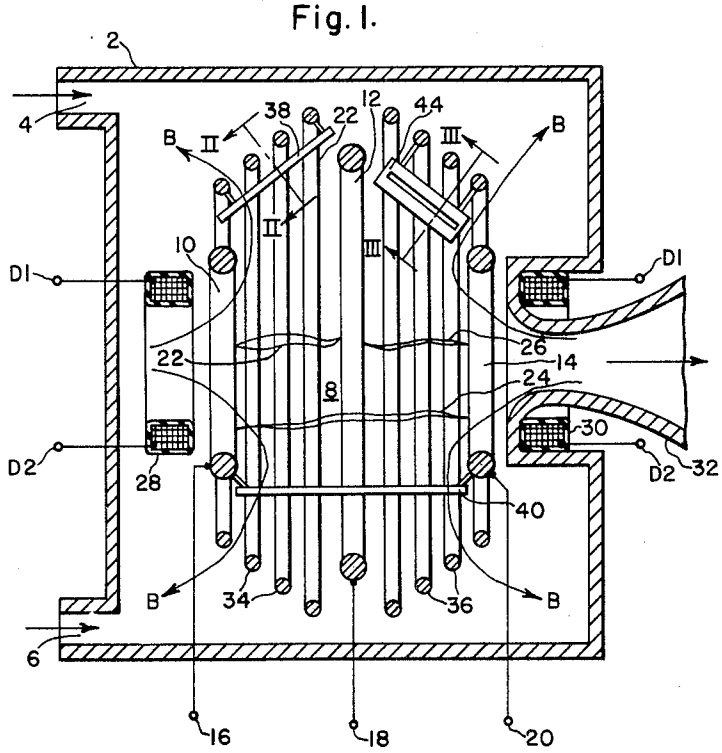
219-121 CROSS REFERENCE SEARCH ROOM

Oct. 19, 1965 J. B. HAMMER 3,213,260

ARC HEATER APPARATUS

Filed Feb. 21, 1963

Fig. 1.



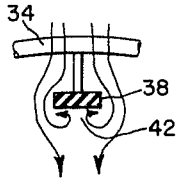


Fig. 2.

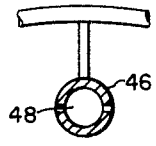


Fig. 3.

WITNESSES

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ARC HEATER APPARATUS

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The present invention relates to apparatus for increasing the enthalpy of a gas, and more particularly to arc heater apparatus for providing a gas at very high temperatures and velocities.

In arc heater apparatus, generally a gas whose enthalpy is to be increased is introduced into a chamber containing a plurality of electrodes. An arc is drawn between the electrodes thus ionizing the gas. By providing a magnetic field substantially transverse to the arc, a cross product force is created, due to the interaction of the current density and magnetic field vectors, to supply a rotational force to the gas, which is then expelled from the chamber through an exit nozzle at high temperature. Apparatus of this type finds many applications especially in high temperature and velocity testing and in chemical synthesis. The various known designs for arc chamber apparatus present many problems. Among these are, the non-uniform heating of the gas resulting from the high angular speed of the gas driving the arc inward. In many chemical synthesizing processes this has a very deleterious effect. Also, relatively large radiation losses result in that the gas usually must be heated over relatively large volumes. Another problem is that electrode life is limited because of low arc spot velocities.

After current zero in arc chamber apparatus utilizing an alternating arcing potential, the arc extinguishes and then must be restruck. Difficulty in restriking the arc after current zero may result if: (1) the forced convection gas currents are sufficiently strong to carry the ionized gas away from the arcing zone during the normally extinguished part of the arcing cycle, or (2) the hot gas in the arcing zone contains a sufficient number of light-weight molecules (such as hydrogen) to carry the thermal energy away from the arcing zone during the normal extinguished period of the arc. From these factors the thermal loss of energy thus effected greatly increases the breakdown voltage of the gas; thus, making it difficult to restrike the arc.

It is therefore an object of the present invention to provide new and improved arc heater apparatus which accomplishes uniform heating of the gas, has low radiation losses and provides for long electrode life, while providing an efficient mode of operation.

It is a further object of the present invention to provide new and improved arc chamber apparatus in which arc restriking problems are eliminated.

