United States Patent [19]

De Corso

[11] **3,891,828**

[45] **June 24, 1975**

[54] **GRAPHITE-LINED INERT GAS ARC HEATER**

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[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

[22] Filed: **Oct. 18, 1973**

[21] Appl. No.: **407,724**

[52] **U.S. Cl.** ..... **219/383;** 219/123; 13/11; 117/226; 117/46 FC; 315/111; 313/231

[51] **Int. Cl.** **H05b 7/18**

[58] **Field of Search** ..... 219/123, 383; 29/259.5; 313/44, 46, 231; 315/111; 13/9, 11, 20, 22, 31; 117/46 R, 46 FC, 226

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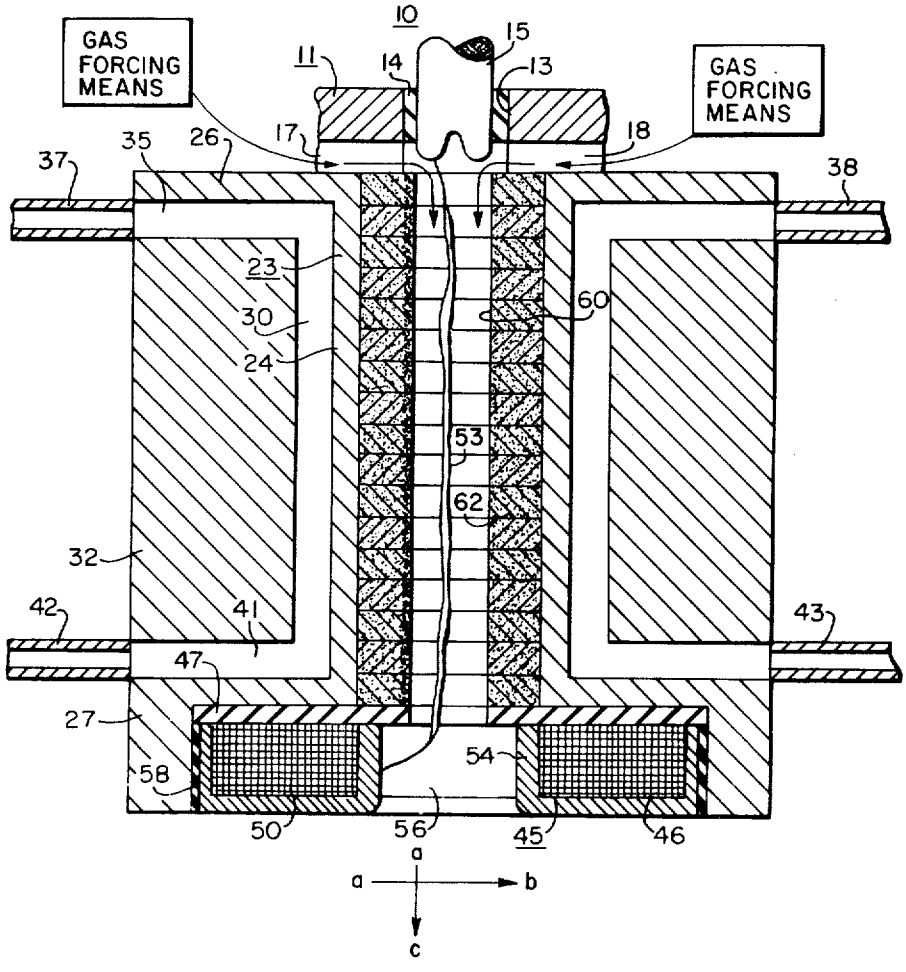
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[57] **ABSTRACT**

An arc heater has a pair of spaced electrodes at the ends of a cooled copper cylinder with means for admitting an inert gas to be heated at one end of the cylinder and a gas exhaust at the other end of the cylinder. The inside wall of the cooled copper cylinder is lined with pyrolytic graphite either in the form of a cylinder or a series of closely stacked discs. The anisotropic structure of pyrolytic graphite results in high thermal conductivity in the direction radial to the axis of the cylinder and a very low thermal conductivity in a direction parallel to the axis of the cylinder. On the other hand, the electrical resistance of the pyrolitic graphite in the latter direction is quite high, being of the order of 0.2 ohms per inch whereas the electrical resistance of the graphite in the radial direction is very low, being of the order of 1.8×10^{-4} ohms per inch. Accordingly, the pyrolytic graphite lined cylinder offers substantial electrical resistance in the direction of the arc between the two electrodes with a small resistance loss through the graphite in that direction.

