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ELECTRIC ARC POWERED JET

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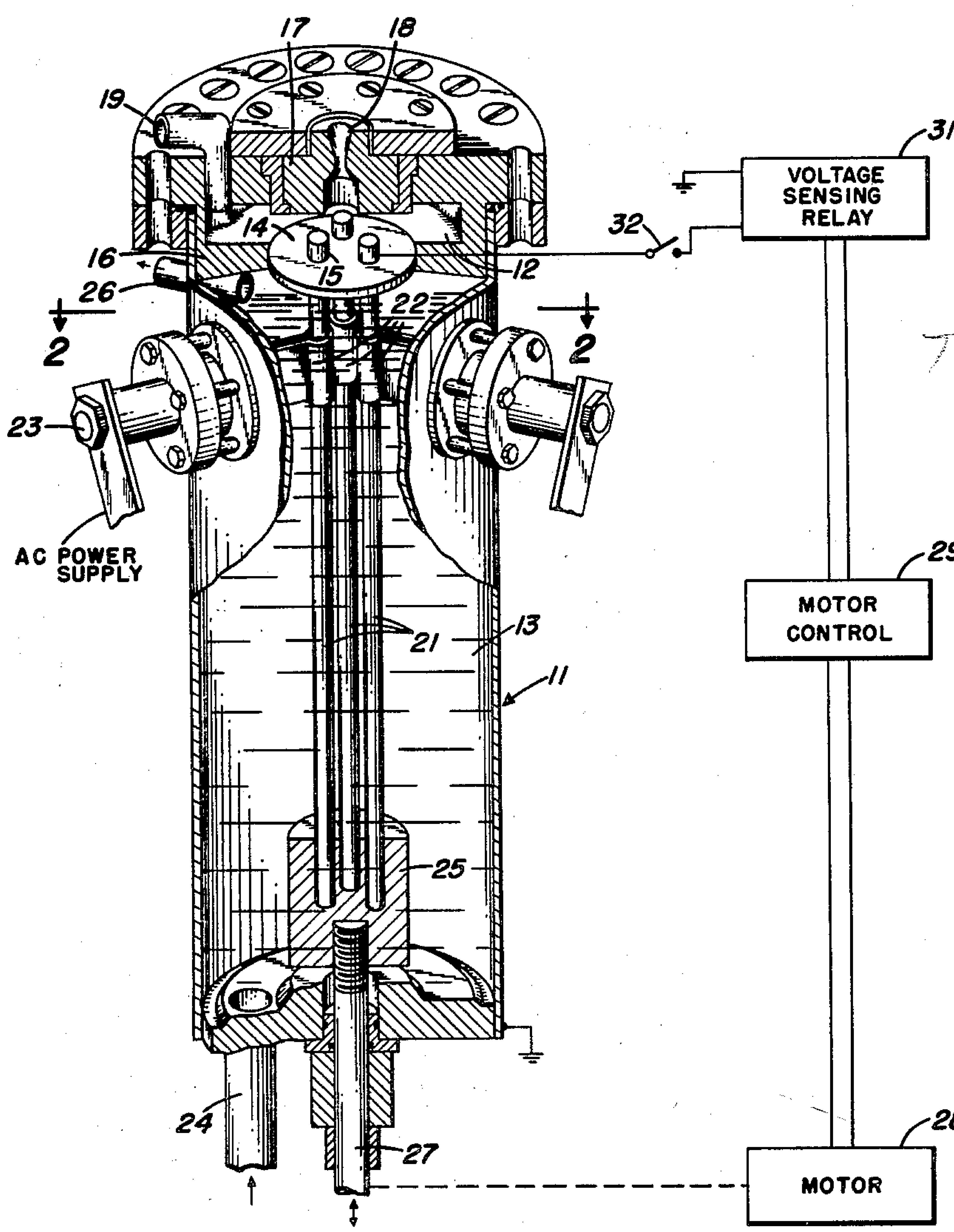

