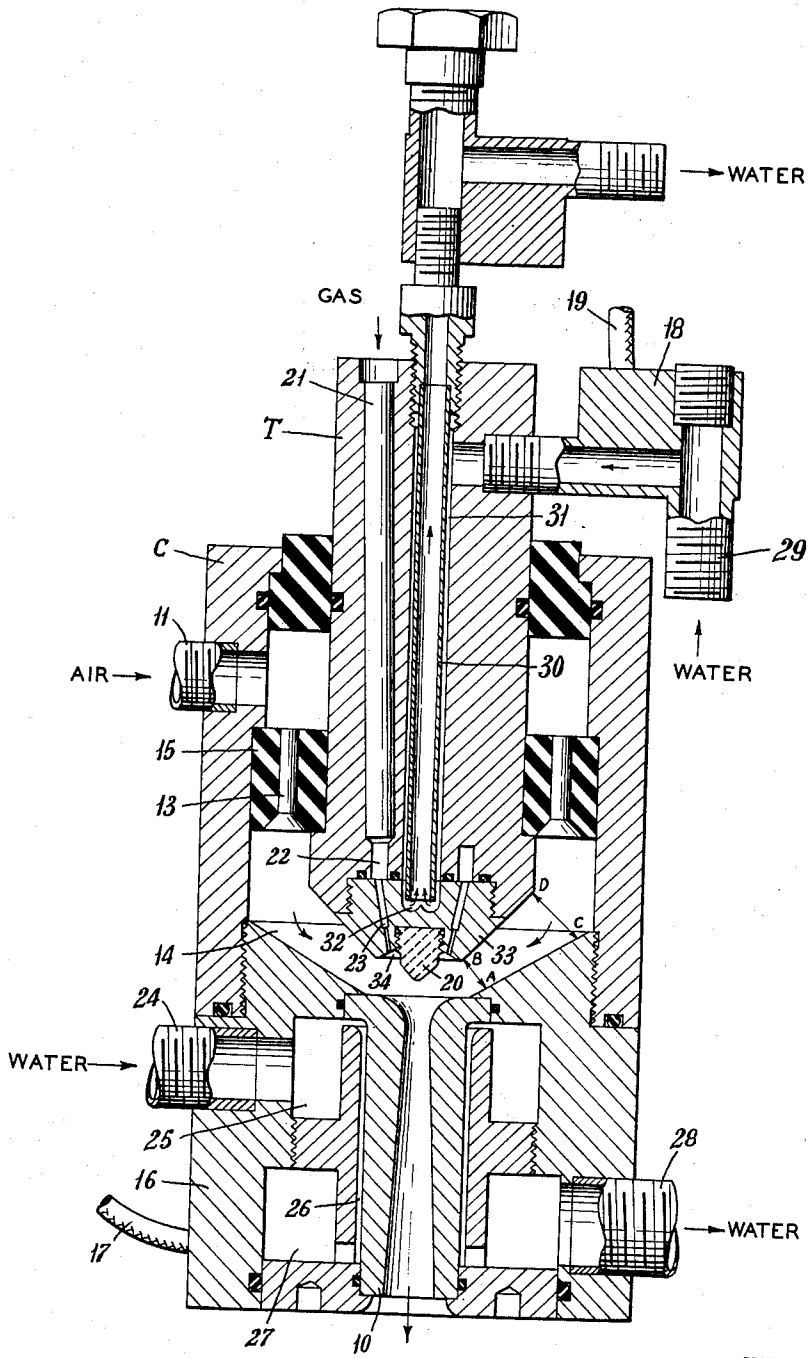
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ARC TORCH DEVICE

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ARC TORCH DEVICE

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The present invention relates to an improved arc 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 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 and 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 space 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 the 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 such 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 improved apparatus for use at power levels up to about 200 kw.

Other objects and advantages will be apparent from the description and drawings in which:

The sole FIGURE is an elevation view taken in cross-section of an arc torch device according to the present invention.

