

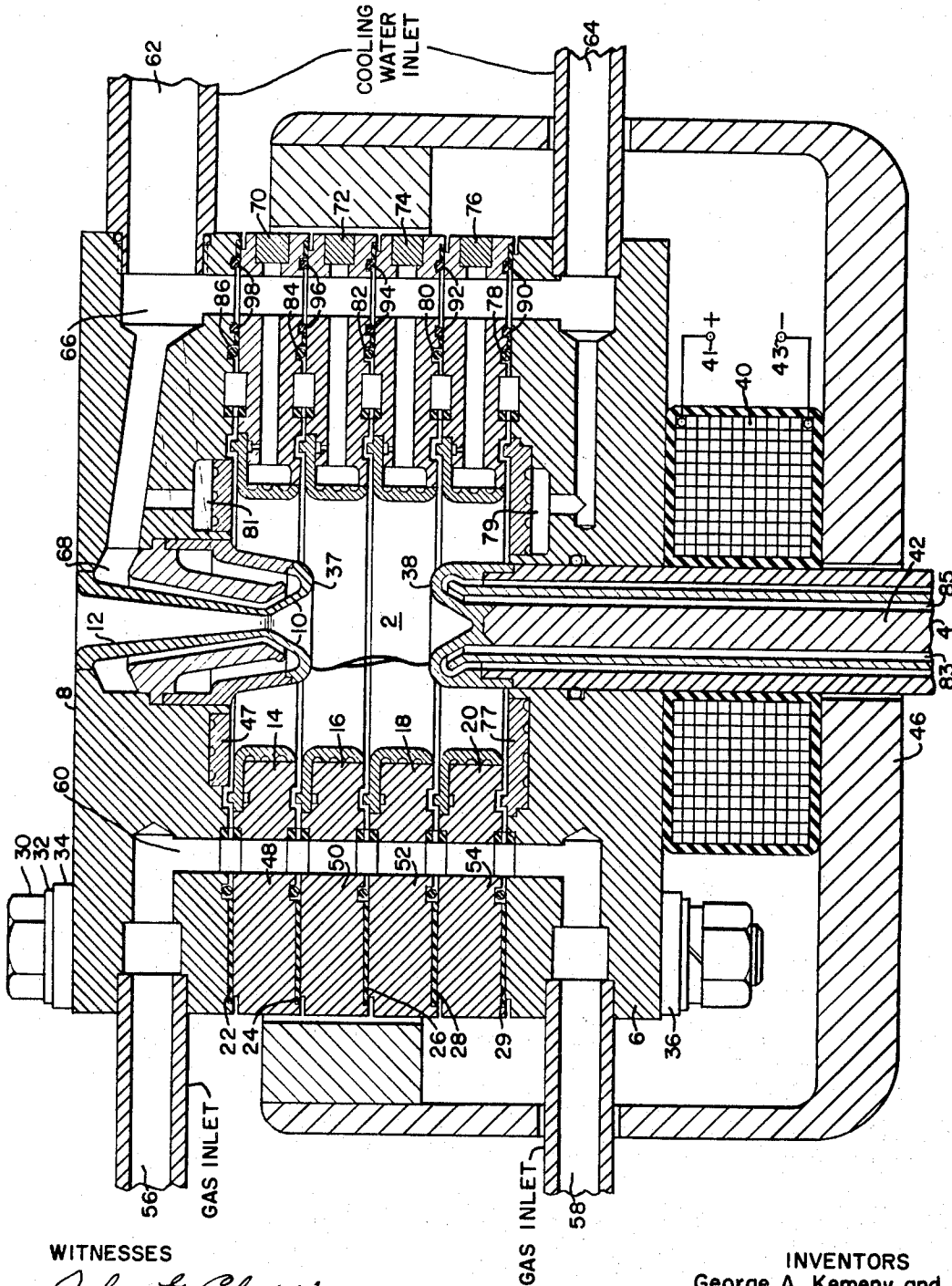
April 23, 1968

G. A. KEMENY ET AL

3,379,908

ARC-HEATER APPARATUS WITH MAGNETIC YOKE

Original Filed Dec. 3, 1962



John L. Clapp
James P. Young

George A. Kemeny and
Charles B. Wolf
BY
Clement L. McHale
ATTORNEY

1

3,379,908

ARC-HEATER APPARATUS WITH
MAGNETIC YOKE

George A. Kemeny, Export, and Charles B. Wolf, Irwin, Pa., assignors to Westinghouse Electric Corporation, Pittsburgh, Pa., a corporation of Pennsylvania
Continuation of application Ser. No. 241,639, Dec. 3, 1962. This application Jan. 13, 1965, Ser. No. 428,599
8 Claims. (Cl. 313-19)

The present invention relates to arc-heater apparatus, and more particularly to arc-heater apparatus for heating gas to extremely high temperatures.