FIG. 1

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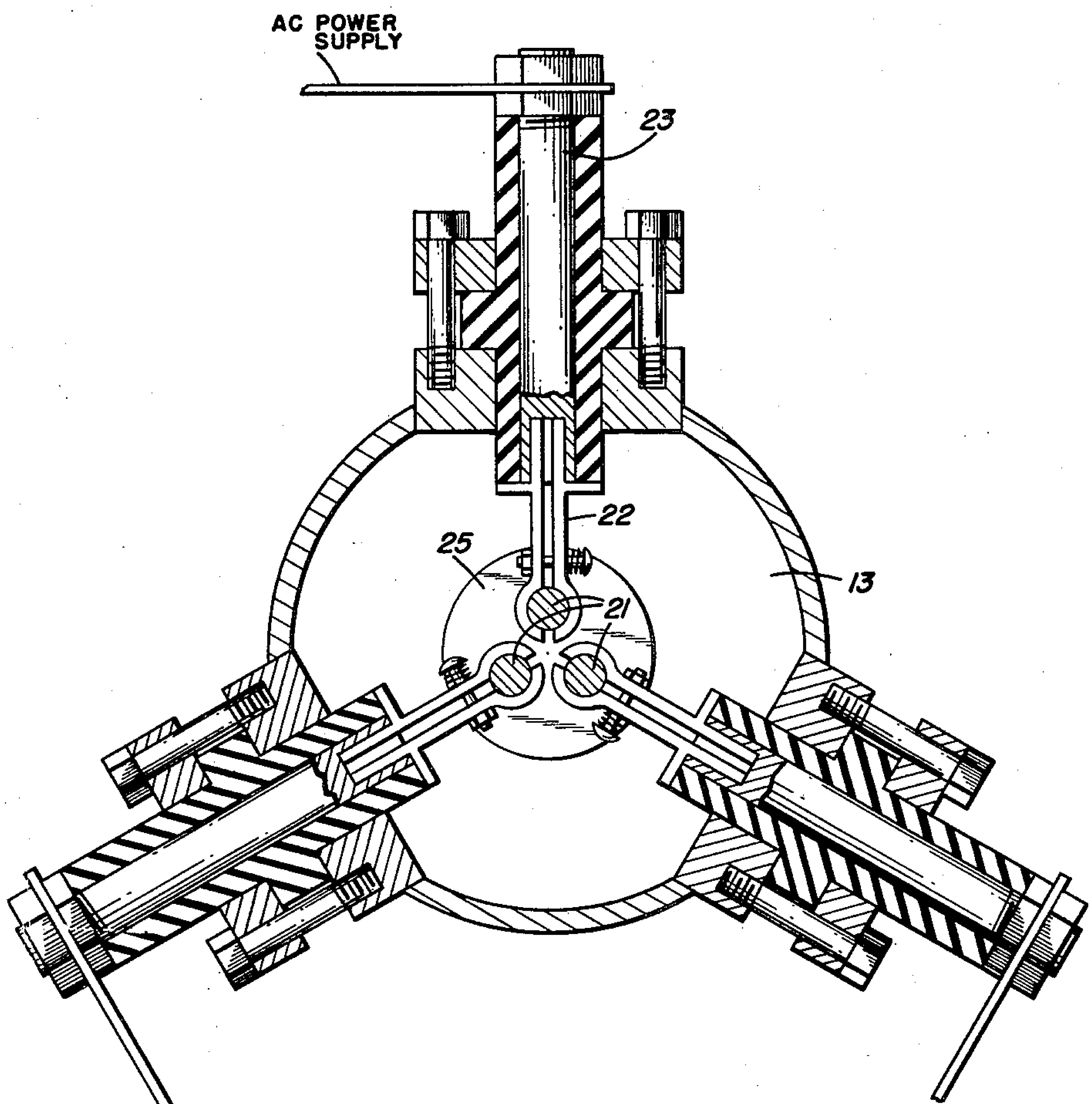

FIG. 2

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ELECTRIC ARC POWERED JET

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Application March 4, 1958, Serial No. 719,176

11 Claims. (Cl. 313—231)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates in general to the production of a supersonic or hypersonic stream of gas at very high temperature and more particularly to the attainment of this objective by the heating of various materials with high intensity A.-C. electric arcs.

Prior art methods of producing high temperature gas streams include chemical (combustion of fuels); mechanical (piston compressors); and electrical (resistance heating, sparks, arcs) methods but all these prior art methods are unsuitable for a variety of reasons. Chemical methods, for example, are incapable of producing the high temperatures desired, while mechanical methods generally involve cumbersome equipment and have a duration of operating time of much less than one second. Electrical resistance heating is also incapable of attaining the high temperatures desired while spark heating results in very short operating times (much less than one second). Other electrical arc methods have been limited as to the speeds attainable, limited to the use of D.-C. power and limited as to the types of materials used for the gas stream.

