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[54] **ARC HEATER HAVING A SPIRALLY ROTATING ARC**
12 Claims, 6 Drawing Figs.

[52] U.S. Cl. 315/111,
313/155, 313/161, 313/231

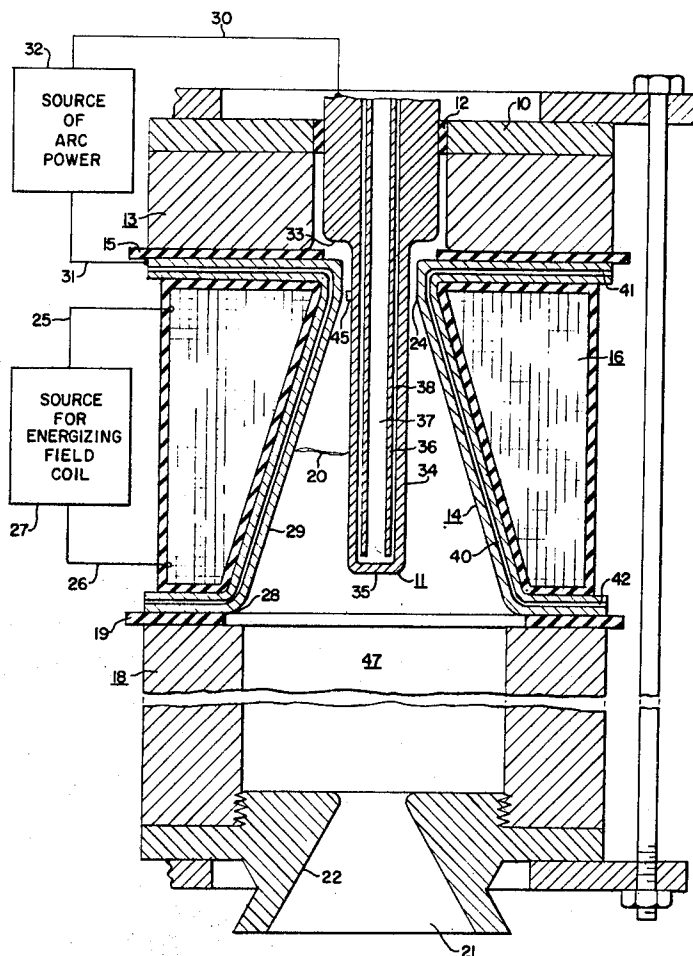
[51] Int. Cl. H01j 1/50,
H01j 7/24, H05b 1/00

[50] Field of Search 313/161,
231; 315/111; 313/155, 231.5; 219/75, 121 (P)

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ABSTRACT: An arc heater has two radially spaced axially coincident electrodes providing a radially extending arc path. One of the electrodes has an arcing surface tapering in diameter, or frustoconical in shape, whereby the arc path increases in length from the upstream ends of the electrodes to the downstream ends thereof. An arc initiated at the minimum gap, which is at the upstream end, is blasted toward the downstream direction due in part to an azimuthal magnetic field produced by a portion of the current path in the inner electrode which is substantially at a 90° angle with respect to the longitudinal axis of the inner electrode, but the arc is moved downstream primarily by a "Jacob's ladder" effect in which current paths in the electrodes set up magnetic fields which are vectorially added to the magnetic field set up by the arc current in the arc itself, on the upper side only, with a resulting force on the arc which moves it down the electrodes, and the arc path is rotated around the inner electrode by an externally applied direct current axial magnetic field, the combined effects producing a spiral pattern of movement for the arc.