This application is a continuation of Ser. No. 241,639, filed Dec. 3, 1962, and now abandoned, and assigned to the same assignee.

Generally in arc-heater apparatus a gas, whose enthalpy is to be increased, is admitted into an arc-chamber where it is heated and ionized by an electric arc drawn between electrodes. A magnetic field may be applied to cause the electric arc to move through the ionized gas or plasma. For satisfactory operation of such electric arc-heater apparatus certain requirements must be met: The hot gas must be confined in the arc zone at reasonable pressure levels. So that the electrode surfaces will not be damaged, the arc must be caused to move rapidly across the electrode surfaces. The arc under the action of a magnetic field must provide sufficient stirring or rotational action so that the gas issuing from the exit nozzle is of a reasonably uniform temperature distribution. The arc-chamber must be electrically insulated to cause the arc to pass through the gas rather than through any surrounding electrically-conducting structure between the electrodes. Lastly, the arc-heater apparatus must be well cooled by external means so as to permit operation for extended periods of time. If these above requirements can be met satisfactorily, arc-heater apparatus can be provided which may be used for many applications, such as, hypersonic testing, high temperature and high velocity testing, chemical synthesis, and many other applications where a high temperature high velocity gas flow over long periods of time is required.

It is therefore an object of the present invention to provide improved arc-heater apparatus wherein the above requirements for satisfactory operation are met.

It is a further object of the present invention to provide improved arc-heater apparatus, wherein the above requirements are met while further providing: novel means for applying the magnetic field, a structure arranged so that the apparatus may easily be inspected and modified for new applications and an integrated cooling system for the electrode and insulating walls of the assembly.

Broadly, the above-cited objects are accomplished by providing arc-heater apparatus, in which: an incoming gas is heated by an arc drawn between a pair of electrodes in an arc chamber which is formed by the electrodes and pressure rings. A magnetic field is provided substantially transverse to the arc, with a magnetic circuit being provided through the arc heater structure itself to concentrate the magnetic field in the arc zone.

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

The single figure is a sectional side view of the arc-heater apparatus of the present invention.

Referring to the figure, the arc-heater apparatus of the present invention is shown having an arc-chamber 2 wherein a gas may be heated. A movable electrode 4 is placed in the bottom pressure plate 6 so that the movable electrode 4 may move up and down in the arc-chamber 2. A top pressure plate 8 is located above the arc-chamber 2 and has an electrode 10 disposed adjacent to the arc-

2

chamber 2. The top pressure chamber 8 also incorporates the exit nozzle 12 through which hot gasses generated in the chamber 2 may be expelled. Between the top and bottom pressure plates, to completely enclose and seal the arc-chamber 2, are placed pressure rings 14, 16, 18 and 20. Four pressure rings are shown in the present example, however, more or less pressure rings may be used according to the design requirements. The pressure rings 14, 16, 18 and 20 are electrically insulated from each other by thin layers of electrical insulation 22, 24, 26 and 28, which, for example, may comprise fishpaper. The pressure plates and pressure ring structure are mechanically held together by a number of bolts such as 30, which are electrically insulated from the pressure plates and pressure rings through a tube 32 surrounding the bolt body and the washers 34 and 36, all of suitable electrically insulating material.

The arc surface 37 of the electrode 10 and the arc surface 38 of the movable electrode 4 may comprise copper or other electrically conducting material. The surfaces of the pressure rings 14, 16, 18 and 20 exposed to the arc-chamber 2 may each comprise such materials as to act as a good heat transfer path but these surfaces may also be comprised of or covered by electrically insulating material.

