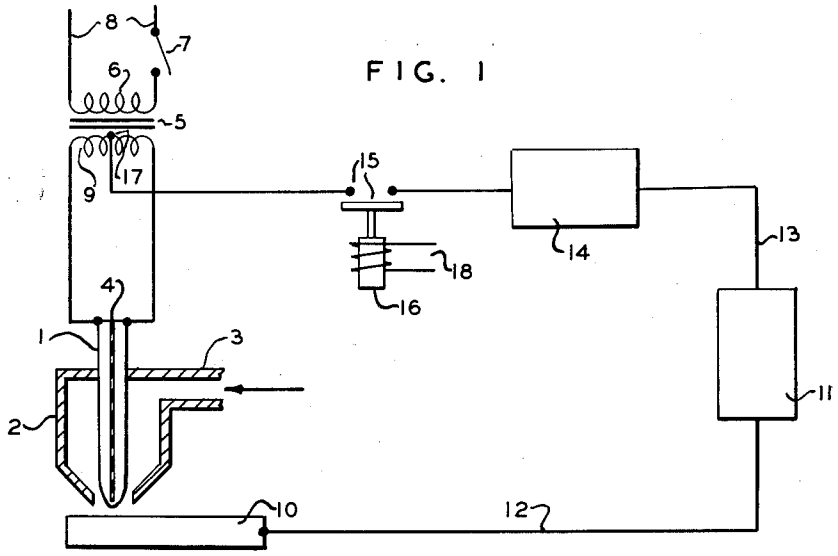
April 17, 1962 N. E. ANDERSON 3,030,495

INITIATION AND MAINTENANCE OF POWER ARCS

Filed April 27, 1959 3 Sheets-Sheet 1

FIG. 1



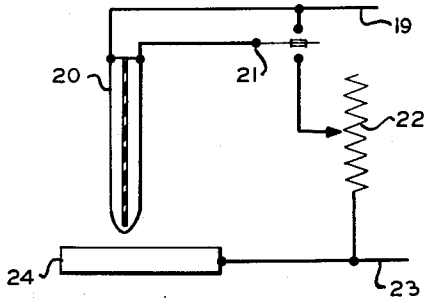
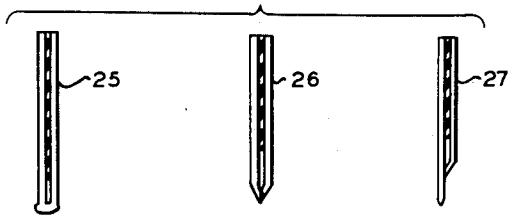


FIG. 2

FIG. 3



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INITIATION AND MAINTENANCE OF POWER ARCS

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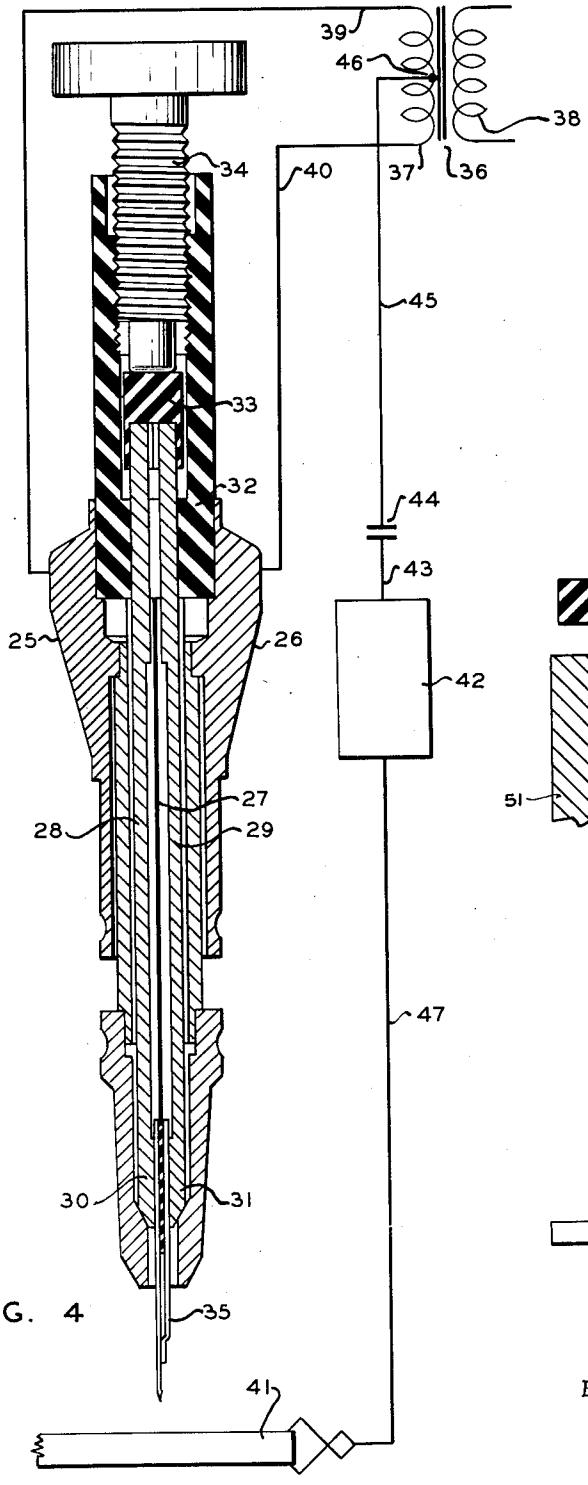
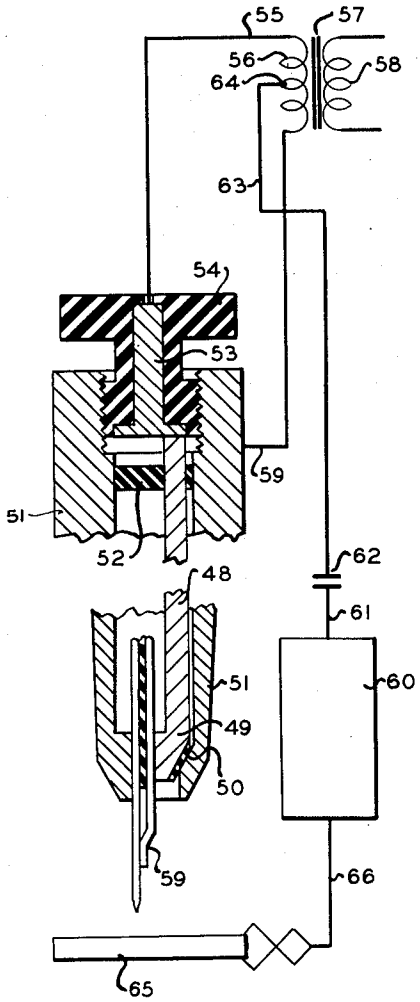


