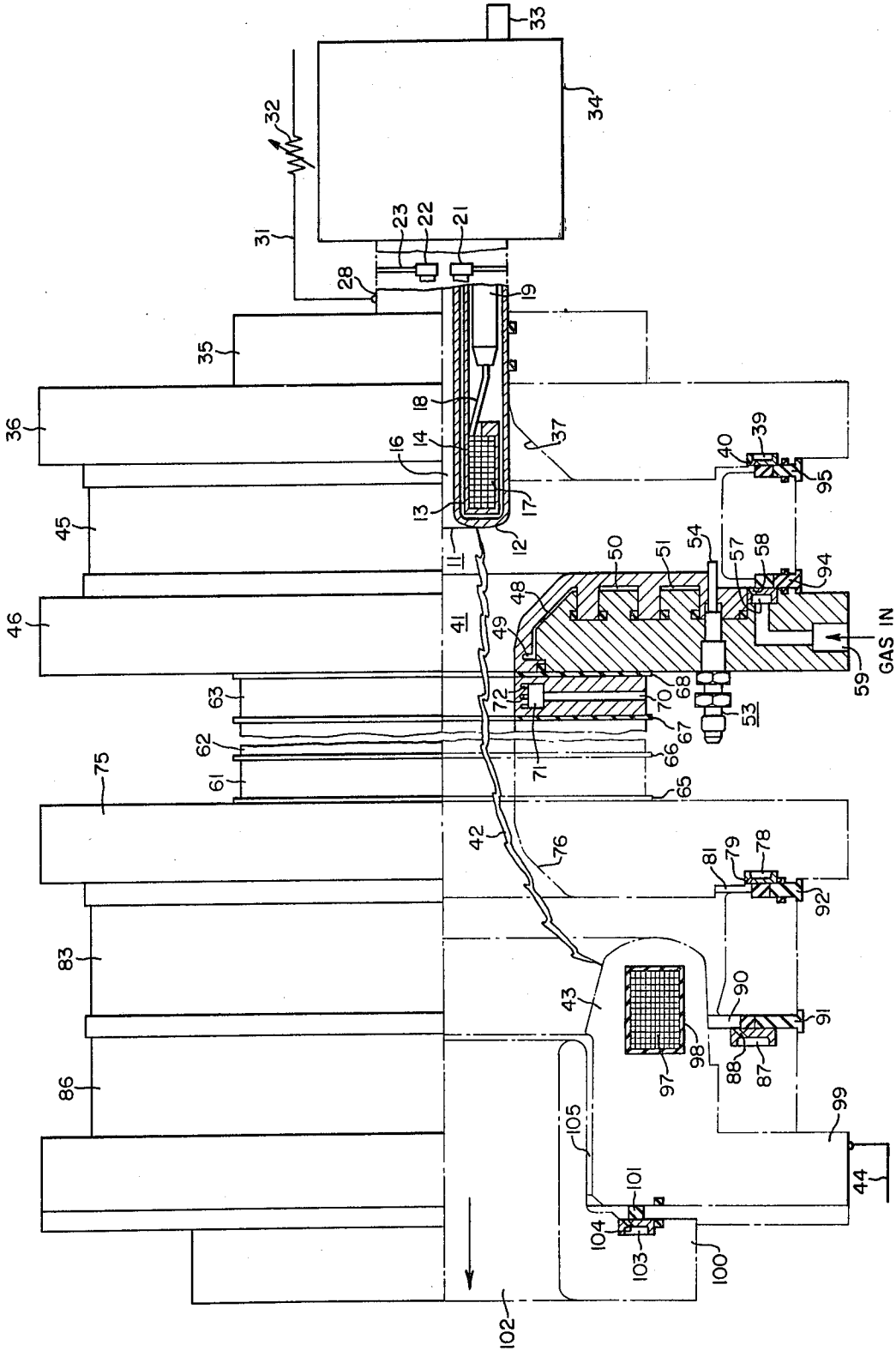
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COAXIAL ARC HEATER WITH VARIABLE ARC LENGTH

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COAXIAL ARC HEATER WITH VARIABLE ARC LENGTH

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ABSTRACT OF THE DISCLOSURE

The arc between electrodes takes place through a constrictor tube; one of the electrodes is of smaller diameter than the inside diameter of the constrictor tube, is electrically insulated therefrom, and is movable axially within the constrictor tube to vary the length of the arc. In addition, a portion of the wall of the constrictor tube is composed of discrete aligned fluid-cooled rings electrically insulated from each other; the number of rings may be varied to additionally vary the arc length and therefore, in accordance with the power of the arc, the arc length may be adjusted to a value below which the heat loss to the wall of the constrictor tube per unit length is equal to the power input of the arc per unit length.