In contrast to the prior art, this invention produces the combination of high temperatures, high speeds, long running time and adaptability to the use of liquid air, gaseous air and other jet materials, to the use of high arc chamber pressure, and to the use of either A.-C. or D.-C. electrical power. Further, as to its individual characteristics this invention has surpassed prior D.-C. electrical arc devices in the high speeds achieved, the high pressures obtained in the arc chamber, in adaptability to the use of gaseous or liquid air and other materials and in the very use of A.-C. power for its own sake. Illustrative but not limiting values of the speed of the jet are of the order of Mach 1 to Mach 20 and values of the temperature of the jet are of the magnitude of 10,000 to 20,000° F. The duration of operation is relatively long being of the order of ten seconds or more.

Prior art D.-C. arc-powered jets are known to the applicants. In contrast to these prior art devices, however, is the capacity of the applicants' invention to use alternating current since alternating current power is more readily available in large quantities. In addition, the prior arc jets powered with direct current were limited to the use of water as a jet material. However, for research on problems in the field of aerodynamics, aircraft structures and aircraft structural materials a high temperature stream of air rather than of evaporated water (or of other materials) is necessary. Thus, an object of this invention is to produce a high speed air stream at pressures which can be varied to simulate a wide range of altitudes in the earth's atmosphere. A further object of this invention is to produce a jet stream of high temperature and high heating rates having a comparatively long operating time such that simulation

of some conditions experienced by hypersonic and reentry vehicles can be accomplished.

An added object of this invention is to devise means to produce a jet stream having both high temperature and high speed and utilizing air as a jet material in order that research facilities may be capable of simulating the effects of aerodynamic heating.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawings wherein:

Fig. 1 is a cutaway view of an arc jet assembly showing the structural features thereof and the automatic control therefor.

Fig. 2 shows the means employed for power input by means of the split power sleeves.

The body of the electric arc-powered jet assembly consists of an upright cylindrical pressure chamber **11** which may be anchored to a large concrete footing through rigid supports (not shown). At the upper end of the pressure chamber **11** and rigidly attached thereto by means of a bolted flange is a cylindrical graphite nozzle electrode **17**. The graphite nozzle electrode **17** serves a two-fold purpose; first, as a nozzle through which the jet material flows from the arc chamber **12**, and second, as an electrode in the operation of the arc. Though the arc-powered jet can be operated on either direct current or alternating current, this disclosure will be limited to the A.-C. application.

Although the use of a graphite nozzle element will be used by way of illustration there are under some conditions undesirable features of the use of this particular nozzle and a substitution may readily be made by using cooled metallic elements of the same contour.

Below the graphite nozzle electrode **17** is located the arc chamber **12** into which is fed the jet material through intake **19**. The jet material may be compressed air, water, or other gases or liquids. For purposes of explanation the remainder of this description will assume the use of compressed air as the jet material.

A ceramic plate **14** forms part of a common wall **16** which separates the arc chamber **12** from the electrode chamber **13**. This electrode chamber **13** may contain water or other satisfactory coolants which coolants enter the electrode chamber **13** by way of coolant inlet **24** and exit by way of coolant outlet **26**. The ceramic plate **14** is provided with holes **15** for passage of the movable electrodes **21**. The movable electrodes **21** slide through the split power sleeves **22** which are connected to the A.-C. power supply. The power sleeves **22** and their connectors **23** pass through the pressure chamber wall as indicated in Fig. 2 and are electrically insulated from it.

The movable electrodes **21** are supported on their lower ends by a holder **25** which, in turn, is attached to the drive rod **27**. The drive rod **27** passes through the bottom end plate of the electrode chamber **13** and packings are provided around this drive rod **27** to prevent leakage of coolant from the electrode chamber **13**.

The drive rod **27** is connected mechanically to an electro-mechanical actuator composed of a voltage sensing relay **31**, a switch **32**, a motor control **29**, and a motor **28**. This series of elements composing an electro-mechanical actuator may be attached to the outside wall of the pressure chamber **11**. The motor **28** through its mechanical connection is capable of imparting an upward or downward motion to the drive rod **27** in order to drive the electrodes **21** toward or away from the graphite nozzle electrode **17**. Although the particular parameter the variation of which is used herein to control the arc-gap is the arc voltage in arc chamber **12**, it is contemplated that control of the arc-gap can also be effectuated by measuring the variation of pressure in the arc chamber **12**, the velocity of the jet stream or the temperature thereof by the use of adequate sensing equipment and thereupon translating such variations into control functions via motor control **29** and motor **31**.