FIG. 4

FIG. 5



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INITIATION AND MAINTENANCE OF POWER ARCS

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FIG. 6

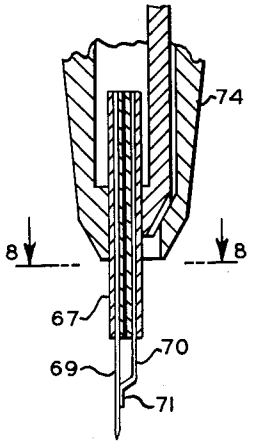


FIG. 7

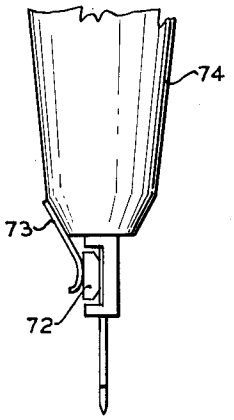


FIG. 8



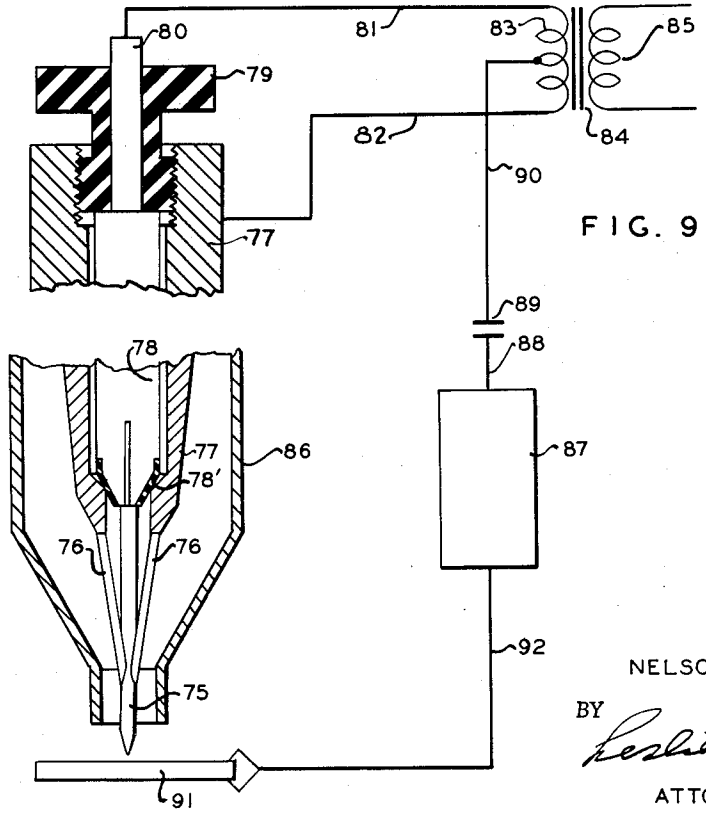


FIG. 9

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United States Patent Office 3,030,495
Patented Apr. 17, 1962

3,030,495

INITIATION AND MAINTENANCE OF POWER ARCS

Nelson E. Anderson, Berkeley Heights, N.J., assignor to Air Reduction Company, Incorporated, New York, N.Y., a corporation of New York

Filed Apr. 27, 1959, Ser. No. 809,033
22 Claims. (Cl. 219—131)

My invention relates to methods and apparatus for insuring the positive and prompt initiation of a power arc such as used in arc cutting and welding operations.

Conventional current sources for power arcs have an open circuit voltage which is adequate for maintaining an arc once it has been established, but which is inadequate for striking an arc across an operating arc gap between the electrodes which supply current to the arc. Consequently, some provision must be made for striking the arc.

Positive and prompt arc starting can be obtained by bringing the electrodes together and thereafter separating them. There are, however, operating conditions where this procedure is undesirable due to the time required to perform the operation or due to the contamination of one electrode by the metal of the other electrode which occurs when they are together at the time of striking the arc. Thus, in machine operations, the time to bring the electrodes together and thereafter separate them may be excessive in view of the frequency at which this operation must be performed or there may be an undesirable contamination of either electrode or both when they are of different material as in gas shielded arc welding and cutting with an arc established between a tungsten electrode and a workpart of aluminum or other material constituting the other electrode.

It has been the practice to avoid electrode contamination resulting from touch starting by using a high voltage spark discharge to break down the arc gap between an electrode and a workpart and establish an ionized conductive channel between them in which the power arc becomes established. This procedure, however, will cause some electrode sputtering with a consequent loss of electrode material and contamination of the workpart thereby. Furthermore, this spark discharge technique of arc starting is not as positive and prompt as touch starting due mainly to statistical factors which are inherent in gaseous discharges that are not self-sustaining. Thus, for example, for the same break down voltage, the elapsed time between the application of a spark producing voltage to the arc gap and the production of a spark discharge capable of establishing the power arc may vary from 1/60 of a second to 60 seconds. This uncertainty in starting time of the spark discharge and of the consequent flow of power arc current presents a serious problem when contamination of the electrode or workpart can not be tolerated and a power arc must be established within a specified small time interval. For instance, in welding or cutting with plural arcs, it is desirable that all of the arcs start in unison. If in welding the variation in starting times is large, incomplete welds for late starts and burn-throughs for early starts will result and in arc cutting failure of all the arcs to start at substantially the same time will result in an imperfect operation of the cutting procedure it is desired to employ.