The above-cited objects are broadly accomplished by providing arc heater apparatus in which gas introduced into an arcing area is ionized by an arc drawn between electrodes within the chamber. A magnetic field is applied substantially transverse to the ionized gas to impart a rotational motion thereto. Structures are provided to restrict the arcs to the arcing area so that the gas is uniformly heated. Structures are also provided between the electrodes to eliminate any restriking problems. The heated gas is then expelled from the chamber.

These and other objects will become more apparent when considered in view of the following specification and drawings, in which:

FIGURE 1 is a cross-sectional diagram embodying the teachings of the present invention;

FIG. 2 is a sectional view taken along the line II—II of FIG. 1; and

FIG. 3 is a sectional diagram taken along the line III—III of FIG. 1.

Referring to FIG. 1, an arc chamber is shown generally enclosed by the wall member 2. The gas to be heated is introduced into the chamber through the orifices 4 and 6. The gas, for example, may comprise air, nitrogen or other gas or mixture that is desired to be synthesized. The gas in the chamber then may pass into the arcing area 8. Within the chamber the ring electrodes 10, 12 and 14 are coaxially placed. The middle electrode 12 is of a larger diameter than the end electrodes 10 and 14. Formed between each electrode pair is an arc gap, that is, an arc gap appears between the electrodes 10 and 12, 10 and 14, and 12 and 14. To establish an arc between each pair of electrodes a three-phase alternating current source of electrical potential may be connected to the electrodes 10, 12 and 14. The source of potential, not shown, may be connected through the terminals 16, 18 and 20, which are electrically connected to the electrodes 10, 12 and 14, respectively. The magnitude of the electrical potential applied between each pair of electrodes is such that the electrical arc may be sustained thereacross. Under these conditions, an arc schematically indicated as 22 is established between the electrodes 10 and 12, an arc 24 between the electrodes 10 and 14, and an arc 26 between the electrodes 12 and 14.

The field coils 28 and 30 are disposed coaxially with respect to the ring electrodes 10, 12 and 14, with the field coil 28 being placed outside of the end electrode 10 and the field coil 30 being placed outside of the electrode 14, about the exit nozzle 32. The field coils 28 and 30 are each excited by a direct current potential from external sources as indicated at D1 and D2.

The field coils 28 and 30 produce a magnetic field B which is substantially perpendicular to the arcs produced between the ring electrodes 10, 12 and 14. The arcs 22, 24 and 26 are generally in a state of rotation. However, the arcs are not necessarily rotating in the same meridinal plane. The rotation of the arcs is caused by the $\bar{j}\times\bar{B}$ force produced on the ionized, conducting gas between the electrodes. The arrangement thus shown of the ring electrodes 10, 12 and 14 being excited by a three-phase alternating source and the field coils 28 and 30 being excited with a direct current causes the circumferential component of the $\bar{j}\times\bar{B}$ force to reverse in direction each half-cycle at the frequency of the alternating potential. Since, however, a three-phase arrangement is used with the phases being 120° apart, the $\bar{j}\times\bar{B}$ forces on the individual arcs will be 120° apart. This gives rise to complicated rotational forces being exerted on the ionized gas in the chamber. More uniform heating of the gas results from the slower angular speed of the gas lessening the tendency of the arcs being driven toward the center of the chamber. After heating and with the gas being rotated as described above it is expelled from the arcing area 8 through the exhaust nozzle 32, which is fitted to the wall member 2 of the arc chamber.

Spaced between the electrodes 10 and 12 are the ring-shaped fence members 34 and between the electrodes 12 and 14, the ring-shaped fence members 36. Four such rings are shown between the electrodes 10 and 12 and 12 and 14. The rings have decreasing diameters from the middle electrode 12 to the end electrodes 10 and 14. The fence members 34 and 36 have a two-fold function. First, by providing these members, the arcs will return to the electrodes rather than shooting off to expand the arcing area. The reason for this is that an arc path through the ring-shaped fence members has a high electrical impedance compared to a direct path between the electrodes, the conductive ring-shaped fence members being electrically neutral with respect to the electrodes

and relatively cold by comparison to the electrodes. This high impedance results from the voltage drop occurring at the gas fence member interface in the event an arc should strike through this path, it being known in the art that there is a voltage drop of about 20 volts when an arc strikes a cold metal surface, due to space charge and other effects. Second, the fence rings 34 and 36 constrict the gas flow entering into the arcing area 8 so that the free convection tendency of the hot gas to move outside of this area will be overcome. If there would be an enlargement of the hot gas zone, such increase would magnify the radiation losses and bring about increased cooling problems.

