housing **39** has insulating end walls **51**, **52**. The jacket sleeve **34***a*, **34***b* is slidably mounted within a hub **52***a* of end wall **52** and is thereby axially adjustable relative to the housing **39** for a purpose to be described.

The column section **12** of the device extends between the upper electrode section **11** and the lower electrode section **13**, being clamped therebetween by the rods **42**, which may be of conductive or non-conductive material. This column section **12** comprises a pair of apertured spacer blocks **43** of insulating material and a single material-injection section **44**. Each of these sections **43** and **44** has a bore **50** substantially equal in diameter to that of the inlet bore **53** of the annular electrode **21** and coaxially surrounding the lower electrode block **31**. The material-injection section **44** is provided with a plurality (illustratively shown as three in number) of inlet pipes **46** communicating with the bore **50** of this section **44** at an angle nearly tangentially of the bore **50**, and also disposed at an acute angle to the axis of the bore **50**. By way of illustration, in the transverse cross-sectional plane illustrated in Figure 2, these pipes may be at an angle of between 30° and 60° to the tangent of the bore **50** and, in the axial longitudinal plane, as illustrated in Figure 4, they may be at an angle of between 30° and 60° to the axis of the bore **50**. A water jacket **47** having a water inlet **48** and a water outlet **49** may be provided on the material-injection section **44**.

As indicated in Figure 4, the jacket sleeve **34***a* for the lower electrode **31** has a tapered end portion **35**. The gas chamber jacket **39** has a tapered aperture **40** in the end wall **51** therein substantially coaxial with the electrodes **21**, **31** and with the jacket sleeve **34***a*. By adjustment of the electrode and jacket assembly **31**, **32**, **34***a*, **34***b*, in an axial direction, the gap **45** between the gas housing end plate **51** and the electrode jacket section **35** may be readily adjusted. In operation, a gas under suitable pressure is supplied to the gas inlet pipe **41**. By virtue of the substantially tangential connection of the gas inlet pipe **41** to the gas chamber **39**, and because of the inlet velocity of the gas entering the chamber **39**, a swirling motion is imparted to the gas substantially concentric with the axis of the device. This gas can escape from the gas chamber **39** only through the annular aperture **45**, and accordingly has a substantially helical motion in its travel through the bore of the device to the upper electrode **21**. Suitable pressures and velocities for the gas may range between 10 and 50 pounds per square inch and 100 to 500 cubic feet per minute at the annular aperture. The particular gas utilized is one which should have high temperature stability and is preferably air or one of the inert gases, such as argon, nitrogen, or the like. Hydrogen can be used, similarly to its use in the atomic hydrogen torch.

In operation, an electrical difference of potential is applied between the electrode **21** and the electrode **31** by suitable connections **54**, **55** to an electrical generator or source (not shown). The arc between the electrode is struck in any suitable manner. For example, a conductive rod may be inserted from the upper end through the bore **50** of the device to contact both the lower electrode **31** and the upper electrode **21**. This conductive rod may thereupon be withdrawn. As it is slowly withdrawn, maintaining contact with the electrode **21**, it strikes the arc between its end and lower electrode **31** and, as the striking rod is completely withdrawn, the arc extends between the electrode **31** and the electrode **21**. The gas forced into the column through the annular aperture **45** surrounds the arc and tends to maintain it in a concentrated stream form. At the same time, this gas is heated, forming an easier path for the flow of ions. As this heated gas leaves the nozzle-like electrode **21** it "blows" the arc outwardly of the electrode **21** and, in fact, the arc assumes a configuration shown by the dash-dot lines **56**, in which within the column portion **12** it is a narrow stream which as it leaves electrode **21** fans upwardly in all directions like a fountain, to fall back upon the outer surface of electrode **21**. This outer portion of the arc at **56***a* is in effect a flaming torch having high temperatures far in excess of those obtainable by those of conventional torches of combustible material, such as gases or the like, or even the atomic hydrogen torch, the temperatures being essentially determined by the electrical energy supplied to the arc.