The use of spark discharges for initiating the operation of power arcs is also objectionable for other reasons, the principal one of which is interference with radio and television communication. Since radio interference is caused by the harmonic components in each high voltage spark producing pulse and since these harmonics increase with the pulse amplitude, the pulse voltage must be kept

at the minimum value needed for striking and stabilizing the power arc. If the pulse magnitude is reduced to a value that keeps radio interference within presently established FCC specifications, the maximum electrode-to-work gap which the spark will jump is too short. Consequently, the pulse generators presently used must be set to supply the minimum voltage for spark break down of the power arc gap and any radio interference resulting therefrom must be tolerated. A preliminary mathematical study of this radiation problem indicates that the interference can be reduced by decreasing the number of high voltage pulses generated and used to initiate or stabilize the arc and arrangements have been proposed for limiting the number of these voltage surges employed and their application to the power arc circuit only when needed so that once the power arc has been established, the disturbance produced by these spark discharges is discontinued. Even so, it is desirable to reduce the pulse amplitude of the voltage employed for striking and maintaining the power arc.

In the case of direct current arcs, it is usually sufficient to provide these spark producing pulses only for striking the power arc whereas for alternating current power arcs, where the current goes through zero at each half cycle of the source of supply; it may be necessary to apply these sparking pulses at each of or alternate current zero periods of the power arc depending upon the electron emitting characteristics of the electrodes under operating conditions. These high voltage pulses are superimposed on the voltage of the power arc source and are usually applied to the electrodes at the same time that the power arc source is applied thereto. These high voltage arc starting pulses may be supplied by spark gap oscillators, fixed frequency oscillators, and a variety of surge current generators although there is a distinct preference for using spark gap oscillators. The usual spark gap oscillator will supply 4,000 volt pulses of a microsecond duration at a frequency rate of one every millisecond so long as the oscillator is in operation. Once the power arc has been initiated or reestablished when it goes to a low or zero current value, the operation of the oscillator may be interrupted in order to decrease radio interference to a minimum.

It is an object of my invention to facilitate the establishment of a maintained power arc across the arcing gap between an electrode and a workpart or counter electrode by supplying electric current through a circuit wholly contained within the electrode to provide by the internal resistance of the electrode a desired preheating effect at its arc supporting terminal portion.

It is a further object of my invention to condition an electrode by resistance heating the same by an internal current flow therethrough prior to initiating a power arc so that the voltage of the power arc current supply is in itself adequate to strike an arc across the arc gap between the preheated electrode and a workpart.

It is also an object of my invention to preheat an electrode by its resistance to current flow therethrough prior to the initiation of a power arc by spark discharges across the arc gap between it and a workpart in order to reduce the energy level of the sparking voltage and the time of its application and thereby reduce electrode consumption due to sputtering and the amount of radio interference produced by this sparking operation.

Further objects of my invention will become apparent from the following description of representative methods and apparatus which I employ to accomplish these results.

In accordance with my invention, resistance heating current and arc current are supplied to an electrode having relative to its arc supporting terminal portion, a series

path therethrough for heating current and parallel paths therethrough for arc current. The heating current thus supplied increases the temperature of the electrode and facilitates striking an arc across the arc gap between the electrode and a workpart. The electrode heating is accomplished under conditions requiring no high voltage sparking to complete the heating circuit and if a high voltage sparking circuit is employed to start the power arc, positive and immediate starts are obtained at energy levels in the sparking circuit which are greatly reduced relative to those heretofore employed with the result that electrode sputtering and electrode consumption is greatly reduced as is radio interference.

The positive and prompt arc starting thus accomplished by employing my invention makes it possible simultaneously to use a plurality of arcs to accomplish like operations on one or a plurality of workparts without encountering the difficulties heretofore experienced due to one or more of the plural arcs having a delayed start relative to the other arcs of the group. Furthermore, the positive and prompt starting of a single power arc accomplished by employing my invention is of great value when this arc is used in welding and cutting operations that are repeated at high frequency.

Electrode heating in accordance with my invention may be maintained after arc starting has been accomplished in order to stabilize the power arc and enable it to operate at low values of direct or alternating current. Thus by employing my invention, the size of the electrode need not be reduced for operation at low current values in the power arc since supplemental electrode heating may be obtained from the heating circuit in the electrode irrespective of the amount of power arc current flowing therethrough.

My invention is of particular utility when the power arc is supplied from a direct current source having its positive terminal connected to the workpart and its negative terminal connected to the electrode (straight polarity operation). Especially is this true when the electrode material is thermionic and a good electron emitter when heated. Materials may be added to the electrode to contribute their free electron emitting characteristics to the electrode material. My invention is not, however, limited to straight polarity direct current arc starting and stabilization, but is also applicable to the starting and stabilization of reverse polarity direct current arcs and to the starting and stabilization of alternating current arcs.

Certain features and advantages of my invention have been considered above. These and further features and advantages will become apparent from a consideration of the structures and uses of the specific embodiments thereof illustrated in the accompanying drawings in which:

FIG. 1 is a diagrammatic representation of an arc welding system embodying my invention as applied to gas shielded arc welding wherein the welding arc is established between a non-consuming tungsten electrode and a workpiece in a shielding atmosphere of a suitable gas. In this system, a separate source of current is provided for resistance heating the arc supporting terminal portion of the electrode, and arc welding current and high voltage sparking current are simultaneously connected across the arc gap to initiate the welding arc after the arcing terminal of the electrode has been heated to a suitable temperature.

FIG. 2 is a diagrammatic representation of a circuit that may be employed for supplying heating current to the welding electrode from the source of supply used for energizing the arc.

FIG. 3 shows three forms of electrodes that may be used in practicing my invention.

FIG. 4 illustrates one form of electrode holder forming part of a gas-arc welding torch which may be used in practicing my invention.

FIG. 5 shows another form of electrode holder that may be used in practicing my invention.