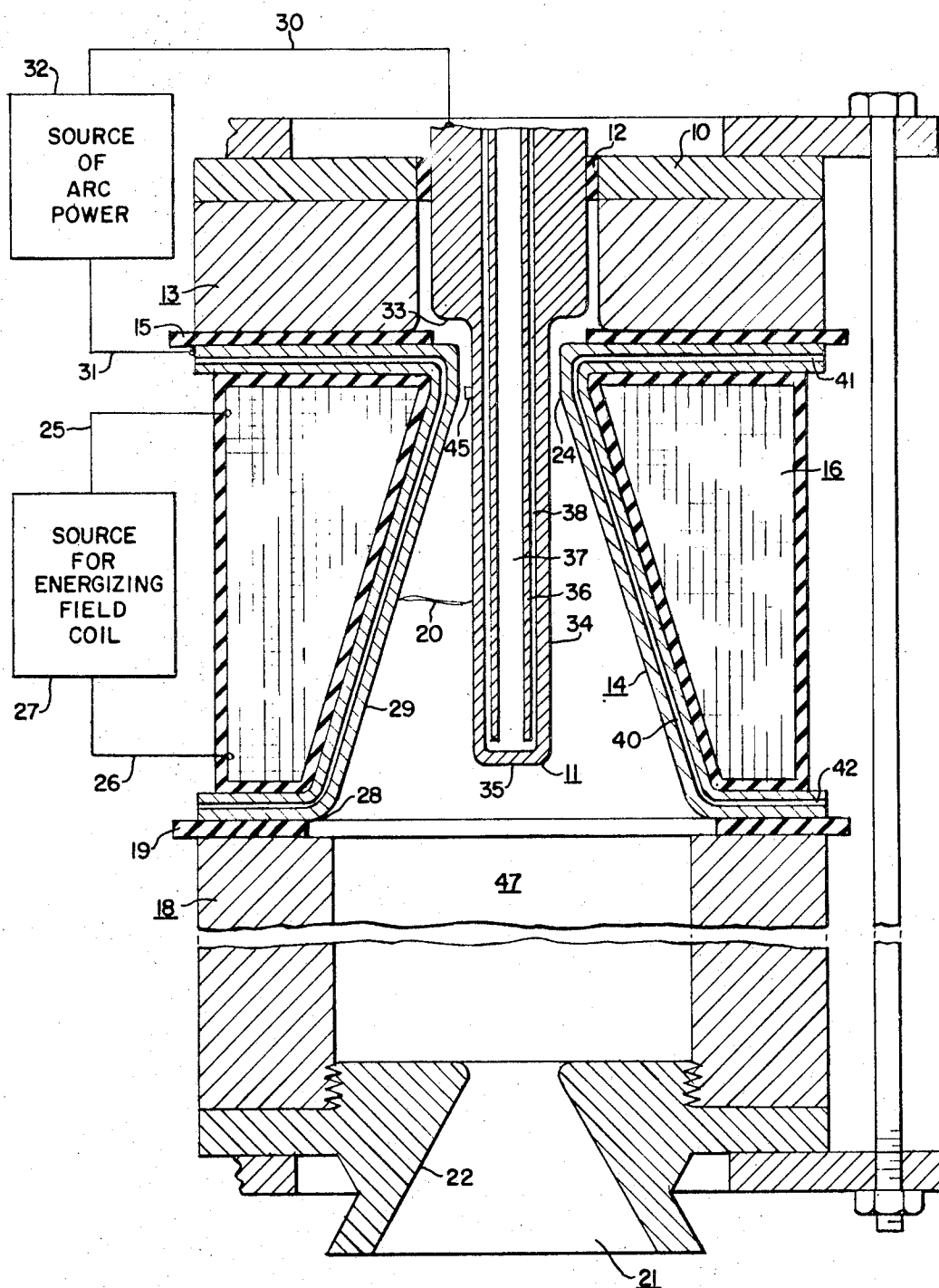


FIG. 1.

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FIG. 2.