The invention described herein was made in the performance of works under N.A.S.A. contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85–568 (72 Stat. 435; 42 U.S.C. 2457).

FIELD OF THE INVENTION

This invention relates to improvements in arc heaters and more particularly to an improved arc heater having means for varying the length of the arc path.

DESCRIPTION OF THE PRIOR ART

It is believed that it has been known in the prior art heretofore that for a given gas mass flow and a given enthalpy there is generally an optimum length of the arc and constrictor tube. Furthermore, it is thought that the prior art shows that stable arc length is a function of the power supply characteristics, particularly the available voltage, and thus to match a particular power supply connection, arc length and accordingly constrictor tube length must be adjustable. In prior art arc heaters employing constrictor tubes, the constrictor tubes are generally made modular to provide that between tests the tube can be altered to the desired length. Furthermore, in prior art arc heaters of the type which this invention relates to, the constrictor tube is also the downstream electrode, and the downstream arc attachment point occurs at some area on the constrictor tube. In such prior art devices the arc may be stretched out and prevented from prematurely striking the constrictor tube by suitable gas emission configurations which result in complicated apparatus and are to some extent unreliable. One commonly used procedure consists of introducing gas tangentially so as to produce a spiralling gas flow in the constrictor tube. This spiralling gas flow however tends to concentrate hot gases in the center, which, while stabilizing the arc, also force colder gases toward the walls of the tube where these gases may remain unheated until the wall itself is substantially heated with a resulting nonuniformity in the temperature of the gas exhausted from the arc heater.

SUMMARY OF THE INVENTION

In summary, our invention varies the length of the arc path by varying the length of a constrictor tube consisting of individual liquid cooled metallic rings interspaced with suitable thin electrical insulators. The downstream arc termination point is exterior to the constrictor tube, and premature arc termination within the tube is prevented by the presence of the electrical insulation. The upstream arc termination point is on a fluid cooled electrode. In our invention we do not utilize the vortex flow of the gas in restricting the arc termination to the desired point. Our invention is made in the realization that the length of the constrictor tube is very important, and that beyond a certain length, heat loss to the wall of the constrictor tube per unit length may be about equal to the power input of the arc per unit length, and once this condition has been reached, additional constrictor tube length decreases the efficiency of the device. We also understand that in an arc heater constructed according to our invention, heat loss to the wall of the constrictor tube or to the wall of the arc chamber forming means may be maximum near the downstream end of the arc, and that the heater should be of such a length that for a given set of operating conditions, maximum allowable heat loss at the downstream constrictor end should not be exceeded.

Additionally, prior art gas heaters of the type described in our invention may move the arc spot by gas vortex flow, and we have found that it is preferable to move the arc spot by electromagnetic means, that is, to move the arc through its interaction with a magnetic field provided for the express purpose of moving the arc so that the arc spot does not remain in one position for a sufficient period of time to produce a burn through.

BRIEF DESCRIPTION OF THE DRAWING

The single figure of the drawing, partially in cross-section, illustrates our invention according to the preferred embodiment thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENT

In the figure, the upstream electrode, which is generally annular or cylindrical in shape, is shown in half-section and is generally designated **11**, and comprises a fluid cooled arcing surface **12** which is relatively thin and which has immediately back thereof a fluid flow passageway **13** for the flow of cooling fluid. The aforementioned passageway **13** may be formed by the space between the annular or cup shaped member **12**, which is U-shaped in cross-section, and a combined coil housing and coil supporting member **14** which has disposed therein a magnetic field coil **17** which may consist of a plurality of turns of hollow conduit, preferably the turns being insulated from each other and being connected by conduit **18** with fluid supply means **19**. It will be understood that if the field coil **17** is composed of turns of hollow conduit having a cooling fluid flowing therethrough, that additional conduit means similar to the conduit means **18** is provided, the additional conduit means not occurring in the cross-sectional plane selected for illustration, the additional conduit means serving as either a fluid inlet or fluid outlet as desired. The magnetic field coil **17** generates a field which exerts a force on arc **42** and causes the arc spot site on electrode **11** to move substantially continuously around the annular arcing surface. Passageway **13** is seen to connect with a fluid header **22** which may be a fluid inlet or fluid outlet header as desired, which is connected by conduit **23** with the outside of the arc heater. An additional fluid header for fluid in passageway **13** as shown at **21**.