FIGS. 6, 7 and 8 show another form of apparatus that may be used in practicing my invention where the parts of the split electrode are of small size and require reinforcement for mounting in an electrode holder.

FIG. 9 shows apparatus that may be employed for supplying heating current to a solid electrode which may be used in place of the divided electrode shown in the preceding figures.

In the apparatus diagrammatically represented in FIG. 1, a tungsten electrode **1** is suitably supported in a gas nozzle **2** with its arc supporting terminal portion in or extending slightly through the open tip thereof. A shielding gas is supplied through a conduit **3** to the interior of nozzle **2** from which it is discharged through its open tip about the arc supporting terminal portion of the electrode, and during welding, about the arc struck between the electrode and a workpart and that portion of the workpart rendered molten by the arc. The shielding gas may be argon, helium, hydrogen, nitrogen, etc. or suitable mixtures thereof depending on the conditions it is desired to establish at the welding arc and at the welding zone in the workpart.

Electrode **1** is divided lengthwise thereof into two parts separated from one another by an electrically insulating material **4** except at its arc supporting terminal portion where the parts are conductively joined to one another. If the conductive connection between the parts of the electrode is formed by a fused union which progressively recedes along the electrode as it erodes during welding, the insulating material should be of a character which progressively disintegrates lengthwise of the electrode with the consumption of the electrode at its arc supporting terminal to permit a progressively fused union of the parts to maintain the conductive connection between these parts at the arc supporting terminal portion of the electrode. This insulating material may be a thin film of aluminum oxide or an equivalent material such as various silicates and it may contain if necessary a material for bonding the electrode parts to one another, a flux that will facilitate a fused union between the electrode parts, or some material that will contribute its free electron emitting characteristics to the electrode material.

Heating current is supplied to electrode **1** by a transformer **5** having a primary winding **6** connected through a switch **7** to a source of heating current supply **8** and a secondary winding **9** the end terminals of which are respectively connected to the two parts of the electrode. The amount of heating current supplied through the electrode will depend upon its size and should be adequate to heat the electrode to the desired temperature prior to supplying welding current and arc starting voltage across the operating arc gap between the electrode **1** and the workpiece **10**. The secondary voltage of transformer **5** is made sufficient to supply the desired current through the electrode and its connections with secondary winding **9** and will usually be from one to five volts. An adjustable impedance may be inserted in the primary or secondary circuit of transformer **5** to adjust the heating current value supplied to the electrode **1**. Alternatively the turn ratio of the transformer windings may be made adjustable or means may be provided for altering the spacing and consequent coupling of the transformer windings. Other means may be provided for adjusting the heating current.

The amount of current generally supplied through the electrode should be sufficient to heat its arc supporting terminal portion to a temperature at which it begins to show a heat color if a high voltage source of sparking current is superimposed on the welding current supply to initiate current flow across the arc gap and start the welding arc. If, however, arc starting is to be accomplished across the gap between the electrode and the workpart by the voltage of the welding current source without the use of a high voltage sparking current, the electrode should be heated to a higher temperature, even

up to incandescence to duplicate conditions of electrode heating during welding when it is possible to restrike an arc immediately after its extinguishment without touching the electrode to the workpiece due to the retained heated condition of the electrode being substantially the same as when operating with a maintained arc.

In the arrangement shown in FIG. 1, one terminal of a source **11** of arc welding current is connected to the workpiece **10** by a conductor **12** and its other terminal is connected through a conductor **13** in circuit with a source of sparking voltage **14** and the contacts **15** of a contactor **16** to a mid-terminal **17** of the secondary **9** of the heating current transformer **5**. The flow of welding current, which may be alternating or direct, splits through the secondary winding **9** of the heating current transformer **5** and prevents saturation of the core of this transformer should it be desired to keep this transformer energized to supply additional electrode heating during arc welding. When a direct current source is employed for supplying the welding arc, its negative terminal is preferably connected to the electrode for straight polarity welding. The contactor **16** is provided with an actuating coil **18** by means of which it is operated to complete and interrupt the welding circuit. When the welding contactor completes the welding circuit, welding current and high voltage arc starting current are simultaneously applied across the operating arc gap between electrode **1** and workpiece **10**.

Instead of using a separate source for supplying heating current to the electrode, the electrode may be heated through a branch circuit energized from the welding current source of supply as shown in FIG. 2. In this circuit, one welding circuit conductor **19** is directly connected to one part of the divided electrode **20** and the other part of this electrode is optionally connected through a switch **21** to the same welding conductor **19** or through an adjustable resistor **22** to the other welding circuit conductor **23** which is connected to the workpiece **24**. Thus, in one circuit making position of switch **21**, a heating circuit is completed through the electrode and through resistor **22** from the source of welding current supply to provide heating current flow through the electrode and in the other circuit making position of switch **21**, both parts of the electrode are connected in parallel with one another for the flow of arc welding current through the electrode to the workpart **24** in circuit with the welding conductors **19** and **23**. When switch **21** is in a mid or open position, the arc welding current flow is confined to one part only of the divided electrode **20**. There are conditions when such operation may be desirable as when welding at low current values and it is desirable to decrease the effective cross section of the electrode to increase the heating effect of arc current flow therethrough.

Usually it is not necessary or required that heating current be supplied to the electrode after the welding arc has been established between it and the workpiece, and the circuit employed in FIG. 2 operates in this manner. There are conditions, however, where it is desirable to continue to supply heating current to the electrode after the welding arc has been established in order to provide a desired heating of the electrode when its arcing terminal is not sufficiently heated by the flow of arc welding current therethrough. Such a condition may exist when welding with low arc current values or when the parts of the electrode are formed of thoriated tungsten which normally has an operating temperature considerably lower than the fusion temperature of tungsten. The formation of the fused metal bridge between the electrode parts at its arcing terminal by the heating current is in a measure self-regulating since more heat is generated by the heating current due to the higher resistance of the bridge when it is of small cross sectional area.