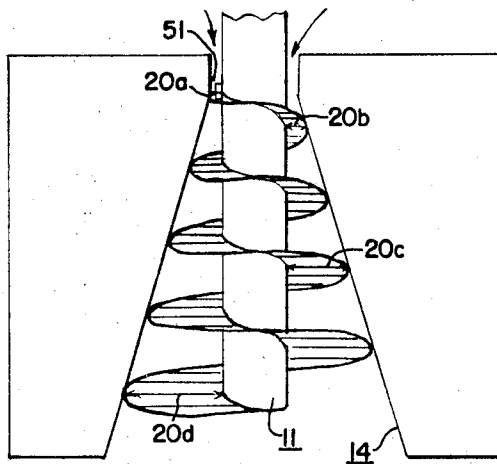
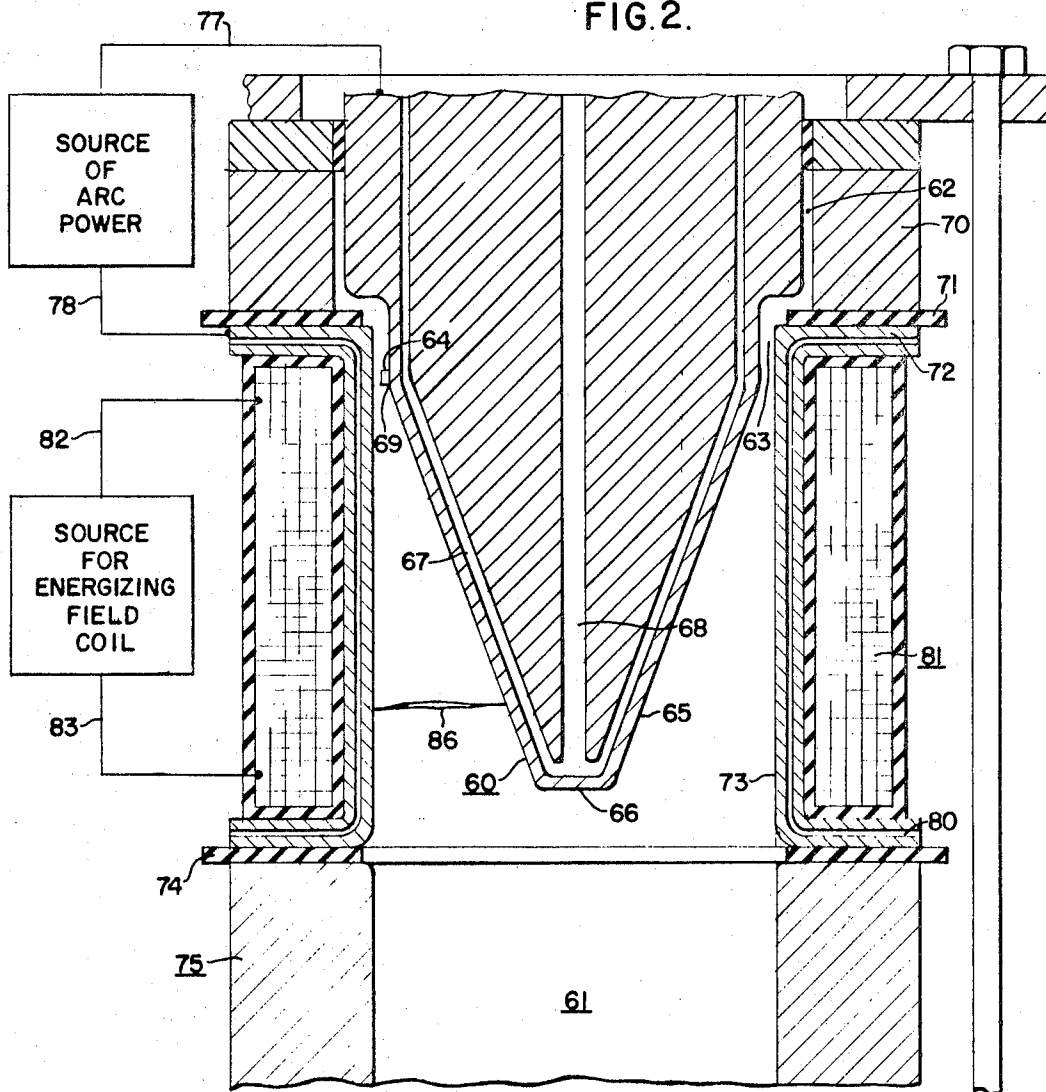


FIG. 3A.

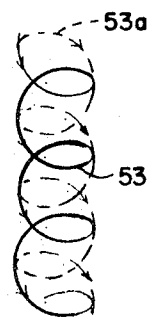


FIG. 3B.