If desired, fluid leaving the aforementioned coil **17** may pass down around the aforementioned fluid supply means **19** and enter a fluid header, not shown, which communicates by way of conduit, not shown, with the outside of the arc heater. The upstream electrode generally desig-

nated **11** is seen to extend through or form part of a cylindrical coupling member **28** which is composed of electrically conductive material and which has lead **31** connected thereto, lead **31** being adapted to be connected to one terminal of a source of potential for producing and sustaining an arc **42** within the arc heater. Member **28** couples device **34** to the remainder of the arc heater. Reading from right to left, the arc heater is seen to include in addition to portions **34** and **28**, an end plate **35**, a plate or disc portion **36** having a central aperture with a tapering opening **37**, the disc portion **36** also including a gas header **39** which may extend around the entire periphery of the disc portion **36** and which has gas inlet means communicating therewith at some other position than the cross-section selected for illustration. Gas header **39** is seen to communicate by a plurality of peripherally spaced bores **40** with the interior of the arc chamber **41**. An arc **42** is seen taking place between the upstream electrode generally designated **11** and a downstream electrode generally designated **43**, hereinafter to be described in greater detail. It may be noted that the downstream electrode generally designated **43** has a lead **44** connected thereto for bringing a current to electrode **43** to produce the arc, lead **44** being connected to the same source as the aforementioned lead **31**, but to the terminal thereof of opposite polarity. For simplicity of illustration, arc **42** is shown as being a single arc, whereas in actuality it may be a diffused arc or an arc having multiple paths.

Preferably, all surfaces within the arc chamber or forming the arc chamber which are exposed to direct radiation from the arc are fluid cooled. The disc member **36** may have fluid cooling means similar to that described in connection with disc member **46**, and the disc member **45** intermediate disc members **36** and **46** may be fluid cooled. The art of fluid-cooling surface exposed to arc radiation has become so well advanced and is so completely described and claimed in numerous copending applications assigned to the assignee of the instant invention, that is thought unnecessary to describe the fluid cooling in detail. One such copending application is that of A. M. Bruning for "Electric Arc Furnace and Non-Consumable Electrode Suitable for Use Therein," Ser. No. 407,332, filed Oct. 29, 1964. In the disc member **46**, two diametrically opposite spaced bores pass therethrough communicating with fluid flow passageways **48**, **50**, and **51**, and fluid flow is circumferential through drilled holes.

The device generally designated **53** having the jet or tube portion **54** passing through a bore in the aforementioned disc member **46** may be used for introducing gas tangentially to the direction of the arc. However, as previously stated, the satisfactory operation of our invention does not depend upon tangential injection of gas, and accordingly the entire device **53** including the tube portion **54** may be omitted, if desired. It is seen that there is disposed in the disc member **46** an additional annular gas header **57** communicating by way of a plurality of peripherally spaced bores **58** with the arc chamber **41**, the gas header **57** having a gas inlet **59**.

An aforementioned feature of our invention was the adjustable length of the constrictor path varying the number of liquid cooled metallic rings interspaced with suitable thin electrical insulators which define at least a portion of the constrictor tube. Three of these rings are shown designated **61**, **62** and **63**, ring **62** being broken away to illustrate and clarify that the number of rings is not limited to three, but any desired number may be employed in accordance with the desired length of the constrictor tube. The three rings shown require four of the aforementioned thin electrical insulators, these being shown at **65**, **66**, **67** and **68**, the latter two being partially shown in cross section. A portion of the ring member **63** is shown in cross-section, and it is seen that the ring member includes a fluid inlet **70** communicating with a fluid header **71** which may extend 360° and which has a fluid outlet connected thereto at a point substantially 180° from the inlet **70**, so that fluid flows through the header **71** in two substantially semi-circular paths. The header **71** has a number of fingers, slots or grooves **72** extending therefrom and approaching the surface of ring **63** which is exposed to radiation from the arc **41**, and the fluid in the grooves **72** assists in conducting heat flux from the surface which is exposed to direct radiation from the arc. It will be understood that the other rings **61** and **62** include fluid cooling means, not shown for convenience of illustration, which may be similar to the cooling means shown for ring **63**. Additionally, details of rings suitable to form part of the heat shield of an arc heater and the cooling means therefor may be found in application Ser. No. 428,599, filed Jan. 13, 1965, by Kemeny et al., and assigned to the assignee of the instant invention.