The split electrode structure which I employ may be prefabricated or may be formed in the electrode holder therefor, by fusing together corresponding ends of twin electrodes by an arc fed by the welding current source of supply and struck between them and a workpiece or a substituted block of carbon. In this way, the corresponding ends of the twin electrodes will be fused together at their arc supporting terminal portions and form an electrode having a series path therethrough for heating current and parallel paths therethrough for arc current. Such an electode is shown at **25** in FIG. 3.

The electrodes may, however, be prefabricated as shown at **26** and **27** of FIG. 3. Electrode **26** is formed by resistance welding together corresponding ends of the parts thereof to form the arc supporting terminal portion of the split electrode and the resistance welding jaws used for this purpose may also be shaped to provide a pointed tip on the end of the split electrode. It is not necessary, however, that the parts of the split electrode be conductively joined to one another at the extremity of the electrode as exemplified by electrodes **25** and **26** of FIG. 3. The connection between the parts of the split electrode may be formed at some distance from the end of one of the parts of the electrode as in electrode **27** of FIG. 3. Electrode **27** comprises an assembly of parts extending lengthwise of one another and electrically insulated from one another except at the end of one of the parts which is joined by a weld to the other of the parts at a location spaced from the corresponding end of this other part. The end of this other part of the electrode which projects beyond the weld between the electrode parts may be suitably pointed as is the practice when using thoriated tungsten of which these parts may be formed. If the extension formed by one of the parts of the electrode is too great, the welding arc may be initiated by the higher temperature portion of the electrode above the weld between the parts but will rapidly transfer and root itself on the tip of the projecting part. I have found that with $\frac{1}{16}$" electrode material for the parts thereof, satisfactory operation is obtained with a $\frac{3}{8}$" electrode extension of one of the parts beyond the weld joining the parts. This arrangement allows several reshaping operations to point the projecting tip portion of the electrode before it is fully consumed up to the weld junction. Thereafter the end of the electrode containing the weld may be removed and a new assembly made to secure the structural arrangement embodied in electrode **27** of FIG. 3.

Various arrangements may be provided for holding the split electrode structure which I employ and for supplying heating current through the series path therein and arc current through the parallel paths therein. Arrangements suitable for this purpose have been illustrated in FIGS. 4, 5 and 6 to 8 inclusive which, in each case, illustrate modified electrode holders for a gas-arc welding torch such as the M–50 Heliweld Machine Holder manufactured and sold by Air Reduction Company, Incorporated.

In FIG. 4 the electrically conductive body portion of the electrode holder has been split lengthwise thereof into two parts **25** and **26** and reassembled by cementing the two parts together with an electrically insulating cement **27**. Two separate electrically conductive collet members **28** and **29** having electrode engaging jaw portions **30** and **31** are contained within and extend longitudinally of the collet chamber within the body portion of the electrode holder. The inner ends of these collet members are held in spaced position relative to one another by members **32** and **33** of insulating material which respectively serve as guides for the collet members and means for exerting end pressure on the inner ends of these collet members. Member **32** is supported in the upper end of the split holder **25—26** in a cavity forming a continuation of the collet chamber therein. End pressure is applied to collet members **28** and **29** by a screw **34** which makes a threaded engagement with the wall of a bore in member **32** in which member **33** is interposed between the end of this pressure screw and the ends of collet members **28**

and 29. The pressure thus applied to the inner ends of collet members 28 and 29 forces their outer conical shaped ends against the conical collet seat in body member 25—26 and causes their jaw members 30 and 31 to be brought into clamping engagement with the side walls of the two parts of the split electrode 35 which has the construction of electrode 27 of FIG. 3. The arrangement is such that the two separate electrically conductive collet members are operated mechanically as a unit but are electrically isolated from one another.

Heating current is supplied through the split electrode 35 by a transformer 36 having a secondary winding 37 and a primary winding 38 which is connected to a suitable source of alternating current supply. One end terminal of secondary winding 37 of transformer 36 is connected through a conductor 39 to part 25 of the electrode holder body and the other end terminal thereof is connected through a conductor 40 to part 26 of the electrode holder body which is electrically insulated at 27 from part 25 thereof. Thus, heating current is supplied to the electrode from one end terminal of the secondary winding 37 of transformer 36 through conductor 39, part 25 of the electrode holder, contact jaw 30 of collet member 28, the series circuit through electrode 35, jaw 31 of collet member 29, part 26 of the electrode holder, and conductor 40 to the other end terminal of secondary winding 37.

Arc welding current is supplied to the arc established between electrode 35 and workpart 41 from one terminal of a welding generator 42, through a conductor 43, the contacts 44 of a welding contactor, a conductor 45, the mid-terminal 46 of secondary winding 37, conductors 39 and 40 in parallel, electrode holder body parts 25 and 26 in parallel, jaws 30 and 31 of collet members 28 and 29 and both parts of the electrode 35 to the workpart 41 and a conductor 47 which is connected to the other terminal of the source of welding current supply. Thus, heating current is supplied through a series path in the welding electrode 35 and arc welding current is supplied through parallel paths therein to the arc established between its arc supporting terminal portion and the workpiece.

FIG. 5 shows an electrode holder by means of which the heating current may be supplied through the series path in the split electrode without using an electrode holder of split construction. In this arrangement, a single electrically conductive collet member is enclosed within and insulated from the body portion of the holder which is electrically conductive. This collet member 48 has a jaw member 49 the back of which is coated with a layer of insulating material 50 where it engages the collet seat formed in the electrode holder body 51. This collet seat is positioned opposite an electrode engaging portion of the electrode holder body 51 so that lengthwise movement of collet 48 against its collet seat forces the jaw member 49 of the collet against one side of the electrode and holds the other side of the electrode in engagement with the electrode engaging portion of the holder body 51. The upper end of collet member 48 is positioned in and insulated from holder body 51 by an insulating washer 52 so that the collet member 48 in its entirety is electrically insulated from the body portion of the electrode holder 51. The upper end of this collet member 48 makes a sliding end engagement with a metallic insert 53 in the stem portion of a pressure screw 54 which makes a threaded engagement with the upper end of an extension of the collet chamber in electrode holder body 51. This insert 53 of pressure screw 54 is connected by a conductor 55 to one end terminal of the secondary winding 56 of a heating current transformer 57 having a primary winding 58 which is connected to a suitable source of alternating current supply. The other end terminal of secondary winding 56 of transformer 57 is connected through a conductor 59 to body portion 51 of the electrode holder. Thus, heating current is supplied through conductor 55, metallic insert 53 of pressure screw 54, collet member 48 to one part of the split electrode 59 and from the other part of split electrode 59 through electrode holder body 51 and conductor 59 to the other end terminal of the secondary 56 of the heating current transformer.