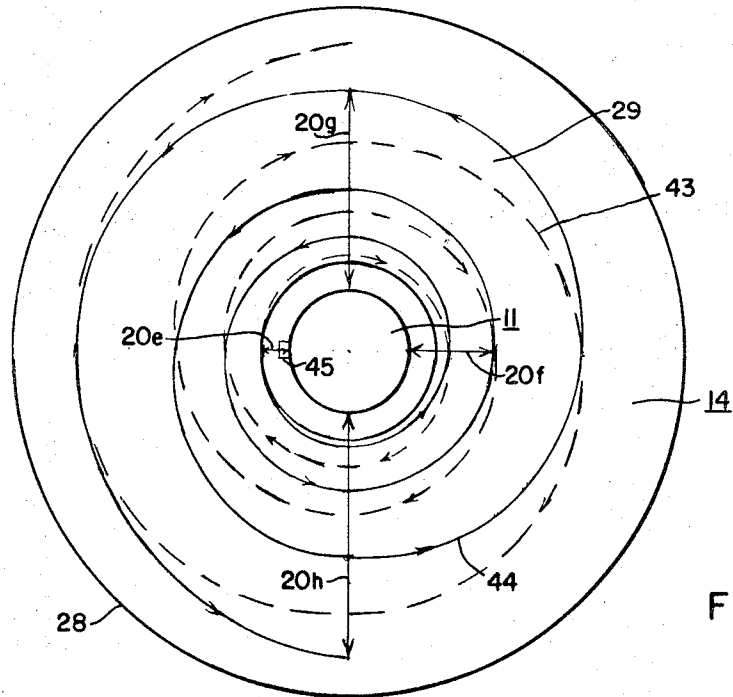


FIG. 4.

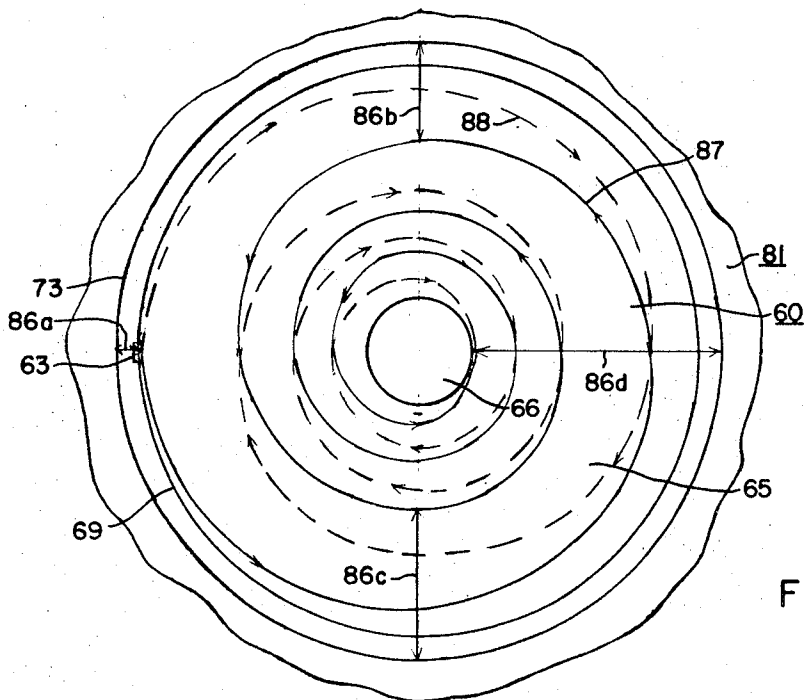


FIG. 5.

ARC HEATER HAVING A SPIRALLY ROTATING ARC

CROSS REFERENCE TO RELATED APPLICATIONS

This application is related to the application of Hirayama et al. for "Process for Producing and Depositing Carbon and Graphite," Ser. No. 533,004, filed Mar. 9, 1966, and now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to electric arc devices for heating fluids.

2. Description of the Prior Art

Arc heaters having radially extending arcs between electrodes are old in the art as exemplified by U.S. Pat. No. 3,201,560 to Mayo et al.; U.S. Pat. No. 3,182,176 to Bunt et al.; U.S. Pat. No. 3,073,984 to Eschenbach et al.; and U.S. Pat. No. 3,316,444 to Mentz.

Generally speaking, prior art arc heaters providing a radial arc path do not utilize the electrode arcing surface uniformly and have other disadvantages and shortcomings.