13 Claims, 4 Drawing Figures



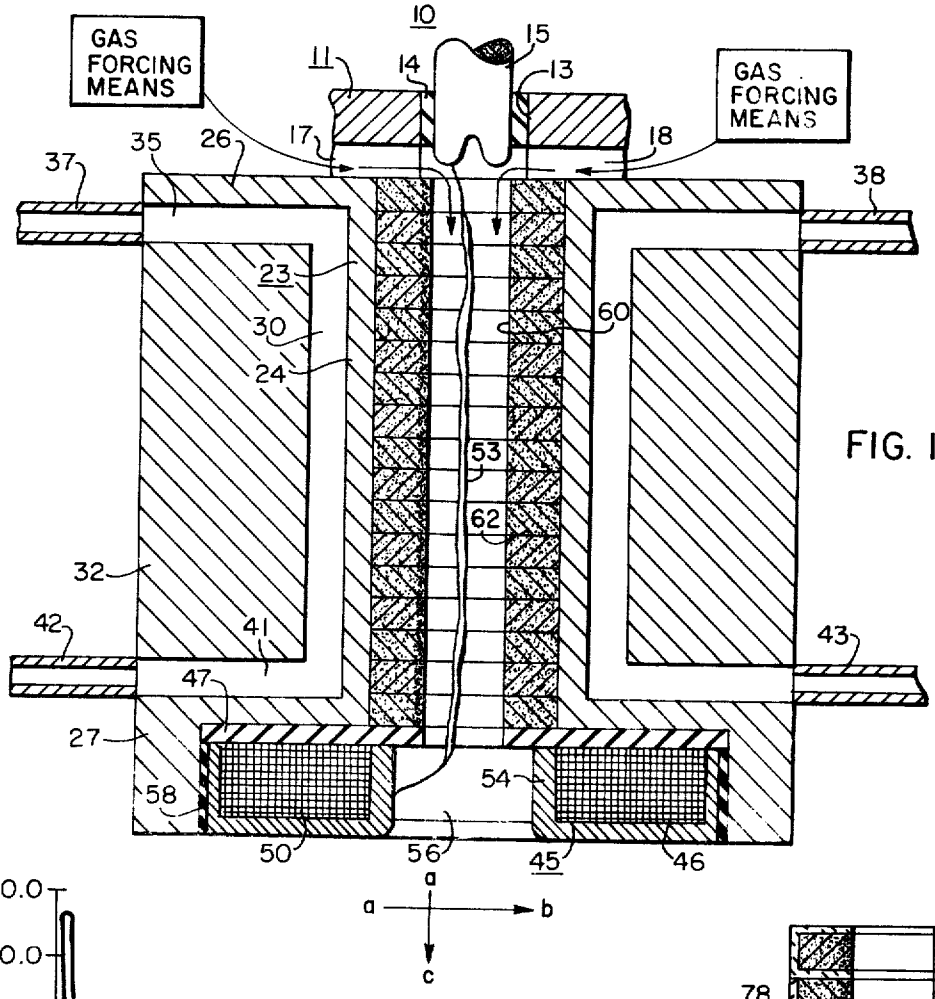


FIG. 1

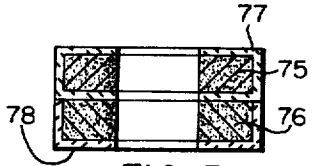


FIG. 3

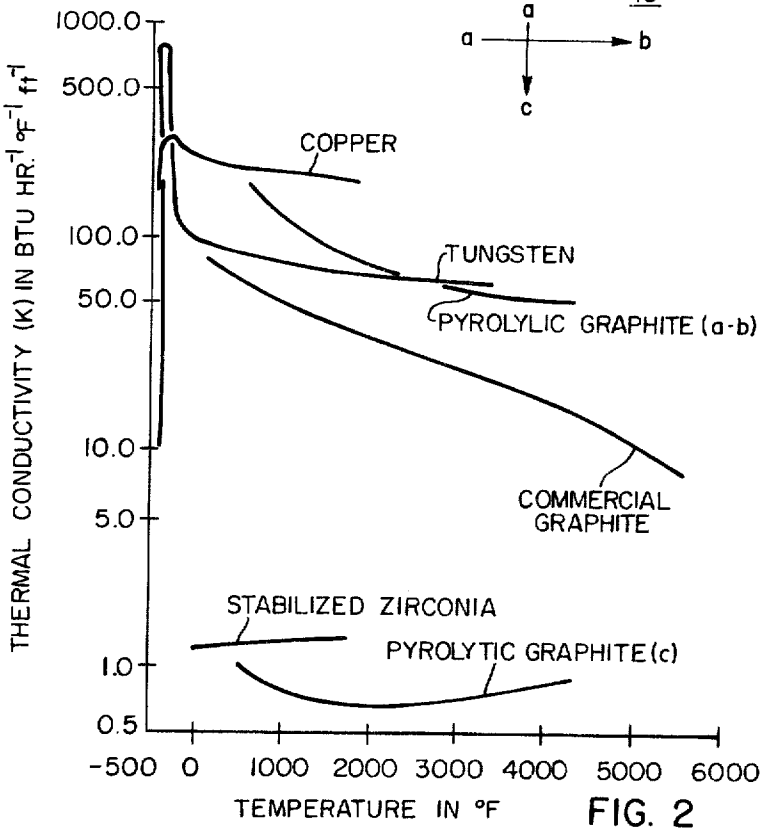


FIG. 2

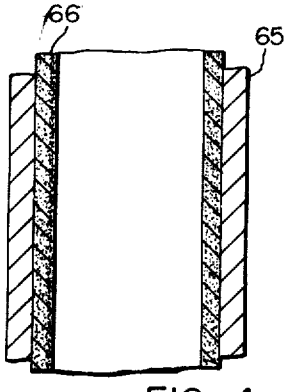


FIG. 4

GRAPHITE-LINED INERT GAS ARC HEATER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention pertains to gas arc heaters. My improvement comprises utilizing a cooled copper cylinder to form an arc chamber and lining the inner wall of the copper cylinder with pyrolytic graphite in the form of stacked discs or a cylinder. The pyrolytic graphite having high thermal conductivity and conducting the heat by radiation and convection in the arc chamber to the adjacent wall of the cooled copper cylinder while at the same time dividing a path for electric current through the graphite in a direction parallel to the arc between spaced electrodes at the end of the cylinder which is large compared to the resistance of the arc path itself.

2. Description of the Prior Art

The prior art appears not to have gone beyond the use of a graphite cylinder to provide a heat shield as exemplified in U.S. Pat. No. 2,964,678 for "Arc Plasma Generator" and U.S. Pat. No. 2,964,679 to H. M. Schneider et al for "Arc Plasma Generator." My invention, on the other hand, makes use of the thermal conductivity of graphite or pyrolitic graphite to conduct heat of radiation and convection within the arc chamber to the wall of a fluid cooled copper cylinder, and furthermore, my invention makes use of the electrical properties of graphite to insure a high resistance path in a direction parallel to the axis of the copper cylinder and high resistance compared to the resistance of the arc path.

SUMMARY OF THE INVENTION