A bluff member 38 is disposed between the electrodes 10 and 12 and is shown affixed to the end rings of the fence members 34. A bluff member 40 is disposed between the ring electrodes 10 and 14 and is shown affixed to the outer rings of the fence members 34 and 36. A cross-sectional view of the bluff member 38 taken along the line of II—II of FIG. 1 is shown in FIG. 2. The bluff member 40 may be of the same shape. Both bluff members are rectangular in shape and have their wide side in the path of incoming gas that is to enter into the arcing area 8. The function of the bluff members 38 and 40 is to eliminate the restriking problem which results from the extinguishment of the arc after zero current. The restriking problem results from the condition that the forces from the convection currents of gas are sufficient to carry the ionized gas away from the arcing area during that part of the voltage cycle in which the arc is normally extinguished. To circumvent this problem, the bluff members 38 and 40 are disposed in the path of the incoming gas. The gas flows around the bluff members and for an appreciable period recirculates downstream of it. In FIG. 2, the stagnant zone is shown in the area 42. During the "on" period of the arc, the rotating arc having passed through the recirculation or stagnant zone has ionized the gas in this zone. Then, during the extinguished or "out" period of the arc, the ionized gas in the particular area of the arcing zone is swept away except for the gas in the stagnant zone. This slow moving ionized gas behind the bluff members remains in the arcing area sufficiently long for the voltage to build up to a value that will permit restriking of the arc through this ionized gas path. By so providing the bluff members a reignition zone is continuously maintained between the electrodes to permit easy restriking after the arc has been extinguished.

A second problem is encountered in many conventional types of arc heating apparatus. This problem evolves from the effect that the hot gas in the arcing area contains a large number of light molecules, such as hydrogen, which transport the thermal energy away from the arcing area during the normally extinguished period of the arc. By losing such thermal energy the breakdown voltage of the gas is greatly increased so to create a restriking problem after the normally extinguished period of the arc. To combat this problem, a slotted tube member 44 is mounted between the electrodes 12 and 14 and is affixed to two rings of the fence member 36. A sectional view of the slotted tube member 44 taken along the line III—III is shown in FIG. 3. As shown in FIG. 3, a circular tube 46 has a slot 48 cut therein along the axis of the tube. The function of the tube member 44 is to confine a zone of ionized gas between the electrodes 12 and 14 so that the light, high speed molecules are incapable of leaving the arcing zone even though the bulk gas speed in that area is relatively low. The slot 48 is cut along the entire length of the tube to allow the restruck arc to move out into the main gas stream during the subsequent part of the arcing cycle. To prevent the arc from striking through and possibly remaining within the slotted tube member 44, it should be of an electrically insulating material. For example, a continuous electrical insulator

or a forced cooled conductor with a thin insulating layer such as aluminum oxide applied thereto, may be used to avert the possibility of the arc remaining within the tube body.

It should be noted that the various bluff members or slotted tube members may be disposed between any pair or between all of the pairs of electrodes of the arc heater apparatus. The mounting structure for placing the various elements of the arc heater within the chamber have been omitted from the drawings in order to facilitate the presentation of the present apparatus, and in that the mounting structure, as such, is not an essential part of the present invention.

Although the present invention has been described with a certain degree of particularity, it should be understood that the present disclosure has been made only by way of example and that numerous changes in the details of construction and the combination and arrangement of parts may be resorted to without departing from the scope and the spirit of the present invention.