SUMMARY OF THE INVENTION

By providing that one electrode has an arcing surface which tapers in diameter, in the case of the outer electrode, an arcing surface which increases in inner diameter toward the downstream end, and in the case of the inner electrode, an arcing surface which decreases in diameter toward the downstream end, an area of minimum gap length is provided and the arc is initiated there. In case of an alternating current arc the arc will be transferred to the minimum gap at each current zero. A magnetic field coil in the outer electrode sets up a magnetic field whereby the arc is rotated helically in opposite directions during alternations of opposite polarity. Thus the entire electrode surface is utilized uniformly. In case of a direct current arc, the arc is moved helically down the electrode by the magnetic field and the arc is transferred to the minimum gap whenever the breakdown strength of the minimum gap becomes smaller than the arc voltage. As previously stated, in one embodiment we use a divergent outer electrode, and the feedback of arc residues toward the upstream end, for instance carbon in case of a heater for chemical processing, is minimized.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an arc heater according to one embodiment of our invention;

FIG. 2 is an arc heater according to a second embodiment of our invention;

FIG. 3A is a sketch assisting in illustrating the operation of the apparatus of FIG. 1; and

FIG. 3B illustrates spiral arc paths in clockwise and counterclockwise directions where alternating current supplies the arc and the magnetic field is produced by direct current;

FIG. 4 illustrates the arc spot paths on the arcing surface of the tapering electrode of FIG. 1 as the arc rotates in clockwise and counterclockwise directions during alternations of opposite polarity; and

FIG. 5 illustrates the arc spot paths on the arcing surface of the tapering electrode of FIG. 2 as the arc rotates in clockwise and counterclockwise directions during alternations of opposite polarity.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In FIG. 1 the arc heater is seen to include generally an upper end plate 10 having a substantially centrally located aperture therein in which is located the center electrode 11, the electrode being insulated from the remainder of the structure by insulator 12. A heat shield 13 which it is understood may be fluid cooled if desired has one end adjacent the end plate 10,

and adjacent shield 13 at the other end thereof is the outer electrode 14 which is seen to be fluid cooled and electrically insulated from heat shield 13 by insulating ring 15. The electrode generally designated 14 has a field coil 16 therein. Disposed adjacent the downstream end of electrode 14 is a heat shield 18 insulated from the electrode by insulating means or ring 19, and it will be understood that heat shield 18 is preferably fluid cooled since it receives direct radiation from the arc 20 and also receives heat of conduction and convection from hot gases. The downstream end of the heat shield 18 has secured thereto a nozzle member 21 having an exhaust vent 22.

The center electrode 11 is seen to be connected by way of lead 30 to a source of arc power 32 which is also connected by way of lead 31 to the outer electrode 14. Current flowing down the center electrode to the arcing surface flows over a portion of its path 33 where current flow is substantially at a right angle with respect to the longitudinal axis of the electrode.

The aforementioned field coil 16 is connected by way of leads 25 and 26 to a source of potential 27 for energizing the field coil.

Paying particular reference to the center electrode 11 it is seen to include a tubular portion 34 preferably composed of copper or other material which has good electrical and thermal conductivity, with an end closed at 35, to have extending thereinto and spaced from the inner wall of the tube 34 an additional tube 36 forming a central fluid flow passageway 37 and an annular passageway 38 for the flow of cooling fluid. Preferably the cooling fluid is brought in through the annular passageway adjacent the arcing surface forming means but the flow of fluid may be in the opposite direction if desired. The passageways 37 and 38 may communicate with fluid headers, not shown for convenience of illustration, which are connected to fluid inlet and fluid outlet means electrically insulated from the remainder of the arc heater structure.

The upper portion of large diameter of electrode 11 provides an optical baffle for insulation 12 so that direct radiation from the arc 20 cannot at any time fall upon insulation 12 and cause deterioration of the insulating qualities.

The aforementioned electrode 14 is seen to have a fluid passageway 40 therein with inlet and outlet annular entrances 41 and 42 or vice versa. The annular exit and entrance ends of the passageway 40 may communicate with fluid headers, not shown for convenience of illustration, having fluid inlets and outlets therefor.

Preferably the aforementioned insulating ring 15 is composed of a highly refractory material, as is insulating ring 19.

The aforementioned heat shield 18 as previously stated is preferably fluid cooled and may be cooled by conventional means well known in the art as by a passageway therein near all of the surface thereof which is exposed to radiation from the arc 20 and to the heat of convection.

The aforementioned nozzle member 21 is preferably fluid cooled, as by a passageway therein, not shown, near all of the surface thereof which forms the exhaust vent and all of the upper face of the member which is exposed to radiation and heat of convection.