I employ a fluid cooled metallic cylinder preferably of copper as a means for forming an arc chamber and a constricted passageway. In one embodiment the inside wall of the cylinder is lined with pyrolytic graphite which may be either a cylinder or stacked discs providing high thermal conductivity of heat in the arc chamber to the copper cylinder and providing a high resistance path in a direction parallel to the longitudinal axis of the cylinder and parallel to the arc path. I may use ordinary graphite, preferably in the form of stacked discs in some applications. In another embodiment, I coat the stacked discs with a thin refractory coating.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention, reference may be had to the preferred embodiments exemplary of the invention shown in the accompanying drawings in which:

FIG. 1 is an arc heater according to the preferred embodiment of my invention;

FIG. 2 is a graph illustrating the operation of the apparatus of FIG. 1;

FIG. 3 is an arc heater according to FIG. 1 in which a coating is used on the stacked discs shown therein; and

FIG. 4 shows an arc heater similar to the one shown in FIG. 1, but where the graphite linear comprises a continuous coating.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and FIG. 1 in particular, an arc heater **10** is shown having an upper wall **11**. The wall has an opening or a passageway **13** therethrough in which is disposed a bushing **14** composed of electrically insulating material through which extends the upstream electrode **15**. The electrode **15** may be an electrode comprised of carbon or graphite; it may also be an electrode of the type which has a fluid cooled arcing surface with a field coil disposed within the electrode to set up a magnetic field which causes the arc to rotate substantially continuously around the arcing surface to prevent a burn-through in which case the electrode tip would be composed of copper or other metal having high thermal conductivity. Gas is admitted to the arc chamber through a plurality of peripherally spaced passageways near the arcing tip of the upstream electrode, two of these passageways being shown at **17** and **18**. Other means for admitting gas to the arc chamber near the upstream electrode **15** may also be provided.

