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3,129,351

MULTIELECTRODE ARC ASSEMBLY

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Fig 1

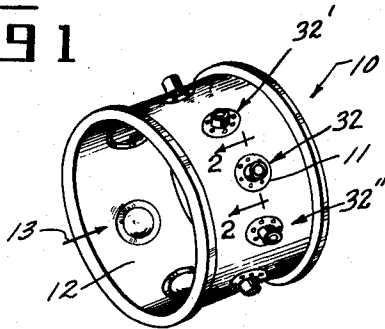


Fig 2

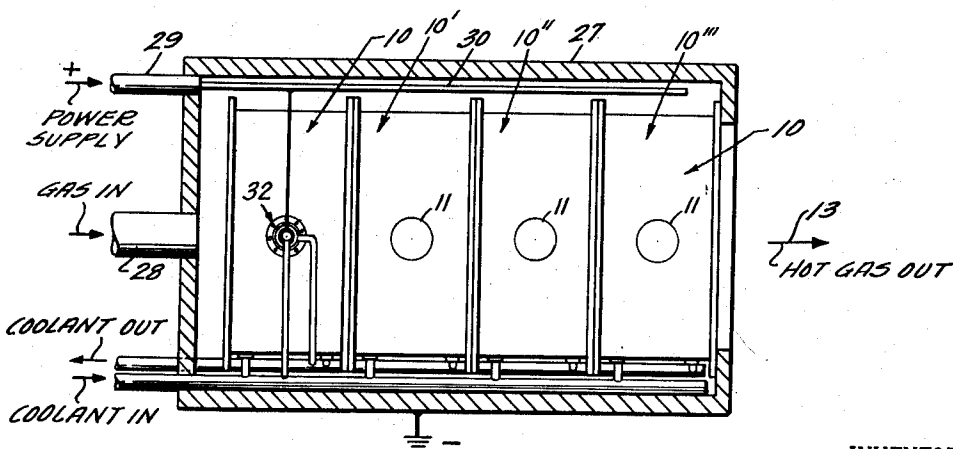
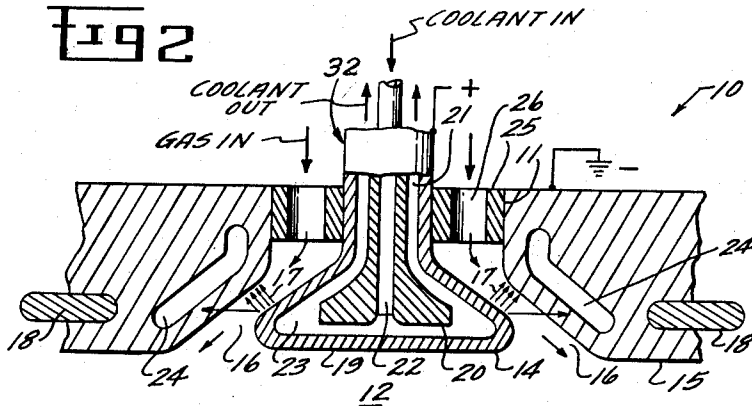


Fig 3

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MULTIELECTRODE ARC ASSEMBLY

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The present invention relates to a multielectrode arc assembly and, more particularly, to such an assembly for the generation of high temperature high pressure gases which may be conveniently ganged for high power requirements.

High temperature arc generators are required in present day technology to create very hot fluids for various purposes such as simulating re-entry conditions of space vehicles. Such generators are known and are in applications and in development fields where high temperature fluids are required for different areas of investigation such as material development. Numerous problems are encountered in the use of such arcs including difficulty of obtaining sufficient power and maintaining the parts cool to avoid melting since extremely high temperatures are involved. Powers over one megawatt are difficult to obtain with a single pair of electrodes because the heat flux into the electrodes due to the electrical discharge not only heats the gas passing through the discharge but also heats the electrodes and the more current that is supplied to create more energy reaches an upper limit at which the electrodes melt to destroy the function of the device as well as contaminate the fluid which is being heated. This is especially true in high pressure arcs operating well above atmospheric pressure and at which the arc tends to contract with corresponding increase in current density. The heat flux from the arc to the electrodes at high current densities is such as to melt or destroy electrodes irrespective of the materials from which the electrodes are made unless the electrodes are cooled and the heat flux is substantially uniformly distributed over a large area of the electrodes. One means of overcoming such objections has been to provide rotating arcs whereby the arcs do not dwell at any point on the electrodes sufficiently long for the heat to melt the electrodes. Thus, it is known to avoid stagnating the arc on the electrodes by moving it rapidly across or around the electrodes and this is accomplished by introducing the gas to be heated in a swirl tending to rotate the arc and to apply a magnetic field across the arc to create a force at right angles to the arc and to rotate it. However, again limits have been reached where this alone is insufficient to provide the necessary heated gas because of the present need for higher power.