A field coil 40 is disposed about the movable electrode 4. The field coil is supplied from external excitation, preferably a unidirectional potential, to the terminals indicated at 41 and 43 to provide a magnetic field in the arc-chamber 2. The bottom portion 42 of the movable electrode 4 is formed from a magnetic material and serves as part of the magnetic circuit of the coil 40.

A yoke member 46, having a cup-shape, is disposed between the movable electrode 4 and the pressure rings 14, 16, 18 and 20. The yoke member 46 is formed from magnetic material to provide a low reluctance magnetic flux path between the movable electrode 4 and the arc-chamber 2. The back portions 48, 50, 52 and 54 of the pressure rings 14, 16, 18 and 20, respectively, may also be formed from magnetic material to reduce the reluctance of the magnetic circuit of the field coil 40. The magnetic circuit of the field coil 40 then includes: the center portion of the movable electrode 42, the yoke member 46 and may include the back portions of some of the pressure rings. The remaining portion of the arc-heater such as the surface 47 of the top pressure plate 8 and the inlet pipes may comprise copper or other material.

The gas that is to be heated is introduced into the arc-chamber 2 through gas inlet pipes 56 and 58. The gas passes through these inlet pipes into the manifold 60 where the gas is then distributed through the spaces between all or some of the pressure rings 14, 16, 18 and 20 into the arc-chamber 2. The gas used may comprise air, nitrogen, hydrogen or any other suitable gas that may be desired for testing or chemical synthesis purposes.

Because of the high temperatures present in the apparatus, it is necessary that cooling be provided for the electrodes, pressure rings and pressure plates. To provide cooling, a fluid such as purified water is admitted through the coolant inlet pipes 62 and 64 into the manifold 66. From the manifold 66, the coolant water is then distributed into the fixed electrode and nozzle structures 10 and 12, through the passage 68 provided therein. The coolant water is also distributed from the manifold 66 into the pressure rings 14, 16, 18 and 20 and then circulated around the pressure rings and expelled through outlet pipes, not shown. The inlets to the pressure rings may be provided by drilling through the pressure rings toward the front area and then sealed with the plugs 70, 72, 74 and 76. The exposed surface 77 of the bottom pressure plate 6 is cooled by cooling water passing through the manifold

79 into the surface area of the bottom pressure plate 6, which may comprise copper or silver, for example. The top pressure plate surface area 47 is cooled by coolant water being provided through the manifold 81. The movable electrode 4 is cooled by passing purified water through the annular passages 83 and 85. Thus, by such a system of cooling water distribution, the entire inner surface area of the arc-chamber 2 is cooled to allow for high arcing temperatures and permit continuous operation of the arc-heater apparatus.

To seal the gas in the arc-chamber 2, the O-rings 78, 80, 82, 84 and 86 are placed between the pressure rings 14, 16, 18 and 20; thus sealing the arc-chamber while also eliminating the necessity for an external pressure vessel to seal the gas within the chamber. This design has the advantages of small size and also eliminates complicated input cooling, gas and electrical apparatus. To seal the coolant fluid from leaking to the outside of the apparatus, the O-rings 90, 92, 94, 96 and 98 are disposed about the manifold 66 so as to prevent such leakage.

A suitable source of potential is provided between the movable electrode 4 and the fixed electrode 10. The pressure plate 8 would usually be at ground or zero potential so that other equipment may be affixed to the pressure plate at the nozzle area. An arc may be struck between the fixed electrode 10 and the movable electrode 4 by moving the movable electrode 4 up into the arc-chamber 2 into close proximity to the fixed electrode 10. An arc may also be struck by placing a fusible member between the electrode surfaces 37 and 38 which will disintegrate upon the application of an electrical potential, thereacross. With an arc between the electrodes, the gas introduced from the gas inlet pipes 56 and 58 through the pressure rings into the arc-chamber 2 will be heated into an ionized plasma state. The pressure rings 14, 16, 18 and 20 serve as the wall for the arc-chamber and for removing heat radiated or convected from the hot interior of the arc-chamber. Moreover, the particular design of the plurality of pressure rings serves to implement the equal division of voltage across the several insulators. Therefore, the possibility of an alternate current path being established between the electrodes is reduced, and so avoiding arcing between the pressure rings and possible damage to the apparatus. The gas sealing O-rings 78, 80, 82, 84 and 86 are protected from line of sight radiation from the arc-chamber 2 by optical baffling. Each of the pressure rings, as described above, is cooled by passing a fluid therethrough which passes around the arc-chamber circumferentially and then is removed through outlet passages, not shown. Another advantage of using a plurality of pressure rings to form the arc-chamber is that the size or capacity of the arc-chamber may readily be changed by either adding new pressure rings or taking pressure rings from the structure.