As previously stated any desired number of rings corresponding to **61**, **62** and **63** may be employed to provide a constrictor path of the desired length in accordance with the desired enthalpy of the heated gas and the power input which produces the arc **42**. Assuming for the purposes of illustration that the ring **61** shown constitutes the most left band of a plurality of rings, ring **61** is seen to abut against a disc member **75** and to be insulated therefrom by insulating member **65** and the disc member **75** is seen to have a central opening with a tapering diameter **76**. Furthermore, the disc member **75** is seen to include an annular gas header **78** which may extend around the entire periphery of the disc member and which communicates by way of a plurality of peripherally spaced bores **79** with annular space **81** for bringing gas into the arc chamber **41**. It will be understood that the gas header **78** has a gas inlet located at some other radial position than the cross-section selected for illustration. Disposed adjacent the disc member **75** is a ring member **83** which may be fluid cooled in any suitable manner, and on the other side of the ring member **83** there is disposed another disc member **86** having an annular gas header **87** therein communicating by a plurality of peripherally spaced bores **88** with annular space **90** and thence with the arc chamber **41**. It will be understood that the gas header **87** is connected to a gas inlet which is not located in the cross-sectional plane selected for illustration, and is therefore not shown for convenience of illustration.

As previously stated, one means used to prevent the arc **42** from striking to the side of the constrictor forming means rather than striking to the electrodes as desired, is to provide adequate electrical insulation between portions of the constrictor forming means. To this end there are provided two annular rings **91** and **92** composed of electrically insulating material, ring **91** being disposed between member **86** and ring member **83**, and insulating member **92** being disposed between ring member **83** and disc member **75**. Insulating rings **94** and **95**, not previously described in detail but located respectively between disc member **46** and ring member **45**, and ring member **45** and disc member **36**, perform similar electrical insulating functions designed to maintain the arc **42** in the desired path in which one arc contact point is on electrode **11** and the other arc contact point is on electrode **43**.

Electrode **43** is seen to have disposed therein an annular magnetic field producing coil **97** in a housing **98**. The magnetic field set up by the coil **97** rotates the arc **42** around the annular surface of the electrode. It will be understood that leads are brought to the field coil **97** for energizing same, these leads not being shown for simplicity of explanation. It will further be understood that the electrode **43** has most or all of the surface thereof which is exposed to radiation from the arc fluid cooled, by fluid flowing in the passageway located near the arcing surface of the electrode and communicating with fluid inlet and outlet headers which in turn, communicate with fluid inlet and outlet conduits, not shown. As previously stated, the art of cooling surfaces in arc heaters to conduct heat flux away from such surfaces is now highly advanced and has been described in numerous copending applications assigned to the assignee of the

instant invention, and in the literature of the art and accordingly it is thought to be unnecessary to describe the cooling circuit for electrode **43** in detail. If further information on preferred practices are desired, reference may be had to Patent No. 3,309,550, assigned to the assignee of the instant invention. If desired the field coil **97** may consist of a plurality of turns of conduit insulated from each other and having a fluid flow passageway therein for the flow of cooling fluid, with means for bringing fluid to the coil and conducting fluid from the coil.

Electrode **43** is seen to include or to be formed integrally with a disc portion **99** spaced from and electrically insulated from a nozzle member **100** by annular insulating spacer **101**. The aforementioned nozzle member **100** is seen to have an exhaust vent **102** and to have an annular gas header **103** therein, the gas header **103** communicating by way of a plurality of peripherally spaced bores **104** with an annular space or passageway **105** between the nozzle member and the electrode, gas from the gas header **103** entering the arc chamber through this passageway. It will be understood that gas header **103** has a gas inlet connected thereto, the last-named gas inlet not being shown for convenience of illustration, and not necessarily occurring in the plane of the cross-section selected for illustration.

If desired insulating clamping means, not shown for convenience of illustration, may be provided for clamping the flange portion of nozzle member **100** to the outside surface of member **35** near the periphery thereof to hold all of the component parts of the arc heater in their desired positions.

Numerous O-rings are shown, disposed in suitable annular troughs or grooves, for providing sealing engagement for parts of the apparatus where such sealing engagement is deemed desirable or necessary.