I claim as my invention:

1. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, a plurality of ring electrodes disposed coaxially within the chamber and being spaced apart to form at least one arc gap; supply means to apply a source of potential to said electrodes of sufficient magnitude to sustain an arc across said arc gap; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed between said electrodes to define an arcing area, the ring fence members being composed of conductive material and axially spaced from each other, said ring fence members being electrically neutral with respect to the electrodes; magnetic means for providing a magnetic field substantially transverse to the arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

2. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, a plurality of at least three ring electrodes disposed coaxially within the chamber and being spaced apart to form a plurality of arc gaps; supply means to apply a source of three phase potential to said electrodes of sufficient magnitudes to sustain arcs across said gaps; inlet means for admitting a flow of gas into the chamber to be heated; a bluff member disposed between two of said electrodes to deflect said flow of gas as it passes between the last-named two electrodes to form a stagnant zone of ionized gas in the arcing area of the chamber; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

3. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, a plurality of at least three ring electrodes disposed coaxially within the chamber and being spaced apart to form a plurality of arc gaps; supply means to apply a source of three phase potential to said electrodes of sufficient magnitude to sustain arcs across said gaps; inlet means for admitting a flow of gas into the chamber to be heated; a slotted member disposed between at least two of said electrodes so that a zone of ionized gas is confined within said slotted member between said two electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

4. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, a plurality of three ring electrodes disposed coxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes; supply means, to apply a source of potential to said electrodes

of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed coaxially with said electrodes to define an arcing area; a bluff member disposed between one pair of electrodes to deflect said flow of gas as it enters the arcing area to form a stagnant zone of ionized gas in the arcing area; a slotted member disposed between another pair of electrodes so that a zone of ionized gas is confined within said slotted member between said last-named pair of electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

5. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, three ring electrodes disposed coaxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes, the end electrodes of said three ring electrodes being of a smaller diameter than the middle electrode; supply means to apply a source of three phase potential to said electrodes of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed coaxially with said electrodes between said end and said middle electrodes to define an arcing area; a bluff member disposed between at least one pair of electrodes to deflect said flow of gas as it enters the arcing area to form a stagnant zone of ionized gas in the arcing area; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

6. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, three ring electrodes disposed coaxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes, the end electrodes of said three ring electrodes being of a smaller diameter than the middle electrode; supply means to apply a source of three phase potential across said electrodes of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed coaxially with said electrodes between said ends and said middle electrodes to define an arcing area; a slotted member disposed between at least one pair of electrodes so that a zone of ionized gas is confined within said slotted member between the pair of electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrodes for discharging the heated gas from the chamber.

7. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, a middle and two end ring electrodes disposed coaxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes; the end electrode being of a smaller diameter than the middle electrode; supply means to apply a source of three phase potential to said electrodes of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed coaxially with said electrodes between said end and said middle electrodes to define an arcing area, the ring fence members being composed of conductive material and axially spaced from each other, said ring fence members being electrically neutral with respect to the electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means for discharging the heated gas from the chamber.

8. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, at least three ring electrodes disposed coaxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes; supply means to apply a source of three phase potential to said electrodes of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed between said electrodes to define an arcing area; a bluff member disposed between at least one pair of electrodes to deflect said flow of gas as it enters the arcing area to form a stagnant zone of ionized gas in the arcing area; a slotted member disposed between at least one pair of electrodes so that a zone of ionized gas is confined within said slotted member between the pair of electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed for discharging the heated gas from the chamber.

9. An arc chamber apparatus for increasing the enthalpy of a gas, the combination of: means forming an arc chamber, three ring electrodes disposed coaxially within the chamber and being spaced apart to form an arc gap between each pair of electrodes, the end electrodes of said three ring electrodes being of a smaller diameter than the middle electrode; supply means to apply a source of three phase potential to said electrodes of sufficient magnitude to sustain an arc between each pair of electrodes; inlet means for admitting a flow of gas into the chamber to be heated; a plurality of ring fence members disposed coaxially with said electrodes between said end and said middle electrodes to define an arcing area; a bluff member disposed between at least one pair of electrodes to deflect said flow of gas as it enters the arcing area to form a stagnant zone of ionized gas in the arcing area; a slotted member disposed between at least one pair of electrodes so that a zone of ionized gas is confined within said slotted member between the pair of electrodes; magnetic means for providing a magnetic field substantially transverse to each arc; and exhaust means disposed coaxially with said electrode for discharging the heated gas from the chamber.

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