One way to provide higher power and thus higher temperatures and pressures is to add more of the same. That is, the use of a plurality of electric arcs discharging into a common plenum chamber is known. This arrangement consists of a plurality of plasma generators or arc units usually arranged around a common plenum chamber and discharging into the plenum chamber. The difficulty with such an arrangement of multiple units with a common manifold is in the reliability and efficiency of the device. In the first place, the device is extremely bulky and complicated and quite large. While each generator itself has a fairly high reliability—up to 90 percent—the total reliability of the ganged device is a product of the number of devices used times the reliability of each device. Thus, if four generators are used it can be seen that the reliability may be only 60 percent. Secondly, the efficiency of such a ganged arrangement is low because each unit is quite large and there are large areas to absorb the radiation from the arc and remove heat to reduce efficiency. Also, it is difficult to provide two arcs that are exactly the same resulting in different temperature gas streams from each unit. The overall efficiency of such a ganged unit is thus

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low compared to the efficiency of each unit separately. Because of the inability to create exactly the same arcs there is constant danger of one or more of the arcs extinguishing itself and it is very difficult to reignite the arcs as they are not self-igniting. Thus, the difficulty of the ganged individual units discharging into a common plenum chamber is low efficiency and low reliability but the ganged arrangement is required for the higher power output necessary.

The main object of the present invention is to provide a multielectrode arc assembly, as opposed to a multi-unit assembly, whereby any power requirements may be obtained by ganging a number of individual electrode units and which assembly is operable at high temperatures and high pressures.

Another object is to provide such an assembly which has smaller areas to cool to result in higher efficiency of the assembly.

A further arrangement is to provide such an assembly which is self-igniting if one of the units is extinguished to increase the reliability and simplify the starting procedure.

A further object is to provide an assembly wherein additional units may be ganged for higher power requirements and the ganged arrangement may be housed in a pressure chamber that is removed from the high temperatures and can be made of available material consistent with its strength requirements.

Briefly stated, the invention provides a multielectrode assembly which uses a cylindrical segment or member as a single electrode, the inner part of the cylinder forming a plenum chamber. Peripherally spaced around the cylinder a number of radially directed apertures are disposed through the cylinder and a central electrode is directed through each aperture to the inner surface of the cylinder. Each central electrode and the cylindrical segment electrode provide a single arc unit or pair of electrodes. The cylindrical segment electrode is therefore common to all the arc units that are formed by each of the radially directed central electrodes. A rotating arc is created at each central electrode by a conventional power source and a magnetic field at each central electrode induces rotation. The heated fluid is then withdrawn axially from the cylinder end of the common cylindrical segment electrode. For higher power requirements any number of the cylindrical segment electrodes may be ganged. Each cylindrical electrode or the ganged arrangement is surrounded by a spaced pressure container through which the fluid to be heated may be inserted to provide a common manifold feed for each individual unit or pair of electrodes as well as a common electrical power feed.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which I regard as my invention, it is believed the invention will be better understood from the following description taken in connection with the accompanying drawing in which:

FIGURE 1 is a perspective view of an individual cylindrical segment electrode;

FIGURE 2 is a partial cross-sectional view through line 2-2 of FIGURE 1 illustrating the details of a single arc unit; and,

FIGURE 3 is a partial cross-sectional view showing the ganged cylindrical electrode arrangement with the pressure chamber.

Referring first to FIGURE 1, there is shown the cylindrical segment electrode 10 which, for convenience, may be thought of as the negative terminal and is adapted for connection to a typical power source such as a D.C. supply by means not shown. The power source and usual electrical connections are conventional and form no part of the present invention so, for purposes of illustration, it will be assumed that suitable leads may be supplied

to provide power to the electrodes for generating an arc. The invention lies in the structural, as opposed to the electrical arrangement. In order to provide individual arc units, a plurality of radially directed apertures 11 are provided on the cylinder surface and peripherally spaced around the surface. These apertures may be equally spaced and any number may be provided depending on the power requirements of the application for which the design is intended. It is intended that fluid shall be heated to a high temperature for use elsewhere and, for descriptive purposes, air will be discussed although the invention is applicable to any fluid to be heated. The fluid to be heated is directed through apertures 26 in the insulating means 25, which mount central electrode 14 in the aperture 11 of the cylinder electrode 10, to the interior of cylinder 10. The interior of electrode 10 defines a plenum chamber 12 as shown in FIGURE 2. The heated fluid thereafter flows from the plenum chamber 12 in the direction indicated by arrow 13 in FIGURES 1 and 3.