In summary, our coaxial arc heater with variable arc length provides for producing very high temperature gas effluent. Furthermore, the length of the arc path in our apparatus is adjustable by changing the number of rings, since there is generally a particular optimum length of the arc and constrictor tube for a given gas mass flow and a given desired enthalpy. Furthermore, we provide for attaining a stable arc length, this arc length being a function of power supply characteristics which may vary in different applications of the arc heater, particularly the available voltage, and in order to match a particular power supply connection we provide for varying the arc length and the constrictor tube length. All of these features of our invention result in improved efficiency.

An additional feature of our invention is that the annular electrode **11** with its internal magnetic field coil is so sized that it may pass through the bore of the electrode and the constrictor tube and that when the electrode **11** is located in the constrictor tube there is a sufficient annular gap between electrode and constrictor tube to allow cold gas to flow through this annular gap. In addition cold gas may be introduced into the arc chamber through the central bore **16** in electrode **11**. We believe that we are the first to provide an electrode corresponding to our electrode **11** which has adequate current carrying capability and which still has a sufficiently small size to pass through the bore of the constrictor tube. We accomplish this in a number of ways, one of these being by providing fluid cooling for the electrode and another being by utilizing a magnetic field to move the arc spot on the electrodes.

Device **34** and knob **33** constitute a suitable servo mechanism of any convenient design operatively connected to the upstream electrode **11** whereby the arc length can be varied during testing so that optimum conditions can be rapidly ascertained. Furthermore, where arc heater apparatus constructed according to our invention includes a certain number of rings corresponding to **61**, **62** and **63**, or under certain conditions, the arc length can be varied by the aforementioned servo mechanism in accordance with a given arc voltage to provide for automatic adjustment of the upstream electrode location and provide the aforementioned conditions for highest output enthalpy or optimum operating efficiency.

Our invention also contemplates and includes means for moving the electrode by suitable hydraulic, pneumatic or electrical mechanism located external to the arc heater cavity.

A further advantage of our invention is that at the arc start, the upstream electrode **11** can be inserted all the way through the constrictor passageway thereby approaching the downstream electrode. If desired, the configuration of the downstream electrode may be such that the upstream electrode may actually come in contact with the downstream electrode. In any event, arc start is more easily obtained because with a short arc gap, voltages required for arc starting are reduced. After the arc is started, the arc is then lengthened as desired by retracting the upstream electrode **11**. A further advantage offered by our starting procedure is that by slowly lengthening the arc, power to the arc can be slowly raised, which is desirable for large high power arc heaters, since it allows the electrical power supply to keep up with the demands of the arc heater without creating electrical supply system disturbances. Our invention includes any upstream electrode which allows the electrode arc attachment area to be localized on the electrode and which allows the position of the upstream electrode to be adjustable axially within an arc constrictor tube. One such electrode is a thermionic emitter.

Rheostat **32** symbolizes means for controlling the power to the arc.

The invention includes additional fluid inlets and outlets where needed, and/or additional fluid headers where needed, these not being shown for simplicity of illustration, their addition being elementary to one skilled in the art.

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

We claim as our invention:

1. A coaxial arc heater with means for providing a variable arc length comprising arc chamber forming means including means forming a constrictor passageway for an arc of adjustable length, a first annular upstream electrode electrically insulated from the means forming the constrictor passageway, said upstream electrode having a magnetic field coil mounted therein near the arcing surface thereof, the upstream electrode having a diameter smaller than the diameter of the passageway, said upstream electrode being movably mounted in the constrictor passageway and spaced from the wall thereof, said upstream electrode having a position adjustable axially over substantially the entire length of the constrictor passageway, an annular downstream electrode located near the downstream end of the constrictor passageway and electrically insulated therefrom, said downstream electrode having an additional magnetic field coil mounted therein near the arcing surface thereof, an exhaust nozzle disposed near the downstream electrode, circuit means connected to the upstream electrode and to the downstream electrode for producing and sustaining an arc therebetween, the magnetic field coil and additional magnetic field coil producing forces on the arc which causes the arc to move substantially continuously over the electrodes, and means for admitting gas into the arc chamber whereby the gas passes through the constrictor passageway and is heated by the arc.

2. An arc heater according to claim **1** wherein the means forming the constrictor passageway is additionally characterized as including a plurality of axially stacked discrete wall forming members electrically insulated from each other to thereby reduce the possibility of the arc striking the wall of the constrictor passageway.