Gas admitted to the chamber provides an inert or non-oxidizing atmosphere to prevent deterioration or destruction of the graphite lining to be described.

The fluid cooled copper cylinder is generally designated **23** and has a cylindrical portion **24** and may include an upstream flange portion **26** and a downstream flange portion **27** extending perpendicular to the longitudinal axis of the cylinder. These flange portions **26** and **27** may be integral with the chamber wall **24**; or the chamber wall **24**, the cylindrical flanges **26** and **27** and a downstream electrode **45** may be clamped together with insulation **47** between the downstream electrode **45** and the copper cylinder **23** to provide for maintaining the various parts of the arc heater in position. One passageway for the flow of cooling fluid is shown at **30**. This passageway **30** may be a cylindrical passageway as shown formed by securing an additional arc chamber wall portion **32** at a spaced distance from the outside wall of the copper cylinder **23** and at spaced distances from the inner walls of the flange portions **26** and **27**. If desired, the passageway **30** may consist of a large number of bores extending the length of the constrictor copper cylinder **23**, the bores being at closely spaced intervals around the entire periphery of the cylinder **23**. In any event, a passageway **35** is formed for admitting fluid to the cooling passageway **30**, passageway **35** having one or more fluid inlets thereto, two being shown at **37** and **38**. Passageway **35** may comprise radially extending openings at spaced intervals around the periphery of the apparatus, all of which are connected to a fluid inlet header **38**. At the downstream end of the copper cylinder **23**, there is an annular fluid outlet passageway **41** connected to one or more fluid outlets, two being shown at **42** and **43**. If desired, the passageway **41** may comprise a plurality of radially extending passageways at spaced intervals around the periphery of the apparatus communicating at their outer ends with fluid outlet headers and thence with a fluid outlet.

The downstream electrode is generally designated **45** and is seen to be spaced from the metallic wall of flange portion **27** by a retaining ring **47** which may be comprised of electrically insulating material which is preferably heat resistant to a high degree. Preferably, the downstream electrode **45** is fluid cooled by means, not shown for convenience of illustration, these means including, if desired, a fluid flow passageway for the flow of cooling fluid disposed back of thin walls of high thermal conductivity which forms the arcing surface. The downstream electrode **45** is seen to have an annular passageway **46** therearound in which is disposed a mag-

netic field producing coil **50** which has means for energizing the coil connected thereto, the energizing means not shown for convenience of illustration. Field coil **50** sets up a magnetic field which causes an arc **53** to rotate substantially continuously around the arcing surface **54.** Heated gas is discharged from the arc heater by an exhaust **56.** The downstream electrode **45** may be supported by the chamber wall **23** and insulated therefrom by annular ring **58** of electrically insulating material. The graphite lining of the cooled copper cylinder is shown at **60** and in FIG. **1** is shown as a plurality of stacked discs, these discs being designated **62.**

Particular reference is made now to FIG. **2** where the thermal conductivity of pyrolytic graphite in the direction *a–b* is shown as a function of temperature in degrees fahrenheit and the thermal conductivity of pyrolytic graphite in the direction *c* is shown as a function of temperature in degrees fahrenheit.

As will be readily understood, pyrolytic graphite is a polycrystalline formed of carbon with a well oriented structure. It is formed by carbon deposition on the surface by decomposition of a hybernaceous gas, for example methane, in a process that is carried out in very high temperatures usually above 1,000°F. The resulting material pyrolytic graphite contains no binder, has high purity and a density that normally exceeds 99.5% of the theoretical density of graphite. Pyrolytic graphite behaves like a metal in the planes parallel to the surface of deposition but is like a ceramic material across these planes. The discs of pyrolytic graphite **62** are carefully chosen or constructed with respect to these planes. The plane parallel to the surface of deposition being called the *a–b* or base of plane, the *c*-direction being the direction normal to these planes. Directions *a–b* and direction *c* with respect to the properties of the graphite are indicated in the drawing and it is seen that the direction *c* lies parallel to the axis of the cooled cylinder and substantially parallel to the arc path, whereas direction *a–b* is radial to the axis of the cylinder and substantially radial to the arc path. As a result of providing pyrolytic graphite in discs, it is seen that the resistance loss for a possible current path in the *c*-direction is seen to be small in comparison with the arc path. For an arc voltage of 700 volts, for example, resistance in the *c*-direction is given by the formula $R_c = (0.2 \times 12 \text{ in.})/1 \text{ in.}^2 = 2.4$ ohms, the current flow in the *c*-direction is calculated to be 300 amperes at most.