The objects of the invention are accomplished in general by providing an improved arc torch device including a torch body which is provided with a longitudinal gas passage through which shielding gas is introduced to the novel device and which is also provided with a longitudinal bore into which is positioned an inner tube. The inner tube and walls of the longitudinal bore define an annular space. A cooling medium preferably water is introduced into the torch body through a water inlet to the annular space and then exits through the inner tube. A gas cup is threaded into the forward end of the torch body and has a cupped portion at the rear thereof. This cupped portion provides communication between the inner tube and the annular space so that cooling water will pass into the cupped portion, cool the gas cup and be directed back up the inner tube. A stick cathode is carried by the front section of the gas cup. Because of the large area at the rear of the gas cup which is in direct contact with the cooling water and since this area is adjacent the cathode carrying portion of the gas cup unusually good cooling is obtained. A plurality of gas passages are provided in the gas cup. These passages communicate with the longitudinal gas passage and permit shielding gas to flow from the gas passages along the stick cathode. An outer casing at least partially surrounds the torch body and is spaced therefrom. In the space is provided an insulator. The insulator has a plurality of gas nozzles which receive pressurized gas from a gas inlet. A torch front section is carried by the outer casing and is adapted to support a nozzle electrode. The nozzle electrode is spaced from and is in axial alignment with the stick cathode. The nozzle electrode has a gas outlet comprising a throat leading to an expansion passage of increasing diameter for the expansion of gas as it is discharged therefrom. A gas passage is provided and is defined by the inner conical walls of the torch front section and the outside inclined surfaces of the gas cup and forward section of the torch body. Such passage receives pressurized gas from the nozzles in the insulator and is so dimensioned so as to give a streamline gas flow to the gas as it approaches the throat of the nozzle electrode. A cooling water inlet and outlet are provided in the torch front section for cooling the nozzle electrode carried in such section.

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.

Referring to the drawing, the apparatus comprises a torch body T provided with a longitudinal gas passage 21 for introducing a shielding gas, such as argon, into the device. Gas passage 21 terminates in an annular chamber 22. The torch body T is also provided with a centrally located longitudinal bore wherein is positioned an inner tube 30. The walls of the bore and the inner tube 30 define an annular space 31. A cooling medium such as water, is provided to the torch body T by injecting water into the inlet 29 through the annular space 31. A gas cup 33 is carried by the forward end of the torch body T and is provided with gas passage 23 which in turn communicates with annular chamber 22. Gas cup 33 is also provided with a cupped portion 32 at the rear thereof so as to provide communication with the inner tube 30 and the annular space 31 so as to allow cooling water to come into contact with a greater area of the gas cup 33 in close proximity to the tungsten electrode 20. Such electrode 20 is carried at the front end of the gas cup 33 in a recessed portion 34. Thus the electrode 20 is internally cooled by providing water from inlet 29 through annular space 31 then out inner tube 30 by way of the cupped portion 32. Shielding gas is introduced into the torch body T through passage 21, the annular chamber 22, to the plurality of gas passages 23. Such passages 23, provided in gas cup 33, discharge into the recessed portion 34 of the gas cup 33 thereby per-

mitting shielding gas to flow along and just grazing the face of the tungsten electrode 20 so as to provide adequate shielding with a minimum of shielding gas flow.

An outer casing C partially surrounds the torch body T and is spaced therefrom by insulating material 15. A plurality of nozzles 13 are provided in the insulator 15. Such nozzles aid in an even radial flow distribution in the passageway 14. Specifically, the divergent section of the nozzle will tend to spread the flow of gas through the passageway 14. The nozzles should be of suitable size and number to effectively spread the gas through the passageway and should be symmetrically spaced about the insulator 15. Eight nozzles 3/16 inch in diameter have been found to be suitable.

Alternatively, the nozzles would be positioned at a suitable angle to the axis of the torch in order to achieve a swirling or vortex flow of gas.

The outer casing C carries at the forward end thereof a front torch section 16. Such front torch section 16 is adapted to support a nozzle electrode 10 space from but in axial alignment with the stick cathode 20. The nozzle 10 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 has a throat section the diameter of which is preferably between 1/4 and 5/8 inches in order to insure that for a given pressure the arc will be maintained within the nozzle in a stable condition. The internal refractory metal electrode 20 carried by the gas cup 33 is preferably constructed of tungsten and preferably contains an emissive material such as thoria so as to increase its current carrying ability. Other materials exhibiting like properties can be used. The electrode 20 preferably projects beyond the gas cup a distance of a 1/4 inch. If it is allowed to project beyond this distance it will be subjected to the erosive effects of the surrounding air stream by being projected into the stream rather than having the flow just graze the tip of the electrode. On the other hand, if its projection becomes much less than a 1/4 inch the cup will become too hot and melt down. The shape of the electrode preferably forms an angle of 90° at its tip to minimize chemical attack by the gases flowing through the torch. For the tungsten electrode a diameter of from 1/4 to 1/2 inch has been found to be suitable in order to insure that it has sufficient current carrying capacity without having an excessive amount of material. In operation, an arc is struck between the nozzle electrode 10 and electrode 20 in a manner to be described hereinafter.