The sequence of operation of the electric arc-powered jet is initiated by the flow of compressed air into the arc chamber **12** through intake **19**. When the desired flow and pressure conditions are established in the arc chamber **12**, the high intensity arcs are struck and are automatically maintained. This is accomplished by moving electrodes **21** toward nozzle electrode **17** until a current flow is established between these electrodes **21** and graphite nozzle electrode **17**. Electrodes **21** are then quickly withdrawn to produce arcs between these electrodes and thereafter the position of the movable electrodes **21** with respect to the nozzle electrode **17** is governed by the voltage sensing relay **31** in order to maintain a constant predetermined voltage across the arc. Voltages in excess of the desired voltage cause the motor control **29** to actuate motor **28** to move the electrodes **21** closer to the nozzle element **17**. Conversely, deficient voltages cause the motor control **29** to actuate motor **28** to increase the gap between the movable electrode **21** and the nozzle electrode **17**. Thus, by maintaining the arc gap and the arc voltage, the movable electrodes **21** are automatically fed upward in the electrode chamber **13** to correct for consumption thereof.

The high intensity electrical arcs established between the movable electrodes **21** and the nozzle electrode **17** heat the compressed air to a high temperature. The arc chamber pressure is thereby increased and the speed of efflux of the jet material from the nozzle orifice **18** is very greatly increased. Illustrative of the speed of the jet while arcs are in operation are velocity values of the order of Mach 20. Illustrative of the temperature of the gas leaving the nozzle orifice **18** are temperature values of the order of 20,000° F. The operation may be maintained until the erosion and/or consumption of the nozzle electrode **17** may render the nozzle orifice **18** ineffective. At the highest power levels available for the use of this apparatus, this will permit operation for approximately 10 seconds. Operation at reduced power levels permits operation for even longer periods of time. Factors limiting the operation of this apparatus are, therefore, the life of the nozzle orifice **18** and the amount of heat the coolant is capable of removing from pressure chamber **11**.

Although the current use for the apparatus disclosed herein is primarily for the testing of materials and structures, future uses may possibly include the use of such apparatus as propulsion units for aircraft and space vehicles. Also, the production of very high temperature gases for use in commercial applications is contemplated.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. Apparatus for the production of high temperature high velocity jet streams, comprising a pressure chamber, said pressure chamber being divided into an arc chamber and an electrode chamber by a relatively impervious electrically non-conductive separator, said separator being rigidly supported upon the envelope of said pressure chamber and being perforated to permit penetration of first electrode means from said electrode chamber into said arc chamber, said electrode chamber having a perforation through the wall thereof allowing penetration of an adapter into said electrode chamber from without said pressure chamber, said adapter being operatively connected to said first electrode means, said first electrode means being adapted to be advanced in a linear direction into said arc chamber and to be retracted therefrom in the reverse linear direction, second electrode means mounted on a wall of said arc chamber, said second electrode means being located in line with the linear direction of movement of said first electrode means, said second electrode means having a portion thereof projecting through an opening in said arc chamber wall, said second electrode means having an orifice therethrough whereby said arc chamber communicates with the space outside said pressure chamber, said orifice having a nozzle configuration and being so oriented as to have the axis of symmetry thereof substantially in alignment with said first and second electrode means, means connecting said first electrode means to a source of alternating potential, means connecting said second electrode means to ground, means for admitting fluid under pressure into said arc chamber, inlet means providing for the admission of cooling fluid to said electrode chamber, outlet means providing for removal of cooling fluid from said electrode chamber, means for moving said adapter thereby advancing said first electrode means toward said second electrode means and quickly retracting said first electrode means whereby arcing is produced between said first electrode means and said second electrode means resulting in such an increase of pressure and temperature of said fluid under pressure in said arc chamber that said fluid leaves said orifice at greatly increased temperature and pressure.

2. Apparatus as set forth in claim 1 in which the source of potential consists of a source of three-phase alternating current, the first electrode means consists of three electrodes arranged equidistant from each other and the means respectively coupling said three electrodes to the three phases of said alternating current source to be energized thereby.