Particular reference is made now to FIG. **4,** a fragmentary view of a cooled copper cylinder in which the graphite lining is a cylinder extending the length of the copper cylinder. In FIG. **4,** the copper cylinder is designated **65** and the cylindrical graphite lining is **66.** This embodiment or configuration may be used where the gas flow is high to provide strong blowing of the arc downstream. The heat flux radiated between the graphite cylinder or sleeve and adjoining cooled copper is at 4,000°F. 1×10^6 Btu/hr. ft.^{2}; at 5,000°F. 1.5×10^6 Btu/hr ft.^{2}; and at 6,000°F. 3.0×10^6 Btu/hr ft.^{2}.

With high wall temperatures, heat inefficiency should be much improved over cooled wall designs. Furthermore, arc starting in an arc heater such as that described would be simplified since arc starting between upstream electrodes and graphite could be readily initiated.

Particular reference is made now to FIG. **3** where an additional embodiment of my invention is shown. Annular rings or graphite discs **75** and **76** have thin refractory coatings **77** and **78,** respectively. The thin coatings increase contact resistance between the cylinders and thus increase resistance in the *c*-direction where it is desirable.

The drawings and the written description shown heretofore are illustrative only and are not to be interpreted in a limiting sense.

I claim as my invention:

1. An arc heater comprising, first and second spaced electrodes adapted to have an electrical arc struck therebetween for heating gas, said electrodes being electrically insulated from each other, a hollow housing means having an elongated arc chamber disposed between said electrodes and electrically insulated therefrom, pressure means for admitting gas to be heated by said electric arc into said chamber and means for exhausting gas from said chamber, a pyrolytic graphite liner for the inner wall of said chamber, said graphite liner being characterized by high thermal conductivity in a direction transverse to the longitudinal axis of said arc chamber and by relatively low thermal conductivity in the direction parallel to the axis of the chamber, said graphite liner being characterized by high electrical resistance in the direction parallel to said longitudinal axis of said arc chamber compared to the electrical resistance in a direction transverse to the axis of said arch chamber, mounting means for supporting together the elements of the arc heater.

2. A liner according to claim **1** in which the pyrolytic graphite is in the form of a cylinder.

3. A liner according to claim **1** in which the pyrolytic graphite is in the form of a plurality of stacked annular discs.

4. A liner according to claim **3** including in addition a refractory coating on each of the said discs.

5. An arc heater according to claim **1** in which the graphite lining is additionally characterized as being in the form of a cylinder.

6. An arc heater according to claim **1** in which the graphite liner is additionally characterized as being a plurality of closely spaced annular discs extending the length of the inner wall of said arc chamber.

7. An arc heater according to claim **1** in which at least one of the electrodes is additionally characterized as including a field coil disposed therein, said field coil producing a magnetic field which causes the arc to rotate substantially continually around the annular arcing surface of one of said first and said second electrodes.

8. An arc heater according to claim **1** in which the gas admitted to said arc chamber is additionally characterized as being inert.

9. An arc heater according to claim **1** in which the gas admitted to said arc chamber is additionally characterized as being non-oxidizing.

10. An arc heater according to claim **1** including in addition fluid inlet means for cooling said arc chamber and fluid outlet means therefor.

11. An arc heater according to claim **1** in which the graphite liner comprises annular discs, said discs normally having arcs formed at the junctions therebetween by current flow, said arcs formed at the junctions of said disc being moved toward the downstream end of the arc heater by the force of the flow of gas within said arc chamber.

12. An arc heater according to claim **1** in which the downstream electrode is additionally characterized as being fluid cooled.

13. An arc heater according to claim **1** in which both the upstream electrodes and downstream electrodes are additionally characterized as being fluid cooled.

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