An individual arc unit 32 is shown in detail in FIGURE 2. In FIGURE 2 aperture 11 is shown through cylindrical segment electrode 10. In order to produce an arc 17 between arc unit 32, and electrode 10 as shown in FIGURE 1, a central electrode 14 is provided in the aperture and is spaced from and extends through the aperture as shown. This central electrode may conveniently be made the positive electrode. Preferably electrode 14 will extend as shown to the inner surface 15 of the cylindrical segment electrode 10 to define an annulus 16 in which an arc 17 rotates after being struck between the electrodes 14 and 15. Rotation may be obtained by having annulus 16 direct the incoming air for entry into chamber 12 in a tangential or swirl direction by suitable vanes not shown. In addition, rotation is also obtained by imposing a magnetic field on the arc. This is obtained by providing magnets 18 in the cylinder 10 around the aperture to provide one pole of the magnetic field. Magnets 18 may be permanent magnets or electromagnets excited by an outside source or by the current in the arc itself by conventional means.

For cooling purposes, the central electrode 14 is made hollow and is formed to provide a mushroom head 19 to ensure entry of the heated fluid in a cone pattern for a purpose to be explained. The other pole of the magnetic field imposed upon the arc is provided by a second magnet 20 which is an inner magnet disposed within hollow electrode 14 concentric therewith and spaced from the inner surface of electrode 14 to provide a coolant duct 21 between the magnet and central electrode. For a complete coolant path magnet 20 is provided with a passage 22 therein which cooperates with duct 21 by virtue of the spaced relationship to permit entry and exit of a cooling fluid for cooling electrode 14. The shape of the magnet 20 and the shape of the inner wall of the central electrode 14 are such that they ensure uniform distribution of the coolant flow through the annular space formed by them and, in addition, their relative shape is such as to ensure highest velocities of the coolant in the areas 23 of the discharge for high rate of heat removal. The other side of the arc may be cooled by a suitable cooling passage 24 in the segmented cylindrical electrode 15. The support and spacing of the central electrode 14 is obtained by insulating means 25 between the two electrodes. Incoming air to be heated is directed into the annulus by openings 26 through insulating means 25. Openings 26 may be canted to provide an initial swirl or to provide the complete swirl desired.

Other arc units substantially like unit 32 may be mounted in electrode 10 as shown in FIGURE 1. Of course, any number around the periphery may be used. It will be appreciated that this multielectrode assembly thus utilizes a single common electrode 10 with any desired plurality of additional arc units 32, 32', 32'', etc.

Reignition may be a problem upon extinguishment of an individual arc unit. The shape of the annulus 16 is

such as to direct high temperature gas from unit 32 toward an adjacent unit such as unit 32'. Thus, if arc unit 32' in FIGURE 1 is extinguished, the ionized gas from unit 32 will flow sufficiently close to unit 32' to re-establish an arc between the central electrode 14' of arc unit 32' and the cylindrical electrode 10. This is assisted by the electrical circuit normally employed in high temperature arcs wherein the voltage drop between the electrodes of an extinguished arc is higher than that of an arc operating so that there is a further tendency to reignite the extinguished arc in the arrangement shown by reason of the orientation of the annulus 16.

The multielectrode arc assembly just described provides a reliable and efficient generation of high temperature air with a given power input. Additional power input may be provided by the arrangement about to be described. It can be seen that the individual segmented cylindrical electrode 10 will be at very high temperature because of the high temperature gas in the plenum chamber therein. Consequently, difficulties are encountered in the use of materials that do not break down at such high temperatures. This is overcome in the instant invention as shown in FIGURE 3. In FIGURE 3, a pressure chamber 27 surrounds and is spaced from each segmented electrode 10, 10', 10'', 10''' and, for additional power, the segmented electrodes 10, 10', 10'', 10''' may be axially stacked as shown and secured to one another. By making electrodes 10, 10', 10'', 10''' the negative terminal it is not necessary to insulate between segments since they are all of the same polarity and the segments 10, 10', 10'', 10''' may merely be secured together in any suitable manner. The fluid to be heated can then enter all of the individual arc units by a single fluid inlet 28 in the pressure chamber from which the fluid may then flow through each arc unit as shown in FIGURE 3 to ensure uniform flow of fluid. In addition, the fluid, by filling the space between the pressure chamber 27 and the individual units 10 acts as a thermal insulation between the two members so that pressure chamber 27 may be kept relatively cool thus avoiding its structural weakening if subjected to direct contact with the heated gas. In addition, this arrangement permits the segmented electrodes 10, 10', 10'', 10''' exposed to very high temperatures, to be pressure balanced since the pressures of the oncoming cool fluid in chamber 27 and the pressure of the heated fluid in plenum chamber 12 defined by the interior of the cylindrical electrodes 10, 10', 10'', 10''' are nearly equal so that the whole unit may be operated under higher pressure output within plenum chamber 12. The electrical connections for the stacked arrangement using pressure chamber 27 also permits the use of a single electric inlet 29 feeding a common bus bar 30 from which suitable connections to the individual central electrodes 14 of the arc units may be made. The coolant for the electrodes 14 and ducts and passages 21-24 can be supplied from a common manifold in the pressure chamber having suitable inlets and outlets and piping to each arc unit (one of which is shown).