An arc start button is shown at 45 disposed in the narrowest or shortest portion of the arc path to provide a minimum gap of desired length.

In the operation of the apparatus of FIG. 1, the arc 20 is normally initiated at the minimum gap and thereafter the arc is blasted toward the downstream direction due to the self-induced magnetic fields of arc currents in the electrodes and the magnetic field of the current of the arc itself and the arc is rotated due to an externally applied axial direct current magnetic field supplied by the aforementioned field coil 16.

Particular reference is made now to FIG. 3A in which the minimum gap area is shown at 51 with the arc 20a starting in

the minimum gap area. Arrows 20a, 20b, 20c and 20d of progressively increasing length depict the elongation of the arc as it spirals down the electrode 11 due to the "Jacob's ladder" effect previously explained. As seen, gas is injected in an annular path between electrodes 11 and 14. In FIG. 3B, the spiral path of the arc during one alternation is indicated at 53, and the spiral path rotating in the opposite direction during the next alternation of opposite polarity is shown at 53a. The magnetic field above referred to as self-induced may be thought of in part as the magnetic field produced by the current in the electrode at the 90° bend as shown in FIG. 1. The aforementioned arc start button 45 supplied to provide a minimum gap may be copper or other electrically conductive material attached to the normal surface of the electrode. As previously stated in case of an alternating current arc the arc will be transferred to this minimum gap at each current zero, and the arc is rotated helically in opposite directions at each half cycle, the path being indicated by the curves 53 and 53a of FIG. 3B.

The helical rotation of the arc insures that the entire electrode surfaces are utilized substantially uniformly.

Where the source 32 supplies a direct current for producing the arc 20 it will be understood that as the arc moves toward the downstream end of the electrodes and becomes elongated, that the arc voltage rises. A point is reached wherein the minimum gap breakdown strength between the start button 45 and the adjacent surface of electrode 14 is smaller than the arc voltage, whereupon the arc returns to the minimum gap and the process of being moved downward along the electrode in response to the magnetic fields repeats itself.

As previously stated, the divergent outer electrode 14 insures that the feedback of arc residues toward the upstream end of the arc chamber 47 is minimized. This may be of particular importance in arc heaters used for chemical processing where for example the residue is carbon.

The structure shown in FIG. 1 and described hereinbefore also minimizes the problems of arc transfers to heat shields and carbon deposits on the insulating rings 15 and 19 in the gaps between the electrode and the adjacent heat shields.

Particular reference is made to FIG. 2 showing a second embodiment of our invention. In FIG. 2, the nozzle member and the end plug at the upstream end of the arc chamber have been omitted for simplicity of illustration, but it will be understood that the inner electrode 60 is securely maintained in position by insulating means, not shown, which insulates the electrode from the remainder of the structure. Gas to be heated enters the arc chamber 61 through the annular passageway 62 passing through the minimum gap area 63 in which is disposed an arc start button 64. The arcing surface 65 of electrode 60 is seen to have an inverted frustoconical shape generally with a snub-nose portion 66 and fluid passageways 67 and 68 therein for the flow of cooling fluid.

Disposed around the inner electrode generally designated 60 are, in the order named, a heat shield 70 which is preferably fluid cooled by means not shown, an insulating ring 71, an outer electrode 72 which has a cylindrical arcing surface 73, an insulating spacer 74 and a heat shield 75 which is preferably fluid cooled by means not shown. Lead 77 connected to electrode 60 and lead 78 connected to electrode 72 are connected to a source of power to supply the arc current, not shown for convenience of illustration. This last-named source may be either alternating current or direct current.

The aforementioned outer electrode 72 is seen to have a passageway 80 for the flow of cooling fluid and to have disposed therein and electrically insulated therefrom a magnetic field coil generally designated 81 having leads 82 and 83 for connecting the field coil to a source of energizing potential, not shown for convenience of illustration.

It will be understood that the fluid passageway 80 of the outer electrode generally designated 72 may communicate with fluid inlet and fluid outlet headers, not shown for convenience of illustration. It will be further understood that

the heat shields 70 and 75 may have similar fluid flow passageways therein on the sides thereof adjacent the arc chamber, these passageways not being shown for convenience of illustration.