While the torch thus far described may be utilized in conventional manner for soldering, brazing, welding, heat-treating, or other uses for conventional torches, the present invention provides further features whereby powdered or comminuted materials may be supplied to the arc itself to be heated therein to extremely high temperatures, which may approach or exceed the vaporization point of the material involved. Such materials are conducted along the axis of the torch through the nozzle electrode **21**, into the extended flame of the torch and therebeyond, where they may be usefully employed, as by spraying upon any objects which it is desired to coat. For this purpose the material to be sprayed is supplied to the pipes **46**, preferably in the form of a powder carried by suitable inert gas under pressure. Because of the angle at which each of the pipes **46** is arranged with respect to the axis of the device, the powdered material is carried upward in the figure in spiral convolutions around, and becomes intimately mixed with, the arc within the column nozzle portion **12**, the portion **21**, and the flame portion **52** of the arc, to be appropriately heated thereby before exiting from the arc for useful purposes.

According to one feature of the present invention, the helical movement imparted to the gas-plus-powder injected through pipes **46** is in the same rotational sense as that of the gases introduced to the bore **50** through aperture **45**, to avoid any disruption of the smooth concentrated arc in bore **50** and to assist in the even distribution of material in the arc, resulting in a smooth and even vaporized spray extending beyond the arc portion **56***a*.

Another feature of the present invention resides in the configuration of the annular electrode **21**; as shown, it has a tapered section **53** with narrowing bore in the direction of flow of the gas and materials, followed by a flared portion. This narrowed portion assures that the helically moving sheath of gas and materials, after its passage along the bore **50** around and in the edges of the columnar arc, is intimately in contact with the arc for effective heating of the materials. Also the flared portion of the electrode **21** serves as a nozzle for the projection of the vaporized or heated materials as a spray, and simultaneously provides a properly formed equi-potential surface to form the axially extended arc into a torch of desired shape.

The nozzle-like electrode **21** offers special advantage. As the stream of gas and material is carried upward along the arc, the inwardly tapering bore **22** serves to assure that the material has intimate contact with the higher temperature portions of the arc. Also, the slight build-up of pressure at the narrowest portion of the bore slows down the vaporized material slightly, assuring a longer association with the arc so as to attain more complete vaporization. At the same time, the material passing beyond the orifice is speeded up so as to be projected beyond the outer arc flame toward the object being coated.

The swirling action of the gas and work material is also a feature of the invention in providing a longer path for the work, also assisting in complete vaporization and elevation of temperature. The longer gas path serves to assist in cooling the inner walls of the column to avoid undue temperatures there.

As indicated above, lower electrode **31** and its jacket **34**, **35** are adjustable vertically within hub **52***a*. This serves to adjust the radial width of annular gap **40**, so as to determine the volume and flow of gas in column **12**. Any desired clamping arrangement may be used to fix elements **31**, **33**, **34** in position, once adjusted.

It will be understood that suitable powdered or comminuted materials and gases may be supplied through the pipes **46** for chemical interaction between such materials and gases to provide chemical and/or physical changes in these materials, the materials after being acted upon being ejected through the nozzle **21** and beyond the arc torch portion **56a** to be collected or utilized as desired.

In operation, the arc torch as shown in Figure 4 is connected by leads **54** and **55** to an electric power circuit comprising a resistor **57**, a capacitor **58**, and the secondary **59** of a high voltage power transformer **60**. The resistor 57, capacitor 58, and secondary **59** are connected in series, and the primary **61** of the high voltage transformer is connected to a suitable source of alternating current power.

For most efficient operation of the arc torch it is essential that the electrical components of the series circuit be properly chosen so that during the stable operation of the arc torch the power circuit in which the arc torch is connected will be in resonance. Resonance may be obtained when the relationship between the electrical components fulfills the two essential conditions herewith specified:

Let R be the electrical resistance in ohms of the resistor **57**, which may include the internal resistance of secondary **59**.

Let C be the capacitance in farads of the capacitor **58**.

Let L be the inductance in henries of the high voltage transformer **60** as measured in the secondary **59** when the arc torch current is flowing.