In order to provide maximum cooling and prevent melting of the nozzle interior, the ratio of the O.D. of the nozzle to the I.D. at its point of smallest cross-section should be between 1.7 and 8.0. Optimumly, when the nozzle diameter is about 1/4 inch at its point of smallest cross-section, the O.D.-to-I.D. ratio of the nozzle is between 2.2 and 4.2. A suitable length for the nozzle divergent section for establishing and maintaining the arc within the nozzle has been found to be from 1½ to 6".

The length of the arc that is finally established is an important feature of the present invention. Specifically, the greater the length of the arc the greater will be the arc voltage. Such increase in arc voltage means that the increased power is being transmitted as heat energy to the gas. Therefore, the greater the set-back of the stick electrode 20 from the nozzle throat, the longer will be the arc that is finally established. Such set-back must be optimumly designed however, since, if the set-back becomes excessive, it will be impossible to keep the arc localized at its desired area in the nozzle. A suitable set-back distance has been found to be from ½ to 1¼ inches when used in conjunction with a nozzle electrode having a throat diameter of from 1/4 to 5/8 inches and an inner electrode having a diameter of from 1/4 to ½ inches.

A passageway 14 is provided in the inventive device between the front section 16 and torch body T and is

defined by the internal conical walls of the front section 16 and inclined surfaces of the gas cup 33 and torch body T. The passageway 14 is of sufficient size to allow high rates of a gas flow such as air to be obtained without damage to the device. Such increased flow will further tend to increase the arc length so as to give greater arc voltages. Suitable dimensions for the passageway 14 are for the downstream end, that is for AB in the drawing, in the range of from 1/4" and 1 inch preferably 3/8 inch and for the upstream end, that is for CD, about the same order as AB and preferably larger by as much as 3/8" and can be as much as 1 inch larger. Therefore, passageway 14 is preferably converging in cross-section in order to give more streamlined flow of gas as it approaches the nozzle electrode 10 and to direct the air away from the tungsten electrode 20.

The passageway 14 has an included angle of between 120 and 150° so that the flow of air will tend to be streamlined with less turbulence and reverse eddy currents.

The approach velocity of the air stream is maintained relatively low, in the range of from about 10 to about 40 ft./sec. and preferably about 17 ft./sec. The low velocity approach does not mean, however, that the exit velocity of the hot gas effluent will be low. Such exit velocity for a given nozzle configuration is dependent upon the amount of heat in the effluent and the pressure into which gas is being emitted. Outlet velocities of at least 5000 ft./sec. have been attained with this device. The low approach velocity aids in providing less turbulent air flow.

In the present device gas cup 33 contains both the tungsten electrode 20 and the plurality of gas supply passages 23. The tungsten electrode 20 is uniquely water-cooled by passing cooling water around the cupped portions 32. These cupped portions allow the cooling water to come into contact with a greater area of the gas cup 33 in close proximity to the tungsten electrode 20. The recessed portion 34 of the gas cup 33 permits the shielding gas to be emitted from the passage 23 by passing the shielding gas flow parallel to and just grazing the face of the conical tungsten electrode so as to provide adequate shielding with a minimum of shielding gas flow and with a minimum of interference from the surrounding air streams in passageway 14. In prior art devices the shielding gases were usually supplied through annular passageways that were formed by the electrode holder or electrodes and a separate protective sleeve. In such devices separate cooling means had to be supplied to the protective sleeve.

The operation of the torch is as follows: A shielding gas, such as argon, is introduced into the device through the passage 21, the annulus 22 and the plurality of passages 23. The chemically inert gas will then mix with the surrounding air which is later introduced to the device as it passes out through the nozzle electrode 10. An arc is established between the tungsten electrode 20 and the nozzle electrode 10 at a point near the entrance of the nozzle electrode by any suitable means. The power supply for the torch is connected to the front section 16 at 17 and to the tungsten electrode cooling water connection 18 at 19. The front section 16 and the water connection 18 are in electrical contact with the nozzle electrode 10 and the tungsten electrode 20 respectively. Alternating current or direct current with straight or reverse polarity may be used as desired. Air or other gases is uniformly introduced into the nozzle electrode 10 by way of inlet 11, the plurality of streamlining nozzles 13, and the annular passageway 14. The arc that is finally established will, because of the set-back of the tungsten electrode and the increased air flow, be of a substantial length and will extend from the tip of the tungsten electrode 20 to an area downstream of the throat of the nozzle electrode.

The nozzle electrode 10 is cooled by passing cooling water from inlet 24 through and around the annuli 25,

26, and 27, and then out through outlet 28. The tungsten electrode 20 is internally cooled by injecting cooling water from inlet 29 through the annular space 31, then out through the inner tube 30 by way of the previously described cupped portions 32.

The following is an example of the operation of this novel device. In the example, apparatus of the type depicted in the accompanying drawing was used.

