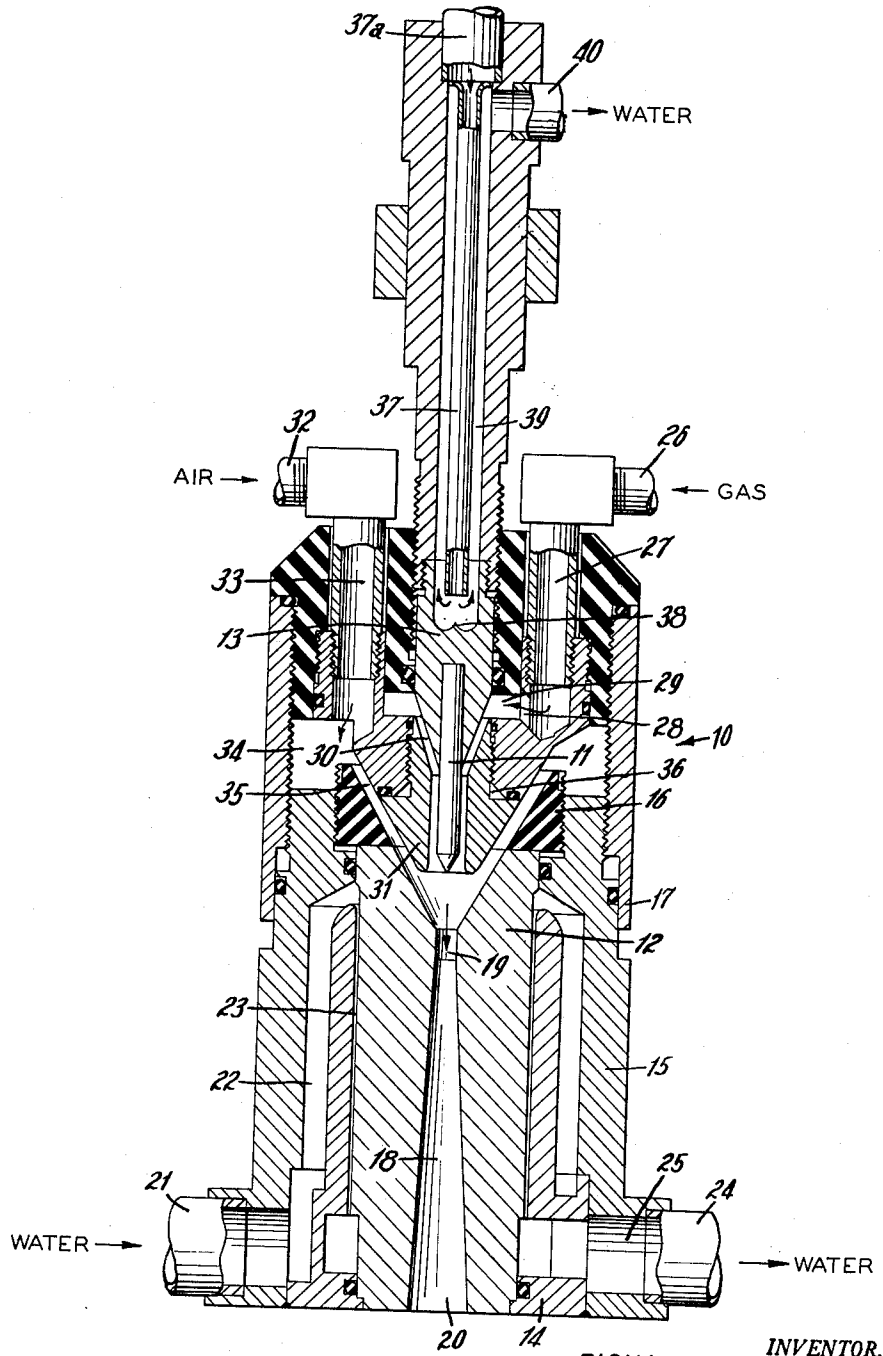
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ARC TORCH DEVICE

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ARC TORCH DEVICE

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The present invention relates to an improved arc torch device for heating a gaseous medium such as air. More particularly, it relates to such a device wherein extremely high power may be supplied to the arc end and thence to the gaseous medium.

There is an increasing need in industry for apparatus that will produce environmental conditions for certain research and tests on a scaled down or laboratory basis. In certain instances, such conditions have been virtually non-reproduceable on such a laboratory basis. In the aviation, missile and space exploration fields, for example, equipment is desired which will produce gas velocities far exceeding the speed of sound and/or temperatures far exceeding the melting points of most known materials. Devices capable of producing such gas velocities and temperatures on a laboratory basis are largely unobtainable. The advantages to be gained from such a device are obvious in terms of making it possible to pretest airframe shapes, material durability at elevated temperatures and the like. Such pretesting is, of course, necessary to the protection of human life and the successful operation and recovery of extremely expensive unmanned vehicles.