3. Apparatus as set forth in claim 1 in which the fluid admitted under pressure into the arc chamber is air.

4. Apparatus for the production of high temperature high velocity jet streams, comprising a container having an opening therein, said opening receiving and being sealed by a closed arc chamber a portion thereof protruding within said container, said arc chamber being rigidly supported to said container about the periphery of said opening whereby two closed chambers are produced having a common wall area, said two chambers being said arc chamber and an electrode chamber, said common wall having an aperture therein, said aperture being closed by a ceramic separator supported by said common wall, said separator being perforated to permit penetration of a plurality of electrodes arranged equidistant from a common axis from said electrode chamber into said arc chamber, said electrode chamber having a perforation through the wall thereof allowing penetration of a drive rod into said electrode chamber from without said container, said drive rod being operatively connected to said plurality of electrodes, said plurality of electrodes being adapted to be advanced collectively in a linear direction into said arc chamber and to be retracted collectively therefrom in the reverse linear direction, a nozzle electrode mounted on a wall of said arc chamber, said nozzle electrode being located in line with said axis common to said plurality of electrodes, said nozzle electrode having a portion thereof projecting through an opening in said arc chamber wall, said nozzle electrode having an orifice therethrough whereby said arc chamber communicates with the space outside said container, said orifice having a nozzle configuration and being so oriented as to have the axis of symmetry thereof substantially in alignment with said axis common to said plurality of electrodes, means connecting said plurality of electrodes to a source of alternating potential, means connecting said nozzle electrode to ground, means for admitting compressed air into said arc chamber, inlet means providing for the admission of cooling fluid to said electrode chamber, outlet means

providing for removal of cooling fluid from said electrode chamber, electromechanical drive means for moving said drive rod thereby advancing said plurality of electrodes toward said nozzle electrode and quickly retracting said plurality of electrodes whereby arcing is produced between said plurality of electrodes and said nozzle electrode resulting in such an increase of pressure and temperature of said compressed air in said arc chamber that said compressed air leaves said orifice at greatly increased temperature and pressure.

5. Apparatus as in claim 4 in which the means connecting said plurality of electrodes to a source of alternating potential comprises a plurality of cables, connectors and power sleeves, said power sleeves being matched with and continuously engaging said plurality of electrodes.

6. Apparatus as set forth in claim 4 in which the nozzle electrode is a cylindrical graphite block having shoulders formed at both ends to facilitate mounting.

7. Apparatus as set forth in claim 4 in which are included automatic control means responsive to a variation of a parameter to be controlled whereby said automatic control means actuates said electro-mechanical drive means.

8. Apparatus as set forth in claim 7 in which the automatic control means is responsive to the arc voltage and comprises a voltage sensing relay, a motor control and connecting means.

9. Apparatus for the production of high temperature high velocity jet streams, comprising an arc chamber, a relatively impervious electrically non-conductive plate received within an aperture in one wall of said arc chamber, said plate being perforated to permit penetration of first electrode means into said arc chamber from outside said arc chamber, said first electrode means extending outside said arc chamber and being adapted to be advanced in a linear direction into said arc chamber and

to be retracted therefrom in the reverse linear direction, second electrode means being received within an aperture in a second wall of said arc chamber, said electrode means being located in line with the linear direction of movement of said first electrode means, said second electrode means having an orifice therethrough whereby said arc chamber communicates with the space outside said arc chamber, said orifice having a nozzle configuration and being so oriented as to have the axis of symmetry thereof substantially in alignment with said first and second electrode means, means connecting said first electrode means to a source of alternating potential, means connecting said second electrode means to ground, means for admitting fluid under pressure into said arc chamber, means for cooling said plate and said one wall of said arc chamber having an aperture in which said plate is received and that portion of said first electrode means extending outside said arc chamber, means for moving said adapter thereby advancing said first electrode means toward said second electrode means and quickly retracting said first electrode means whereby arcing is produced between said first electrode means and said second electrode means resulting in such an increase of pressure and temperature of said fluid under pressure in said arc chamber that said fluid leaves said orifice at greatly increased temperature and pressure.

10. Apparatus as set forth in claim 9, in which the source of potential consists of a source of three-phase alternating current, the first electrode means consists of three electrodes arranged equidistant from each other and the means respectively coupling said three electrodes to the three phases of said alternating current source to be energized thereby.

11. Apparatus as set forth in claim 9 in which the fluid admitted under pressure into the arc chamber is air.

No references cited.