Let f be the frequency in cycles per second of the alternating current source to which the primary **61** is connected—

Then,

1. R^2 must be less than $\frac{4L}{C}$

2. $2\pi f=\sqrt{\frac{1}{LC}-\frac{R^2}{4L^2}}$

As an illustration of the magnitudes of these components for an actual operating condition, the following values are given:

f=60 cycles per second
R=4.6 ohms
L=0.685 henries
C=11.55 microfarads

During this operation the following measurements were taken:

The arc current 20 amperes
Voltage across the capacitor **58** 4000 volts
Voltage across the arc torch 800 volts
Voltage across the transformer secondary **59** 400 volts.

It has also been discovered that such a torch such as disclosed in Patent No. 2,059,276 or as described above may be used very effectively for welding, having many advantages over other welding apparatus and methods already known.

In Fig. 5, the torch there illustrated has an inner electrode **71** and an outer electrode **72** surrounded by a water jacket **73**. The inner electrode may have a central opening **74** as shown. The electrodes are mounted upon an insulating base **75** having a ring of insulating material **76** permitting them to be held rigidly together. The base **75** may have openings **77** therein as shown.

In using the torch for welding the work will be grounded as illustrated at **78** as will be electrode **72**. An alternating or direct current of suitable high voltage may be applied between the electrodes **71** and **72** by means of the leads **79** and **70**. The arc may be struck by a momentary metallic connection between the electrodes. After the arc is started, the torch may be brought into proximity with the work **78**. The arc will then transfer itself from the electrode **72** to the work **78** and the welding operation may then be performed. Filler material may be supplied to the arc through the center opening **74** in the electrode **71** or, if desired, a suitable gas may be supplied to the arc through this electrode. A suitable gas such as air, an inert gas, hydrogen, or any other gas which may be desired may also be supplied through the openings **77** either by the draft created by the arc or under pressure as desired or required by the work to be done. All materials which may be supplied to the arc either through the opening **74** in the electrode **71** or through the openings **77** in the base **75** are included within the term arc material, as there is no concern here with the particular materials to be used but with the method involved. It is noted, however, that this device and method may be used for example for atomic hydrogen welding by supplying hydrogen. Also it may be used as a shielded arc by supplying an inert gas. The welding material supplied through the opening **74** may be in powdered form or in the form of a wire or rod.

It will be understood that the arc torch described with respect to Figs. 1–4 may be used here in exactly the same manner as the torch of Fig. 5.

As stated above, the arc may be struck and the operation of the torch commenced independently of the work. The arc will then play out from the flared end of the inner electrode and return to the outer electrode but will transfer to the work upon being brought in proximity thereto, as the work will offer a shorter return path to ground available to the arc than will the outer electrode.

In use it will be noted that the torch may be used for preheating the work as the arc is not rigidly confined to a single spot.

This new method of welding has a number of advantages many of which will be understood from the foregoing description. It might be also mentioned that it may be used with relative ease for overhead welding, with filler material supplied to the weld. The electrode **71** does not melt in use and, therefore, does not require frequent replacement. The arc is easy to direct and control, being directed and steadied by the draft of air surrounding the arc and directed toward the weld. When used for atomic hydrogen welding, it is economical of hydrogen, the gas being directed toward the weld, and therefore, more or less confined to the actual position where it is needed.

The above description is, of course, illustrative only, since other equivalents to its various features may be known, the actual invention being defined solely by the appended claims.

What is claimed is:

1. An axially extended electric arc torch comprising a first electrode block, a cylindrical gas chamber surrounding said electrode block, a gas inlet communicating with said chamber substantially tangentially thereof, a second electrode spaced axially from said first electrode block, said second electrode having an axial bore converging away from said first electrode block and also having a flaring bore outer portion, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, said column also including a single hollow material-injection section aligned with and between said spacer sections, clamping means for retaining said chamber, column and second electrode in axial alignment, and a plurality of material-injecting inlets formed in said injection section and including a plurality of pipes disposed at an acute angle to the axis of said device in both longitudinal and transverse planes, each of said pipes being at an angle of between 30° and 60° to the radius of said column in a transverse plane and at an angle of between 30° and 60° to the axis of said column in a longitudinal plane.