High velocity, high temperature air streams are desired for wind tunnels and other materials testing devices. In such devices high gas velocities and temperatures are required.

Electric arcs are essentially high temperature devices and have been used for many years as cutting torches, for plating processes, for cracking hydrocarbons in the production of acetylene, and other similar uses. Of recent years, these arc devices have become useful in various high temperature gas heating applications. In such applications, it is of prime importance to supply a maximum amount of power to the arc and then to transfer such power to the gas effluent. It has been found that if higher power to an arc device is achieved solely through current increases, such additional power is used up primarily in heating the electrodes and their cooling fluid streams. Voltage increases, on the other hand, are substantially completely transmitted as higher heat to the arc gas.

It is accordingly a primary object of this invention to provide an electric arc gas heating device capable of handling large amounts of power and of transferring a large percentage of such power to the gas.

It is a further object to provide such a device having improved structure and cooling means which allows same to remain operable at high power levels.

It is a still further object to provide improved means for obtaining maximum heat transfer to the gas.

A further object is to provide an improved apparatus for use at power levels up to about 300 kw.

Other objects and advantages will become apparent from the following detailed description and drawings in which the sole FIGURE is a front elevation taken in cross-section of the inventive device.

The objects of the invention are accomplished generally by providing an electric arc gas heater which includes a stick cathode carried by a collet or cathode supporting means. The collet is cooled to prevent damage due to heat. A cylindrical tube or protective sleeve surrounds the arc end of the cathode and is in spaced concentric relation therewith so as to form an annular space. The protective sleeve is also cooled. A shielding gas is

supplied to the annular space formed about the cathode to protect the arcing end. A nozzle anode having an internal conical gas passage at least partially surrounds the end of the tube and is also in spaced concentric relation therewith. An insulator having a conical internal gas passage cooperates with the internal passage in the nozzle anode to form one continuous gas passage around the outer periphery of the protective sleeve. Means are provided for supplying a gas such as air under pressure to the continuous gas passage. The nozzle anode has a gas outlet comprising a throat, which preferably has a diameter of between ¼ and ⅝" and a length ¼ to 2 times its diameter, and a divergent expansion passage, which preferably has an included angle of between 4 to 15 degrees and a length of from 1½ to about 6 inches. Means are provided for striking an arc between said nozzle anode and the arc end of the cathode. The nozzle anode is provided with cooling means.

The torch preferably operates in a wall-stabilized mode such as described in U.S. 2,858,411, issued October 28, 1958, to R. M. Gage.

A more detailed description follows by referring to the drawings wherein the apparatus shown consists of a torch body, noted generally at **10**, an inner stick cathode **11**, the shape of which preferably forms an angle of 60° at its tip in order to minimize chemical attack by the gases flowing through the torch, and a nozzle anode **12**. The stick cathode is supported by the collet **13** while the nozzle anode is held in position by the water sleeve **14**, the water jacket **15**, and the insulator **16** all three of which are securely held by sleeve **17**. The stick cathode **11** is preferably constructed of tungsten and preferably contains an emissive material such as thoria so as to increase its electrical emissivity. It preferably has a diameter of from 3/16 to ½ inch in order to insure that it has sufficient current carrying capacity without having an excessive amount of material. The nozzle anode **12** is constructed of copper because of its high electrical and thermal conductivity. Such material is also useful to minimize electrode damage in the presence of oxidizing atmospheres.

The nozzle anode **12** has a divergent section **18** that is so designed to give a desired pressure drop between the nozzle throat **19** and the nozzle exit **20**. Such pressure drop enables a high velocity air stream to be emitted from the nozzle exit. Specifically, the divergent section has an included angle of sufficient magnitude to yield sufficient differences in cross-sectional areas between the nozzle throat and exit to obtain the desired pressure drop. However, it has been found that if the angle becomes excessive, the gas will not be able to expand rapidly enough at supersonic velocities and will separate from the nozzle walls causing velocity losses due to shock wave interference. Too large an angle will also create too great a pressure drop causing a loss of arc voltage. Likewise too small an angle will not create enough pressure drop to sufficiently increase the air stream velocity. An included angle of from 4 to 15 degrees has been found suitable.