Further summarizing the advantages of both the embodiment of FIG. 1 and that of FIG. 2 of our invention, two divergent coaxial arrangements are shown. Each provides for a minimum gap for arc initiation and transfer, this occurring periodically in the case where the arc current is either alternating current or direct current. A novel current path or paths is provided as indicated in FIG. 3B for the axial blast of the arc due to the self-induced azimuthal and other magnetic fields. Further, the arc is rotated by the axial magnetic field produced by the field coils 16 and 81 of FIGS. 1 and 2, respectively.

Particular reference is made now to FIG. 4, where the view may be that of one looking into the nozzle of FIG. 1. The sloping arcing surface 29 of electrode 14 is seen to have boundaries 24 and 28 of smaller and larger diameter respectively, the path of the arc spot as the arc spirals in a clockwise direction being designated by the dashed line 43, the path of the arc spot as the arc spirals in a counterclockwise direction being designated by solid line 44, arrows 20e, 20f, 20g and 20h of progressively increasing length representing the progressive elongation of the arc during counterclockwise movement; it will be seen that a similar progressive elongation takes place during clockwise movement. As noted in FIG. 1, the inner electrode 11 does not extend as far down as the outer electrode, so that arrow 20h representing the greatest elongation of the arc does not extend to circular line 28 representing the lower extremity of the arcing surface of the outer electrode.

Particular reference is made now to FIG. 5, where the view may be that of one looking into the nozzle of FIG. 2. The sloping arcing surface 65 of the inner electrode is seen, the flat end being shown at 66. Circle 69 represents the outer boundary of the electrode, and the arcing surface of the outer electrode is seen at 73. The solid line 87 represents the path of the arc spot as the arc spirals in a counterclockwise direction, and the dashed line 88 represents the path of the arc spot as the arc spirals in a clockwise direction. Arrows 86a, 86b, 86c, and 86d represent progressive elongation of the arc as it spirals down the electrodes.

Where alternating current supplies the arc, preferably the current energizing coil 16 or 81 is adjusted in accordance with the value of the arc current, whereby the force exerted on the arc by the magnetic field causes the arc to rotate at a speed whereat a number of revolutions are completed per alternation, and the arc reaches the lower extremities of the arcing surfaces at or about current zero.

The dimensions of the arc start button may be selected to provide for breakdown at the arc voltage attained when a direct current arc is at or near the lower ends of the electrodes.

The foregoing written description and the drawings are illustrative and exemplary only and should not be interpreted in a limiting sense.

We claim:

1. An arc heater comprising, in combination, inner and outer electrodes spaced from each other, the inner and outer electrodes being adapted to be electrically connected to a source of potential to produce a substantially continuous radially extending arc therebetween, means for bringing gas to be heated in an annular path to the space between electrodes where said space between electrodes is substantially narrowest, electrical connections to the inner and outer electrodes being made at axial positions not farther downstream than the position where the space between electrodes is narrowest, one of the electrodes having a substantially cylindrical arcing surface, the other of said electrodes having an arcing surface which tapers in diameter along the length thereof whereby a relatively short space exists between the arcing surface of the inner electrode and the

arcing surface of the outer electrode at the upstream ends of said electrodes and a relatively large space exists between said arcing surfaces at the downstream ends of the electrodes, means for exhausting heated gas from the arc chamber, the arc between electrodes being initiated in the minimum gap area at the upstream ends of the electrodes and blasted toward the downstream direction due to the magnetic fields of the currents in the electrodes and in the arc, and magnetic-field-producing means disposed near the arcing surface of the outer electrode for producing a substantially continuous magnetic field for rotating the arc between electrodes, said arc following a spiral path on the surfaces of the electrodes.

2. An arc heater according to claim 1 including in addition arc start button means on the arcing surface of one of the inner and outer electrodes in the minimum gap area to provide a shortened gap length between the button means and the opposite electrode to insure that the gap has a breakdown voltage which will result in gap breakdown when the arc is near its most elongated state at a position near the downstream ends of the electrodes.

3. Apparatus according to claim 1 in which the arc heater is additionally characterized as having a heat shield upstream of the outer electrode and an additional heat shield downstream of the outer electrode, both of the heat shields being insulated from the outer electrode.