3. An arc heater according to claim **1** including in addi-

tion means operatively connected to the upstream electrode for adjusting the axial position of the upstream electrode within the constrictor passageway while the arc heater is in operation.

4. An arc heater according to claim 1 wherein the upstream electrode is additionally characterized as having an axial passageway therethrough for the flow of gas, and the means for admitting gas into the arc chamber is additionally characterized as communicating with said axial passageway through the upstream electrode.

5. An arc heater according to claim 1 including in addition other means for bringing in gas to be heated adjacent the downstream electrode.

6. Arc heater apparatus according to claim 1 including in addition means in the circuit means for adjusting the arc current to control the power of the arc.

7. A coaxial arc heater with means for providing a variable arc length comprising arc chamber forming means including means forming a constrictor passageway for an arc of adjustable length, said constrictor passageway having a relatively small diameter portion at the center thereof and relatively large diameter portions at the ends thereof, a first annular upstream electrode electrically insulated from the means forming the constrictor passageway, having a diameter smaller than the small diameter portion of the passageway, movably mounted in the constrictor passageway and spaced from the wall thereof and having an adjustable position axially over substantially the entire length of the constrictor passageway, an annular downstream electrode located near the downstream end of the constrictor passageway and electrically insulated therefrom, said downstream electrode having an inside diameter larger than the diameter of the small diameter portion of the constrictor passageway, an exhaust nozzle disposed near the downstream electrode, circuit means connected to the upstream electrode and to the downstream electrode for producing and sustaining an arc therebetween, magnetic field producing means in the upstream electrode and other magnetic field producing means in the downstream electrode for producing magnetic fields which cause the arc to move substantially continuously over the electrodes, and means for admitting gas into the chamber to be heated by the arc.

8. An arc heater for heating gas in which the arc length may be varied and adjusted while the heater is in operation to provide for imparting optimum enthalpy to the gas in accordance with the arc current, comprising a constrictor tube, the constrictor tube including a selected number of stacked coaxially aligned fluid cooled rings electrically insulated from each other and each having a central passageway therethrough of a predetermined diameter, a first disc member mounted adjacent the ring at one end of the aligned rings electrically insulated therefrom and having a central passageway therethrough which forms a continuation of the passageway through the rings, the passageway through the first disc member tapering in a manner to increase the diameter thereof on the side of the disc member away from the adjacent ring, a second disc member mounted adjacent the ring at the other end of the aligned rings and electrically insulated therefrom, said second disc member having a central passageway therethrough which forms a continuation of the passageway through the rings, the passageway through the second

disc member tapering in a manner to increase the diameter thereof on the side of the second disc member away from the adjacent ring, an annular downstream electrode coaxially aligned with the rings and disc members and axially spaced and electrically insulated from the second disc member, said downstream electrode having a magnetic field coil therein, means for enclosing the space between the downstream electrode and the second disc member, an annular fluid cooled upstream electrode having a magnetic field coil therein and movably mounted coaxially with the rings and disc members, the diameter of the upstream electrode being such that it may be moved axially through the central passageways of the rings and disc members with predetermined annular spaces existing between the wall of the upstream electrode and the adjacent walls of the passageways, the upstream electrode and the downstream electrode being adapted to be connected to terminals of opposite polarity of a source of potential to produce an arc therebetween, the magnetic field coils in the electrodes generating magnetic fields which exert forces on the arc which cause it to rotate substantially continuously around the annular upstream and downstream electrodes, means operatively connected to the upstream electrode for adjusting its position axially within the constrictor tube, exhaust means for the arc heater adjacent the downstream electrode and electrically insulated therefrom, and means for admitting gas to be heated at a plurality of peripherally spaced positions from which the gas must pass through the constrictor tube before reaching the exhaust means, said gas being heated by the rotating arc in the constrictor tube, the tapering passageways in the first disc member and second disc member assisting in preventing arc attachment to the inner wall of the constrictor tube.

9. An arc heater according to claim 8 in which the upstream electrode is additionally characterized as having an axial passageway therethrough for bringing in cold gas to be heated in the arc heater.

10. An arc heater according to claim 8 including in addition means for admitting cool gas to be heated at a plurality of peripherally spaced positions between the second disc member and the downstream electrode.

11. An arc heater according to claim 8 additionally characterized as having means defining an enclosed space adjacent the first disc member of substantially larger diameter than the passageways through the rings and disc members, and means for introducing gas into said space tangentially to the direction of the arc for causing a vortex motion of the arc.

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