The length of the divergent section has been found to be critical. Specifically, in high power, high velocity torch applications such as this, the nozzle must be of sufficient length to prevent the arc from "extending" out of the nozzle exit and becoming localized somewhere on the end of the torch body. However, the length should not become excessive since any length beyond what is required to prevent the arc from "so extending" would unnecessarily take away the heat from the gas. A suitable length for the divergent section has been found to be between 1½ inches and 6 inches.

The length of the nozzle throat **19** has also been found to be critical. If the nozzle throat is of insufficient length it will approach a "pointed" construction causing the throat to "melt down" because of the high heat concentra-

tion. If, however, the length becomes excessive the arc will tend to localize at the throat rather than along the divergent section 18 of the nozzle. A suitable length for the throat section 19 has been found to be between one quarter and twice the throat diameter. A throat diameter of from about ¼" to about ⅝" has been found to be suitable to give the best mass flow rate for the allowable pressures for the torch.

The nozzle 12 is kept from melting during operation by water cooling. The water enters the cooling jacket 14 through inlet 21, passes toward the front portion of the nozzle through annulus 22, then passes rapidly through annulus 23, and then out through outlet 24 through annulus 25. In order to provide maximum cooling and prevent melting of the nozzle interior, the ratio of the O.D. of the nozzle to its I.D. at its point of smallest cross-section should be between 1.7 and 8.0. Optimumly, when the internal diameter of the throat section is about ¼ inch, the O.D.-to-I.D. ratio of the nozzle is between 2.2 and 4.2. For a throat diameter of ½ inch, the O.D.-to-I.D. ratio should be about 1.7 to 3.5.

Shielding gas, such as argon, under pressure enters through inlet 26, passes through conduit 27 and 28 to the annulus 29, then along the stick cathode 11 through annulus 30 formed between the stick cathode 11 and the protective sleeve 31 and out through the nozzle anode 12 by way of the throat section 19 and divergent section 18. Protective sleeve 31 is electrically insulated through insulator 50. Annulus 30 must be at an angle optimum size to insure proper shielding of the tungsten cathode 11. Specifically, the annulus must be small enough to achieve high shielding gas velocities and yet be large enough to insure a uniform flow of gas. Such high shielding gas velocities prevents the incoming air streams from coming into contact with the tungsten cathode. An annulus width of from 1/32 to ⅛ inch has been found to be suitable.

The stick electrode 11 is preferably made flush with the tip of the protective sleeve 31. If it is allowed to project beyond the tip of the sleeve it will be subjected to the erosive effects of the surrounding air stream. On the other hand, if it is set back from the tip of the sleeve the sleeve will become too hot and melt down.

Air under pressure enters through inlet 32, passes through conduit 33 into annulus 34, then through passage 35 between protective sleeve 31 and the combination of insulator 16 and anode nozzle 12. The passage 35 forms an included angle within the passage of from 45° to 90° and preferably about 60° for efficiently directing uniform gas flows to the nozzle anode. The air then mixes with the shielding gas as they both pass out through the nozzle 12. The annular passage 35 should have a length of from ½ inch to 2 inches and preferably about 1⅜ inches in order to provide for a streamline gas flow. Its width should be between about 1/16 and ¼ inch. However, when choosing any one length-width combination, care must be taken to maintain a length-to-width ratio of the passage of at least 3 and preferably about 10 in order to insure that the flow will be streamlined.

In order to insure that there will be equal quantities of air flow through out the annular passage 35, the annulus 34 is off-set from the axis of the conduit 33. If this were not done, there would be a tendency for the air to flow from the conduit 33 directly into the portion of passage 35 nearest passage 33 rather than being first dispersed evenly through annulus 34. This description of the apparatus is pertinent when axial gas flow is employed. Alternatively, the main gas stream could be introduced to annulus 34 in a tangential fashion to produce a vortex gas flow through passage 35 and subsequently through nozzle passages 18 and 19.

The protective sleeve 31 is cooled to prevent it from melting and eroding during operation by passing cooling water through annular passage 36 from a suitable inlet source (not shown).

The stick cathode 11, which has a diameter of about ¼ inch to ½ inch, it optimumly set-back from the throat 19 of the anode nozzle 12. Specifically, the greater the setback the greater will be the length of the arc that is finally established. The greater the length of the arc, the greater will be the arc voltage. Such increased arc voltage means that the increased power is being transmitted as heat energy to the gas. The set-back cannot become excessive, however, because of arc stability. A set-back distance of from ½ to 1¼ inches has been found to be suitable when used in conjunction with a nozzle having a throat diameter of from ¼ to ⅝".