The heated gas in the chamber is given a rotational motion by the interaction of the arc and the magnetic field supplied by the field coil 40. The field supplied is substantially transverse to the arc between the electrodes 4 and 10. Pressure in the arc chamber forces the heated gas into the exit nozzle 12 where its velocity is increased by a suitable configuration of the nozzle 12 adjacent the chamber and expelled therethrough. By using the magnetic circuit comprising the movable electrode 4 of a magnetic material, the magnetic yoke member 46 and the pressure rings of a magnetic material, except for the surface areas, the magnetic field in the arc-chamber 2 is concentrated in the arc-chamber, thus decreasing the amount of electrical energy that must be supplied to the field coil 40. Moreover, through the use of the magnetic circuit, as shown, the field coil can advantageously be placed outside of the high temperature areas of the arc-heater apparatus. If it is desired, to aid in providing the rotational motion to the electric arc, the gas may be produced tangentially at the periphery of the chamber so that an additional moment will be added to the gas. It is

also possible and may be desirable to admit gas tangentially in a direction opposite to the direction of rotation of the arc so as to improve mixing.

It can thus be seen from the above description that the configuration of the arc-chamber of the present invention provides many advantages besides meeting the necessary requirements, as set forth above, for high temperature gas arc-heaters. Among these advantages are: The movable electrode may be removed for easy inspection of the interior parts. The combination of field coil and the closed loop magnetic circuit provides an easy means for providing the radial magnetic field necessary to induce rotational motion of the arc. The coolant manifold passages are completely contained in the pressure plates and rings, and by using high purity water as the coolant, the water forms a high resistance path between the various components to minimize the possibility of arcing between the components of the apparatus by equalizing the voltage gradient between the components. For ease of construction, the top pressure plate electrode and exit nozzle are embodied in one structural member. And moreover, the modular structure of pressure plates and pressure rings allows a simplified procedure for assembly and modification of the unit.

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.

We claim as our invention:

1. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a first electrode; a second electrode comprising a magnetic material spaced from and substantially aligned with the first electrode whereby an arc path substantially parallel to the axes of the first and second electrodes is formed between the first and second electrodes; means including a plurality of substantially axially aligned pressure rings disposed between said first and second electrodes to form an arc chamber, the inner diameter of the rings being greater than the outer diameters of the first and second electrodes; gas inlet means for admitting gas into said arc chamber; means for sustaining an arc between said first and second electrodes within said arc chamber; and a magnetic circuit including said second electrode, a yoke comprising a magnetic material extending from said second electrode to the outer peripheries of said pressure rings, and magnetic field producing means at a preselected position in the magnetic circuit to provide a magnetic field in said arc chamber, the magnetic lines of force extending from the yoke surface adjacent the pressure rings to the adjacent surface of the second electrode thereby producing a magnetic field substantially transverse to the arc between said electrodes.

2. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a fixed electrode; a movable electrode comprising a magnetic material; a plurality of pressure rings comprising a magnetic material disposed between said electrodes to form an arc chamber; gas inlet means for admitting gas into said arc chamber; electric means for sustaining an arc between said electrodes within said arc chamber; and a magnetic circuit including said movable electrode, said pressure rings, a yoke comprising a magnetic material extending from said movable electrode to the outer periphery of said pressure rings, and a magnetic coil disposed about said movable electrode to provide a magnetic field in said arc chamber substantially transverse to the arc between said electrodes.

3. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a first electrode; an exit nozzle; a second electrode comprising a magnetic material spaced from the first electrode whereby an arc path is

5

formed between the first and second electrodes; a plurality of pressure rings disposed between said first and second electrodes to form an arc chamber; gas inlet means for admitting gas into said arc chamber; electric means to sustain an arc between said first and second electrodes within said arc chamber and ionize the gas therein; a magnetic circuit including said second electrode, a yoke comprising a magnetic material extending from said second electrode to the outer periphery of said pressure rings, and magnetic field producing means at a preselected position in the magnetic circuit to provide a magnetic field in said arc chamber substantially transverse to the arc between said first and second electrodes; and coolant means to provide a flow of coolant fluid to said pressure rings and said electrodes.

4. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a fixed electrode including an exit nozzle; a movable electrode comprising a magnetic material; a plurality of pressure rings comprising a magnetic material disposed between said electrodes to form an arc chamber, said pressure rings being electrically insulated from each other; gas inlet means for admitting gas into said arc chamber; electric means for sustaining an arc between said electrodes within said arc chamber and ionizing the gas therein; a yoke comprising a magnetic material extending from said movable electrode to the outer periphery of said pressure rings; and a magnetic coil disposed about said movable electrode to provide a magnetic field in said arc chamber substantially perpendicular to the arc established between said electrodes.

5. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a first electrode including an exit nozzle; a second electrode comprising a magnetic material; a plurality of pressure rings disposed between said electrodes to form an arc chamber; gas inlet means to supply a flow of gas into said arc chamber; electric means to sustain an arc between said electrodes within said arc chamber and ionize the gas therein; a magnetic circuit including said second electrode, a yoke comprising a magnetic material extending from said second electrode to the outer periphery of said pressure rings; and a magnetic coil disposed about said second electrode to provide a magnetic field in said arc chamber substantially perpendicular to the arc between said electrodes, and coolant means to provide a flow of coolant fluid to said pressure rings and said electrodes.

6. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a fixed electrode including an exit nozzle; a movable electrode which may be moved toward said fixed electrode, said movable electrode comprising a magnetic material; a plurality of pressure rings comprising a magnetic material disposed between said electrodes to form an arc chamber, said pressure rings being electrically insulated from each other; gas inlet means to supply a flow of gas into said arc chamber; electric means to provide an electrical potential to establish an arc between said electrodes within said arc chamber and ionize the gas therein; a magnetic cir-

6

cuit including said movable electrode, said pressure rings, a yoke comprising magnetic material extending from said movable electrode to the outer periphery of said pressure rings, and a magnetic coil disposed about said movable electrode to provide a magnetic field in said arc chamber substantially perpendicular to the arc established between said electrodes.

7. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a first electrode; a first pressure plate disposed about said first electrode; a movable electrode comprising a magnetic material; a second pressure plate disposed about said movable electrode; a plurality of pressure rings composed of a magnetic material disposed between said electrodes to form an arc chamber, said pressure plates and said pressure rings including first and second manifolding means integrally disposed therein; gas inlet means to supply a flow of gas into said arc chamber through the first manifolding means of said pressure rings; electric means to provide an electrical potential to establish an arc between said electrodes within said arc chamber and ionize the gas therein; coolant means to supply a coolant fluid through the second manifolding means of said pressure rings and plates adjacent arc chamber; a magnetic circuit including said movable electrode, said pressure rings, a yoke comprising magnetic material extending from said movable electrode to the outer periphery of said pressure rings, and a magnetic coil disposed about said movable electrode to provide a magnetic field in said arc chamber substantially perpendicular to the arc established between said electrodes.

8. In arc-heating apparatus for increasing the enthalpy of a gas, the combination of: a fixed electrode; a movable electrode comprising a magnetic material; a plurality of pressure rings comprising a magnetic material disposed between said electrodes to form an arc chamber, said movable electrode being readily removable from said arc chamber; gas inlet means to supply a flow of gas into said arc chamber; electric means to provide an electrical potential to establish an arc between said electrodes within said arc chamber and ionize the gas therein; a magnetic circuit including said movable electrode, said pressure rings, a yoke comprising magnetic material extending from said movable electrode to the outer periphery of said pressure rings, and a magnetic coil disposed about said movable electrode to provide a magnetic field in said arc chamber substantially perpendicular to the arc established between said electrodes; and coolant means to provide a flow of coolant fluid to aid pressure rings and said electrodes.

References Cited

UNITED STATES PATENTS

2,031,435	2/1936	Thompson	313—156 X
2,411,893	12/1946	Peters	219—123 X
3,048,736	8/1962	Emmerick	313—161

DAVID J. GALVIN, *Primary Examiner.*