The multielectrode assembly just described, as opposed to a multi-unit assembly, thus permits higher temperatures and higher pressures in a stacked relation to obtain any power desired. Reignition is ensured and cooling is ensured in the critical areas while at the same time divorcing the stress problem by using the pressure chamber surrounding the electrode segments and maintaining the chamber cool by using the space between the pressure chamber and the electrodes as a plenum chamber of the gas to be heated. This results in uniform pressure between the pressure chamber and the individual electrode segments for uniform gas entry through the individual arc units.

While I have hereinbefore described a preferred form of my invention, obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood

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that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

I claim:

1. A multielectrode arc assembly comprising;
a cylindrical segment electrode,
said cylinder forming a plenum chamber therein and,
having a plurality of radially directed apertures through
the cylinder and peripherally spaced around the
cylinder,
a plurality of central electrodes spaced from and extending one through each aperture to the inner cylinder surface to form a single arc unit,
magnetic means in the cylinder around each aperture to provide a rotating arc between each central electrode and said cylindrical electrode,
and means to direct fluid to be heated through the space between the electrodes in each unit,
and passage means through which said heated fluid may exit through one end of the cylinder forming a plenum chamber.
2. Apparatus as described in claim 1 having;
a pressure chamber surrounding and spaced from said cylindrical electrode and supporting it therein and having,
fluid and electric power inlets to the space between the chamber and cylindrical electrode to supply each individual arc unit.
3. Apparatus as described in claim 1 wherein said apertures are;
equally spaced around the cylinder periphery and,
the central electrodes are hollow and have a magnet therein cooperating with said magnetic means in the cylinder.
4. Apparatus as described in claim 2 having;
a plurality of segmented cylindrical electrodes axially stacked and secured to each other and,
said pressure chamber surrounds all said stacked segments.
5. A multielectrode arc assembly comprising;
a cylindrical segment electrode,
said cylinder forming a plenum chamber therein and,
having a plurality of radially directed apertures through
the cylinder and equally spaced around the cylinder,
a plurality of hollow central electrodes spaced from
and extending one through each aperture to the inner
cylinder surface to form a single arc unit having an
annulus between the electrodes,
magnet means disposed concentrically within and
spaced from said hollow central electrode to define
a coolant duct therebetween,
magnet means in the cylinder around each aperture to

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- provide a rotating arc in the annulus between the electrodes,
insulating means between the cylindrical electrode and central electrode having openings therein to direct fluid to be heated through said arc to the plenum chamber,
and passage means in the plenum chamber through which said heated fluid may flow from said plenum chamber.
6. Apparatus as described in claim 5 wherein the annulus between the electrodes in each arc unit is;
oriented to direct the heated fluid into said plenum chamber in a cone.
 7. Apparatus as described in claim 6 having;
a plurality of segmented cylindrical electrodes axially stacked and secured to each other,
a pressure chamber surrounding and spaced from said segment electrodes and supporting them therein,
said pressure chamber having fluid and electric power inlets to the space between the chamber and segments to supply each individual arc unit.
 8. An arc unit in a multielectrode assembly having;
a cylindrical segment electrode with a plenum chamber therein,
said unit comprising a radially directed aperture through said segment electrode,
a hollow central electrode spaced from and extending through said aperture to a mushroom head at the inner cylindrical surface to form a directed annulus between said electrodes,
magnet means in said segment electrode around the aperture,
a magnet with a passage therethrough,
said magnet disposed concentrically within and spaced from said central electrode to define a coolant duct through said passage and space between said electrode and magnet,
the magnetic field established by said magnet and said magnet means in the space between the central electrode and the cylindrical segment electrode reacting with an arc between the segment electrode and the central electrode to cause said arc to rotate around said hollow central electrode,
insulating supporting means between the cylindrical electrode and central electrode and having openings therethrough to direct fluid to be heated through said arc and directed annulus into said plenum chamber in a cone,
passage means through which fluid within the plenum chamber flows therefrom.

No references cited.