2. An axially extended electric arc torch comprising a first electrode block, a cylindrical gas chamber surrounding said electrode block, a gas inlet communicating with said chamber substantially tangentially thereof, a second

electrode spaced axially from said first electrode block, said second electrode having an axial bore converging away from said first electrode block and also having a flaring bore outer portion, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, said column also including a single hollow material-injection section aligned with said spacer sections, clamping means for retaining said chamber, column and second electrode in axial alignment, and a plurality of material-injecting inlets formed in said injection section and including a plurality of pipes disposed at an acute angle to the axis of said device in both longitudinal and transverse planes.

3. An axially extended electric arc torch comprising a first electrode block, a cylindrical gas chamber surrounding said electrode block, a gas inlet communicating with said chamber, a second electrode spaced axially from said first electrode block, said second electrode having an axial bore converging away from said first electrode block and also having a flaring bore outer portion, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, said column also including a single hollow material-injection section aligned with and between said spacer sections, clamping means for retaining said chamber, column and second electrode in axial alignment, and a plurality of material-injecting inlets formed in said injection section and including a plurality of pipes disposed at an acute angle to the axis of said device in both longitudinal and transverse planes.

4. An axially extended electric arc torch comprising a first electrode block, a cylindrical gas chamber surrounding said electrode block, a gas inlet communicating with said chamber, a second electrode spaced axially from said first electrode block, said second electrode having an axial bore, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, said column also including a hollow material-injection section aligned with said spacer sections, clamping means for retaining said chamber, column and second electrode in axial alignment, and a plurality of material-injecting inlets formed in said injection section and including a plurality of pipes disposed at an acute angle to the axis of said device in both longitudinal and transverse planes.

5. An axially extended electric arc torch comprising a first electrode, a gas inlet chamber surrounding said first electrode, a gas inlet communicating with said chamber, a second electrode spaced axially from said first electrode, said second electrode having an axial bore and also having a flaring bore outer portion, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, said column also including a hollow material-injection section, clamping means for retaining said chamber, column and second electrode in axial alignment, and a plurality of material-injecting inlets formed in said injection section and including a plurality of pipes disposed at an acute angle to the axis of said device in both longitudinal and transverse planes.

6. An axially extended electric arc torch comprising a first electrode, a gas inlet chamber surrounding said first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore and also having a flaring bore outer portion, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, said chamber having an aperture in register with said spacer bores and surrounding said first electrode with an annular gap therebetween, means for supplying gas under pressure to said chamber with a swirling movement about the axis of said column to pass through said annular gap into said column bore with said swirling movement, said column also including a hollow material-injection section, clamping means for retaining said chamber, column and second electrode in axial alignment, and means in said material-injection section for injecting material to be acted upon into said column bore and with a swirling movement in the same sense as said gas swirling movement.

7. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore, a hollow column spacing said electrodes, and comprising a plurality of insulating spacer sections, each having a bore extending axially of said electrodes, means for passing inert gas through said column bore with a swirling movement about the axis of said column, said column also including a hollow material-injection section, clamping means for retaining said chamber, column and second electrode in axial alignment, and means in said material-injection section for injecting material to be acted upon into said column bore and with a swirling movement in the same sense as said gas swirling movement.

8. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore, a hollow column longitudinally spacing and in insulated relation with said electrodes, and having a bore, means for passing inert gas through said column bore with a swirling movement about the axis of said column, means for retaining said electrodes and column in axial alignment, and means for injecting material to be acted upon into said column bore at a point between said electrodes and with a swirling movement in the same sense as said gas swirling movement.

9. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore, a hollow column spacing said electrodes, and having a bore, means for retaining said electrodes and column in axial alignment, means for passing inert gas through said column bore with a swirling movement about the axis of said column, and means for injecting material to be acted upon into said column bore at a point longitudinally between said electrodes.

10. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore, a hollow column spacing said electrodes and having a bore, clamping means for retaining said electrodes and column in axial alignment, means for passing inert gas through said column bore in the direction of flow through said second electrode, whereby said first electrode may be termed the upstream electrode and the second electrode may be termed the downstream electrode, and means for injecting material to be acted upon into said column bore at a point downstream from said upstream electrode.

11. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode in its entirety, said second electrode having an axial bore, a hollow column separating said electrodes and having a bore in alignment with said electrode bore, means for passing inert gas around said first electrode into said hollow column and helically along the bore thereof and along said second electrode bore, and means

for injecting material to be acted upon by said arc into said column bore at a point between said electrodes and with a helical motion along the axis of said column bore, whereby said arc is extended between said electrodes and beyond said second electrode and said material passes along said arc axially through and beyond said second electrode.

12. An axially extended electric arc torch comprising a first electrode, a second electrode spaced axially from said first electrode, said second electrode having an axial bore, a hollow insulating column separating said electrodes and having a bore in alignment with said electrode bore, means for passing inert gas around said first electrode into said hollow column and helically along the bore thereof and along said second electrode bore, and means for injecting material to be acted upon into said column bore at a point between said electrodes and with a swirling motion advancing said material helically along said column bore.

13. An axially extended electric arc torch comprising a first electrode, a second electrode having a bore and axially spaced from said first electrode, a hollow column longitudinally entirely separating said electrodes and having a bore in alignment with said first bore, a housing surrounding said first electrode with an annular gap therebetween, and means injecting gas under pressure into said housing substantially tangentially thereof and in a plane perpendicular to said bore axis.

14. An axially extended electric arc torch as in claim 13, wherein said first electrode is supported on a tapered support, and including means for axially adjusting said support relative to said housing to adjust the width of said annular gap.

15. An axially extended electric arc torch comprising a first electrode, a second electrode having a bore and entirely axially spaced from said first electrode, a hollow column separating said electrodes and having a bore in alignment with said first bore, and means for injecting material to be acted upon into said column bore at a point between and spaced from both said electrodes and with a swirling motion advancing said material helically along said column bore.

16. An axially extended electric arc torch comprising a first electrode, a second electrode having a bore and axially spaced from said first electrode, a hollow insulating column longitudinally separating said electrodes and having a bore in alignment with said first bore, the bore of said second electrode converging away from said first electrode and having an outer flared portion, and means for passing gas along said column bore outwardly of said bored electrode to produce an axially extended arc.

17. An axially extended electric arc torch, comprising a first electrode, a second electrode having a bore and axially spaced from said first electrode, a hollow column separating said electrodes and having a bore in alignment with said first bore, a high voltage power transformer having a primary winding adapted to be coupled to a source of alternating current and also having a secondary winding, a capacitor, a resistor, said secondary winding, capacitor and resistor being connected to said electrodes in a series circuit, said circuit being resonant at the frequency of said source during the existence of said arc.

18. An axially extended electric-arc torch, comprising a first electrode, a second electrode having a bore and axially spaced from said first electrode, a hollow insulating column longitudinally entirely separating said electrodes and having a bore in alignment with said first bore, and electric-excitation means connected to said electrodes and including means electrically resonant with said torch during the existence of an arc between said electrodes.

19. In an electric-arc torch, spaced electrodes including a hollow electrode having a bore on an arc axis extending from one of said electrodes to said hollow electrode, pressurized-gas supply means including means developing an arc-confining swirl helical about and along said axis, and electric-excitation means connected to said electrodes and including means resonant with said torch during existence of an arc confined by said swirl.

20. In an electric-arc torch, an arc chamber comprising a plurality of interfitting hollow sectional elements defining an elongated passage, said sectional elements including at the downstream end thereof an element of conductive material defining a downstream electrode, the element adjacent said downstream electrode being of insulating material, an upstream electrode positioned coaxially with respect to an upper sectional element of said arc chamber, and means for inducing a flow of gas along said chamber and through said downstream electrode.

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