The stick cathode 11 is cooled by passing cooling water through the tube 37 from inlet 37*a*, around the cupped portions 38, through annular passage 39, and then out the outlet 40. The cupped portions 38 allow a greater amount of cooling water to come into a greater area in close proximity to the stick cathode.

In operation, an electrical power source (not shown) is connected between stick cathode 11 and nozzle anode 12 between which an arc is established by some suitable means. Direct current, straight polarity is the preferred type of power for this device. The combined air-shielding gas streams force the arc down into the divergent section 18 of the nozzle anode 12. The gases passing through this high intensity arc are heated to a high energy content and are discharged in a supersonic hot jet.

In the following examples of the operation of the device, apparatus of the type depicted in the accompanying drawing was used.

Example I

In this example, the nozzle anode had a throat diameter of .355 inch, and the stick cathode had a ½" diameter. Air and argon were supplied at the rate of 5700 c.f.h. and 1300 c.f.h. respectively resulting in an arc chamber pressure of 184 p.s.i.g. upstream from the nozzle throat. Under these conditions, and with 600 amperes supplied to the device, the total power developed was 244 kw., the arc voltage was 406 v., the power to the gas was 167 kw., the equivalent enthalpy of the gas effluent was 1200 B.t.u./lb., the efficiency based on the power to the gas was 68%, and the calculated gas velocity was 4800 ft./sec. which is approximately Mach 2.0 for these conditions.

Example II

In this example, the nozzle anode had a throat diameter of .335 inch and the stick cathode had a 3/16 inch diameter. Air and argon were supplied at the rate of 3000 c.f.h. and 300 c.f.h. respectively resulting in an arc chamber pressure of 105 p.s.i.g. upstream from the nozzle throat. Under these conditions, and with 500 amperes supplied to the device, the total power developed was 147 kw., the arc voltage was 294 v., the power to the gas was 96 kw., the equivalent enthalpy of the gas effluent was 1500 B.t.u./lb., the efficiency based on the power to the gas was 65%, and the calculated gas velocity was 4170 ft./sec. which is approximately Mach 1.7 for these conditions.

While the invention has been described by referring to the preferred embodiment, it is to be understood that certain modifications may be made without departing from the spirit and scope of the invention. For example, any gas which is in inert relation to the cathode, such as helium hydrogen, krypton, neon, nitrogen, xenon, carbon monoxide, and mixtures thereof may be used as a shielding gas. Also other reactive gases may be used in place of air. Further an A.C. power may be used instead of D.C. power.

As is apparent from the drawing and the description the internal parts of the torch, such as the inner electrode, the nozzle electrode, and the protective sleeve are replaceable.

What is claimed is:

1. An electric arc gas heater comprising the combina-

tion of a stick electrode, a collet supporting said electrode, means for providing a coolant to said collet, replaceable protective sleeve surrounding the arc end of said electrode in spaced concentric relation and electrically isolated from said electrode, means for providing coolant to said protective sleeve, means for delivering a shielding gas to the annular space between said sleeve and electrode which is discharged from said sleeve about such end of said electrode, a nozzle electrode having an internal conical gas passage at least partially surrounding the end of said sleeve in spaced concentric relation, said nozzle having an O.D.-to-I.D. ratio between about 1.7 and 8 measured at its point of smallest I.D., insulator means having a conical internal gas passage cooperating with said internal conical gas passage of said nozzle electrode to form one continuous annular gas passage having a length-to-width ratio of at least about 3 around the end of said sleeve, means for delivering gas under pressure to said continuous gas passage for flow about such end of such sleeve, said nozzle electrode having a gas outlet comprising a throat leading to an expansion passage of divergent cross-section for expansion of such gas as it is discharged therefrom, said divergent cross-section having an included angle of from about 4 to 15 degrees and a length of between about 1½ and 6 inches and said throat having a length of from between ¼ and about

2 times the throat diameter, said throat diameter being between about ¼ and ⅝ inch, means for striking an arc between said nozzle electrode and the arc end of said stick electrode for heating the gas discharged from said nozzle, and means for supplying a coolant to said nozzle anode.

2. Apparatus according to claim 1 wherein said stick cathode has a diameter in the range of from about ¼ inch to about ½ inch and such cathode is set-back a distance of from about ½ to 1¼ inches from said nozzle throat.

3. Apparatus according to claim 1 wherein said protective sleeve forms an annulus with said cathode having a width of from 1/32 to ⅛ inch.

4. Apparatus according to claim 3 wherein said continuous annular gas passage has a length-to-width ratio of about 10.

5. Apparatus according to claim 1 wherein said nozzle electrode is non-consumable and in which at least a portion of said arc is wall-stabilized.

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