Arc welding current is supplied from one terminal of a welding generator 60, through a conductor 61, contacts 62 of a welding contactor, a conductor 63, the mid-terminal 64 of the secondary 56 of transformer 57, the two halves of this secondary winding, conductors 55 and 59 in parallel, insert 53 of pressure screw 54 and collet member 48 in parallel with the body 51 of the electrode holder and the two halves of the split electrode 59 to the arc established between it and workpiece 65 which is connected through a conductor 66 to the other terminal of the welding generator 60. The layer of insulation 50 between the jaw portion 49 of collet member 48 and the seating surface for this jaw member in electrode holder body 51 may be formed by anodizing the surface of the collet member 48 and thereafter vacuum impregnating it with an insulating resin. Since the voltage drop in the electrode is of the order of 1 to 5 volts, this insulating coating 50 may be made thin to provide good heat transfer from collet 48 to holder body 51 and yet provide sufficient insulation for the voltage drop across this layer of insulation.

When arc welding with low current values and a small size split electrode, it may prove desirable to reinforce the electrode parts by employing the adapter extension illustrated in FIGS. 6, 7 and 8 of the drawings. As shown in these figures, the adapter comprises a double-hole copper tube 67 that has been split lengthwise between the two holes and then assembled by cementing together the two halves with an insulating cement 68. The two parts 69 and 70 of the split electrode 71 are inserted in the electrode passageways provided by the holes in the adapter and are held in engagement with the side walls of these passageways by a shoe 72 of ceramic or other insulating material which is located in a side wall opening in the adapter which exposes the electrode parts in these passageways. Shoe 72 is held in engagement with parts 69 and 70 of the electrode 71 by a spring 73 which is attached to the end of the body portion 74 of the electrode holder as shown in FIG. 7. The electrode holder is shown as having the construction previously described above and illustrated in FIG. 5. With the arrangement thus provided, it will be seen that the adapter extension thus employed supplies heating current and welding current to the electrode in the manner above described in connection with FIG. 5.

The welding electrode need not be of divided construction in order to provide a path therethrough for the flow of heating current. In FIG. 9, I have shown one form of electrode holder by means of which the electrode heating current is supplied through a series circuit in a section of a solid electrode which is spaced from its arc supporting terminal portion. In this arrangement, the electrode 75 is held by a collet clamp and heating current is supplied through the section of the electrode which is between the collet clamp and a pair of jaws 76 which are attached to the electrode holder body portion 77 in which the collet member 78 is located and electrically insulated therefrom. The upper end of collet 78 is spaced from the collet chamber by a pressure screw 79 of insulating material which is threaded into the upper end of the holder body 77. The wedging surfaces between the jaws of collet 78 and its seat in the holder body 77 are insulated from one another by a layer of insulation 78' applied to the end of collet 78. Current is supplied to collet 78 through a metallic insert 80 in screw 79 which extends therethrough and forms a part of the collet. Insert 80 of screw 79 and the body portion 77 of the electrode clamp are respectively connected through conductors 81 and 82 to the end terminals of the sec-

ondary winding 83 of the heating transformer 84 whose primary 85 is connected to a suitable source of alternating current supply. Thus, a conductive circuit through the section of the electrode adjacent its arc supporting terminal portion is completed through conductor 81, insert 80, collet 78, jaws 76, electrode holder body 77 and conductor 82. Shielding gas is supplied about the arcing terminal of the electrode through a nozzle structure 86. Arc welding current is supplied to the electrode from one terminal of a welding generator 87, through a conductor 88, contacts 89 of a welding contactor, a conductor 90, the two halves of secondary winding 83 of transformer 84, conductors 81 and 82 in parallel, collet 78 in parallel with electrode body 77 and jaws 76 attached thereto, electrode 75, workpiece 91 and a conductor 92 to the other terminal of the welding generator 87.

By employing two tapered jaw members 76 as shown in FIG. 9, a non-turbulent gas flow can be obtained through nozzle 76 and about the arcing terminal portion of the electrode. Two jaws are preferably used since if a single jaw were employed, the necessary pressure engagement between the jaw and the electrode would deform the electrode. Furthermore, a single jaw would cause turbulence of the gas stream supplied through the torch nozzle 76 about the arcing terminal of electrode 75. Jaw members 76 are cooled by the cooled body portion 77 of the holder and consequently produce a chilling effect on the electrode so that the electrode section above the jaw members must be maintained at a comparatively high temperature to maintain the electrode tip at a desired operating temperature.

The specific embodiments of my invention above described have all been for gas shielded arc welding with an arc established between a non-consuming electrode and a workpiece. My invention is, however, not to be so limited in its application since the principles involved therein apply to preheating an electrode or electrodes by a supply of resistance heating current therethrough in order to facilitate the starting and maintenance of a power arc at or near atmospheric pressures irrespective of the use made of the power arc.

Thus, my invention is applicable wherever it is desired to start and maintain a power arc across the operating arc gap between electrodes or an electrode and a workpiece. It is not limited to the preheating of thermionic non-consuming electrodes since it may be applied readily to welding with consuming electrodes of split construction constituting the equivalent of the twin electrode example given above in connection with welding with non-consuming electrodes. Of course, with consuming electrodes means must be provided for feeding the electrodes in accordance with their consumption in the arc, but such means are known or can be readily devised in view of the known prior art. Obviously, my invention is not limited to welding in a shielding gas since the arc starting action accomplished thereby may take place in air or other media so long as the presence of such media does not interfere with the methods and means for arc starting and arc maintenance which I have disclosed above.