4. Apparatus according to claim 1 in which the arc heater is additionally characterized as having at least one heat shield adjacent the upstream end of the inner electrode, said heat shield having an inside diameter greater than the outside diameter of the adjacent end of the inner electrode, the inner electrode having an upstream portion of large diameter relative to the portion thereof which forms an arcing surface, the lead between the source of potential and the inner electrode being connected to the outer surface of the portion of larger diameter of the inner electrode whereby the arc current tends to follow a path along the outside surface of the inner electrode between the lead and the arcing surface, said current path including at least one 90° bend at at least one of the points where the inner electrode changes in diameter, the arc current at the 90° bend producing a magnetic field the lines of force of which lie in a direction to move an arc between the inner electrode and the outer electrode toward the downstream end of thinner electrode.

5. An arc heater according to claim 1 in which the upstream end of the outer electrode has a central aperture of smaller diameter than the diameter of said aperture at the downstream end of said outer electrode to form a tapering arcing surface.

6. Arc heater apparatus according to claim 1 in which the diameter of the outer electrode is substantially uniform throughout and the diameter of the inner electrode is substantially larger at the upstream end thereof than the diameter of the inner electrode at the downstream end thereof to form a tapering arcing surface.

7. Apparatus according to claim 1 in which the magnetic-field-producing means includes a field coil disposed within the outer electrode for setting up a magnetic field which tends to rotate the arc as the arc is moved toward the downstream ends of both electrodes, in which the source of potential for producing the arc is alternating current and the arc follows a spiral path in a clockwise direction during one alternation of the alternating current and follows a counterclockwise spiral path during the next alternation of the alternating current

which supplies the arc.

8. Apparatus according to claim 5 in which the source of potential for producing the arc is alternating current and the arc follows a spiral pattern in a clockwise direction during one alternation of the alternating current as it moves from the upstream end to the downstream end, and follows a spiral path in a counterclockwise direction as it moves from the upstream ends of the electrodes to the downstream ends thereof during the alternation of opposite polarity of the alternating current.

9. Apparatus according to claim 1 in which both the arc current is a direct current and the magnetic-field-producing means includes a direct current source, the arc being initiated between the inner and outer electrodes at the minimum gap area at a short arc gap and being rotated by the magnetic field as it moves from the upstream ends of the electrodes toward the downstream ends thereof, the arc becoming elongated as it moves from the upstream ends of the electrodes toward the downstream ends thereof as the distance between arcing surfaces increases, the arc at last reaching a position where the breakdown strength of the minimum gap is less than the arc voltage required to maintain the arc at a downstream position, the direct current arc thereafter being transferred to a position at the minimum gap and the process of being moved down the electrodes in a spiral path being repeated.

10. In an arc heater including a pair of coaxially mounted radially spaced electrodes so shaped that the distance between the arcing surfaces of the electrodes increases as the axial distance from the upstream ends of the electrodes increases, the electrodes being adapted to be connected at the upstream ends thereof to a source of potential to produce a substantially continuous arc therebetween, an arc chamber, and means for bringing fluid to be heated to the arc chamber and conducting fluid after heating from the arc chamber, the improvement comprising means providing at the upstream ends of the electrodes a minimum gap for arc initiation, and means including magnetic field generating means so positioned with respect to the electrodes that a substantially constant substantially axially extending magnetic field is produced in the space between electrodes for causing the arc to thereafter move to a position whereat the arc is elongated to such a length that the voltage required to sustain the arc equals the breakdown voltage of the minimum gap.

11. An arc heater according to claim 10 in which the arc is initiated at the gap, wherein the arc current is direct current and wherein the arc is periodically transferred to the gap and periodically moves to a position where the arc is elongated.

12. An arc heater of the type employing inner and outer electrodes radially spaced and so shaped that the distance between the arcing surface of one electrode and the arcing surface of the other electrode increases as the axial distance from the upstream ends of the electrodes increases, the electrodes being adapted to be connected to a source of potential for producing a substantially continuous arc therebetween with means for bringing fluid to be heated to an arc chamber and conducting fluid after heating from the arc chamber, comprising the improvement of means for providing for an axial blast of the arc due to a self-induced azimuthal magnetic field, said last-named means including means for generating a substantially continuous magnetic field for rotating the arc which extends radially between the inner and outer electrodes.