In this example, the electrode nozzle had a throat diameter of ¼ inch and an outlet diameter of ½ inch. The outer diameter was 1 inch. Air was supplied at the rate of 9000 c.f.h. Argon was supplied as the shielding gas at the rate of 1000 c.f.h. The combined flows yielded a chamber pressure of 220 p.s.i.g. With the nozzle acting as the anode, 400 amperes was supplied to the device. Under these conditions, the total power developed was 256 kw. of which 213 kw. went to the gas, the arc voltage was 640 v., the enthalpy of the gas was 1000 B.t.u./lb. and the calculated exit velocity of the hot gas effluent was 4500 ft./sec. which is approximately Mach 2.2 for these conditions. The torch efficiency based on the power to the gas was 83%.

Thus, it is seen that the torch operates at high efficiency yielding high arc voltages and gas velocities.

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 inert relative to the cathode such as helium, hydrogen, krypton, neon, nitrogen, xenon, carbon monoxide, and mixtures thereof may be used as shielding gas. Also other reactive gases may be used in place of air.

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 gas cup are replaceable.

What is claimed is:

1. An electric arc gas heater comprising in combination an electrode, a gas cup supporting said electrode, means for supplying a coolant to said gas cup, a plurality of gas passages in said gas cup, means for supplying shielding gas to said gas passages for flow along said electrode to protect such electrode from chemical attack and electrical erosion, an outer casing surrounding said electrode and gas cup in spaced concentric relation, means for supplying gas under pressure to the annular space formed therebetween, an insulator in said annular space between said casing and said electrode and gas cup and being provided with nozzle means for supplying gas under pressure to the vicinity of said electrode, a front section carried by said outer casing and having an internal conical passage surrounding said electrode and gas cup and communicating with said nozzle means to give streamline flow to said gas under pressure as it approaches the vicinity of said electrode, a nozzle electrode carried by said front section and spaced from and in axial alignment with said electrode and having a gas outlet comprising a throat leading to an expansion passage of divergent cross-section for expansion of gas as it is discharged therefrom, means for cooling said nozzle electrode and means for striking a high pressure arc between said nozzle electrode and electrode for heating the gas discharged from said nozzle electrode.

2. An arc torch comprising the combination of a torch body provided with a longitudinal gas passage for introducing a shielding gas to said torch and a longitudinal bore, an inner tube positioned in said longitudinal bore and defining an annular space with the walls of said longitudinal bore, means for introducing a cooling medium to said tube and annular space, a gas cup carried by the forward end of said torch body, a stick cathode carried by the front section of said gas cup, a cupped portion at the rear end of said gas cup and communicating with said inner tube and annular space for providing greater cooling of said stick cathode, a plurality of gas passages in said gas cup in communication with said longitudinal gas passage for permitting shielding gas to flow from said gas passage along said stick cathode, an outer casing partially surrounding said torch body and spaced therefrom, an insulator provided in the space between said casing and said torch body, a plurality of gas nozzles in said insulator, means for providing a gas under pressure to said nozzles, a torch front section carried by said outer casing, a nozzle electrode supported in said torch front section spaced from and in axial alignment with said stick cathode and having a gas outlet comprising a throat leading to an expansion passage of increasing diameter for the expansion of gas as it is discharged therefrom, a gas passage defined by the inner conical walls of the torch front section and the outside surfaces of the gas cup and forward section of the torch body for receiving said pressurized gas from said gas nozzles in said insulator and dimensioned to give a streamline flow to said gas as it approaches said throat of said nozzle electrode, means for striking a high-pressure arc between said nozzle electrode and said stick cathode for heating the gas discharged by said nozzle electrode, and means for cooling said nozzle electrode.

3. Apparatus according to claim 1 wherein said means provided in said insulator are eight symmetrically spaced gas nozzles.

4. Apparatus according to claim 1 wherein said nozzle electrode has a divergent section having a length of from about 1½ to 6 inches and has a throat diameter of from approximately ¼ inch to ⅝ inch.

5. Apparatus according to claim 1 wherein said nozzle electrode has an O.D.-to-I.D. ratio of about 1.7 to 8.0 at its point of smallest cross-section.

6. Apparatus according to claim 5 wherein said electrode is set back from about ½ to 1¼ inches from the throat of said nozzle electrode.

7. Apparatus according to claim 2 wherein said gas passage has a width of from about ¼ inch to about 1 inch.

8. Apparatus according to claim 2 wherein said gas passage has a width at its downstream end of from about ¼ inch to about 1 inch and the width of the upstream end is about ⅜ inch larger than the downstream width.

9. 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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