Thus in view of the above description of my invention, modifications and applications thereof other than those specifically considered will occur to those skilled in the art to which it relates. I, therefore, aim to cover by the appended claims all such modifications and adaptations of my invention which fall within the true spirit and scope thereof.

What I claim is:

1. Apparatus for supplying heating current and arc current to an electrode having relative to its arc supporting terminal portion a series path therethrough for heating current and parallel paths therethrough for arc current, said apparatus comprising means for supplying arc current through at least one of said parallel paths in said electrode to an arc established between its arc supporting terminal portion and a workpart, and means for supplying heating current through said series path in said electrode to produce a resistance heating effect at its arc supporting terminal portion.

2. Arc welding apparatus comprising an electrode having relative to its arc supporting terminal portion a series path therethrough for heating current and parallel paths therethrough for arc welding current, means for supplying arc welding current through said parallel paths in said electrode to an arc established between its arc supporting terminal portion and a workpart, and means for supplying heating current through said series path in said electrode to produce a resistance heating effect at its arc supporting terminal portion.

3. Arc welding apparatus comprising an electrode having relative to its arc supporting terminal portion a series path therethrough for heating current and parallel paths therethrough for arc welding current, means for supplying heating current through said series path in said electrode to produce a resistance heating effect at its arc supporting terminal portion, and means for simultaneously supplying through said parallel paths in said electrode an arc initiating current and an arc welding current respectively to strike and thereafter maintain an arc between the arc supporting terminal portion of said electrode and a workpart.

4. A holder for an electrode having an internal heating circuit completed through parts thereof which are electrically insulated from one another lengthwise of said electrode except at its arcing terminal and which have external contact surfaces extending lengthwise of said electrode through which heating current may be supplied to its said internal heating circuit, said holder comprising a nozzle having an open tip through which gas supplied to said nozzle is discharged, means for supporting said electrode in said nozzle with its arc supporting terminal portion at the open tip thereof, means for supplying a shielded gas to said nozzle from which its discharge through its open tip about the arc supporting terminal portion of said electrode, means including contacts positioned in said holder to engage the external longitudinal surfaces of said parts of said electrode for supplying current through the internal heating circuit of said electrode, and means including said contacts for supplying arc current through said electrode to its arc supporting terminal portion.

5. Arc welding apparatus comprising an electrode having an internal heating circuit completed through parts thereof which are electrically insulated from one another lengthwise of said electrode except at its arc supporting terminal portion and which have longitudinal external contact surfaces through which current may be supplied to said internal heating circuit, a nozzle having an open tip through which gas supplied through said nozzle is discharged, means for supporting said electrode in said nozzle with its arc supporting terminal portion at the open tip thereof, means for supplying a shielding gas to said nozzle for discharge through its open tip about the arc supporting terminal portion of said electrode, means including contacts in said apparatus which engage the longitudinal external surface of said parts of said electrode for supplying heating current through the internal circuit in said electrode, and means including said contacts for supplying arc welding current through said electrode to its arc supporting terminal portion.

6. An electrode holding collet clamp having a hollow body member of electrically conductive material divided lengthwise into two parts electrically insulated from one another and enclosing a collet chamber terminating in a collet seat adjacent its open end, two collet members of electrically conductive material in and extending lengthwise of said collet chamber, each of said collet members having adjacent the open end of said body member a jaw at its outer end with an end surface which mates with and makes an electrically conductive engagement with

that portion only of said collet seat formed in one of said parts of said hollow body with which it coacts upon lengthwise movement relative thereto to force its jaw into clamping engagement with an electrode located between said jaws of said collet members, insulating means for holding said collet members in spaced relation relative to one another and said body member and for guiding them in their longthwise travel relative to said body member, means mounted on said body member for applying endwise pressure to the inner ends of said collet members and means for respectively connecting electric conductors to each of said parts of said body member.

7. An electrode holding collet clamp having a body member of electrically conductive material enclosing a collet chamber which terminates in a collet seat on one side of the open end of said body member which is opposite an electrode engaging surface of said body member in its said open end, a collet member located in said collet chamber of said body member and electrically insulated therefrom, said collet member having a jaw end with a surface which mates with said collet seat in said body member for movement of said jaw toward said electrode engaging surface in the open end of said body member upon lengthwise movement of said collet member relative to said body member, means mounted on said body member for forcing said collet member lengthwise of said body member toward said collet seat therein, and means for respectively connecting electric conductors to said collet member and to said body member.

8. An electrode holder having opposed electrically conductive clamping members electrically insulated from one another, an adapter divided lengthwise into two parts of electrically conductive material which are electrically insulated from one another, said adapter being insertable between said clamping members of said holder with each part thereof in electrical contact with only one of said clamping members and said adapter having in each part thereof an electrode passageway which extends lengthwise thereof from one end of said adapter past an opening in the side wall of said adapter which exposes both of said passageways, a shoe located in said side wall opening in said adapter and spanning said electrode passageways in the parts thereof from which it is electrically insulated, and means for biasing said shoe towards said adapter.

9. An electrode holding collet clamp comprising a hollow body member of electrically conductive material having therein a collet chamber terminating near the open end of said hollow body in a collet seat, a hollow collet member of electrically conductive material located in said collet chamber of said body member and having a split end portion with an external configuration for mating with said seat in said body member, means for electrically insulating said collet member from said body member, means for forcing said collet member lengthwise of said body member against its seat in said body member to close its split end portion into clamping engagement with an electrode extending through said collet member and the open end of said body member, jaw members of electrically conducting material conductively connected to said body member and projecting beyond the open end thereof, said jaw members being biased toward one another for engaging an electrode projecting from the open end of said body member, and means for respectively connecting electrical conductors to said collet member and to said body member.

10. Apparatus for arc welding and cutting comprising an elongated electrode having lengthwise thereof a circuit through which current is supplied to produce resistance heating of its arc supporting terminal portion, a transformer having a primary winding and a secondary winding, connections completing a series circuit through said secondary winding of said transformer and said resistance heating circuit in said electrode, a terminal which is connected through substantially equal turns of said secondary winding of said transformer to said connections between said secondary winding and said resistance heating circuit in said electrode and through which arc current is supplied to the arc supporting terminal portion of said electrode, and means for establishing at atmospheric pressure a shielding gas about the arc supporting terminal portion of said electrode.

11. An arc welding electrode of electrically conductive material divided lengthwise thereof into parts electrically insulated from one another except where conductively joined to one another at the arc supporting terminal portion of said electrode which in use is fusible and erodes during welding so that its arc supporting terminal portion progressively recedes lengthwise thereof, the material by which said parts of said electrode are electrically insulated from one another being progressively disintegrated lengthwise of said electrode with its arc erosion to permit during welding a progressively fused union of said parts to maintain said conductive connection therebetween at the arc supporting terminal portion of said electrode.

12. An arc welding electrode comprising an assembly of electrically conductive parts extending lengthwise of one another and electrically insulated from one another except at the end of one of said parts which is joined by a weld to the other of said parts at a location spaced from the corresponding end of said other part which forms a projecting arc supporting tip on said electrode.

13. An arc welding electrode of electrically conductive material divided lengthwise thereof into parts separated from one another by an electric insulating material which, upon erosion during welding of the arc supporting terminal portion of said electrode formed at the end thereof by a fused union of corresponding ends of said parts, progressively disintegrates lengthwise of said electrode with the recession of its said arc supporting terminal portion to permit a progressive fused union of said corresponding ends of said parts to maintain its said arc supporting terminal portion.

14. An arc welding electrode of electrically conductive material divided lengthwise thereof into parts separated from one another by an electric insulating material which, upon erosion during welding of the arc supporting terminal portion of said electrode formed by a fused union of corresponding ends of said parts, progressively disintegrates lengthwise of said electrode with the recession of its said arc supporting terminal portion to permit a progressive fused union of said corresponding ends of said parts to maintain its said arc supporting terminal portion, each of said parts of said electrode having exposed conductive surfaces extending lengthwise of said electrode along said parts for the supply of electric current to said parts.

15. The method of striking and maintaining an arc with current supplied from a source having a voltage which will maintain an arc across an operating arc gap between an electrode and a workpart after the flow of arc current across said gap has been initiated, said method comprising utilizing an electrode of electrically conductive material divided lengthwise thereof into parts separated from one another by an electric insulating material which, upon erosion with usage of the arc supporting terminal portion of said electrode formed by a fused union of corresponding ends of said parts, progressively disintegrates lengthwise of said electrode with the recession of its said arc supporting terminal portion to permit a progressive fused union of said corresponding ends of said parts to maintain its said arc supporting terminal portion, fusing together the corresponding ends of the parts of said electrode to form at one end thereof its said arc supporting terminal portion, spacing said arc supporting terminal portion of said electrode from said workpart by the operating arc gap of an arc to be maintained therebetween by said source of arc current supply, and supplying electric resistance heating current through a circuit completed through

said parts of said electrode and its said arc supporting terminal portion to produce at its said arc supporting terminal a temperature at which an arc will strike across said gap between said electrode and said workpart at said voltage of said source of arc current supply.

16. The method of striking and maintaining an arc with current supplied from a source having a voltage which will maintain an arc across an operating arc gap between an electrode and a workpart after the flow of arc current across said gap has been initiated, said method comprising utilizing an electrode of electrically conductive material divided lengthwise thereof into parts separated from one another by an electric insulating material which, upon erosion with usage of the arc supporting terminal portion of said electrode formed by a fused union of corresponding ends of said parts, progressively disintegrates lengthwise of said electrode with the recession of its said arc supporting terminal portion to permit a progressive fused union of said corresponding ends of said parts to maintain its said arc supporting terminal portion, fusing together corresponding ends of the parts of said electrode to form at one end thereof its said arc supporting terminal portion, spacing said arc supporting terminal portion of said electrode from said workpart by the operating arc gap of an arc to be maintained therebetween by said source of arc current supply, supplying electric current through a circuit completed through said parts of said electrode and the fused union between said parts to produce by the electric resistance of said circuit a heating effect at said arc supporting terminal portion of said electrode, and applying across said gap a voltage of sufficient magnitude to produce between said heated electrode and said workpart a pulse of current which initiates an arc which is thereafter maintained by current supplied from said source.

17. The method of establishing a power arc across the arcing gap between an electrode and its counter electrode which comprises facilitating the establishment of said arc by preheating the arc supporting terminal portion of said electrode with resistance heating current supplied through said electrode in series circuit with current conducting contacts engaging spaced surfaces on said electrode, and establishing said arc with current supplied through the preheated terminal portion of said electrode by said contacts connected in parallel with one another to a source of supply having a voltage which unaided is insufficient to strike an arc across said gap but which is sufficient to maintain an arc across said gap after a flow of current across said gap has been initiated by preheating the terminal portion of said electrode.

18. Arc striking apparatus comprising a thermionic non-consuming welding electrode which in use is spaced from a workpart by an operating gap of substantially the length of a welding arc to be maintained therebetween, means for applying to said electrode the negative potential of a source of arc welding current having a voltage which unassisted is insufficient to strike an arc across said gap but which is sufficient to maintain an arc across said gap after a flow of arc welding current across said gap has been initiated, and means for supplying resistance heating current through said electrode between current conducting contacts which are in surface engagement therewith to preheat the arc supporting terminal portion of said electrode to a temperature producing an electron emission therefrom which initiates current flow across said gap from said source of arc welding current.

19. Arc striking apparatus comprising a thermionic non-consuming welding electrode which in use is spaced from a workpart by an operating gap of substantially the length of a welding arc to be maintained therebetween, means for applying to said electrode the negative potential of a source of arc welding current having a voltage which unassisted is insufficient to strike an arc across said gap but which is sufficient to maintain an arc across said gap after a flow of arc welding current across said gap has been initiated, means for connecting a source of arc initiating sparking voltage across said arc gap, and means for resistance heating the arc supporting terminal portion of said thermionic electrode to an electron emitting temperature at which the energy level of said arc initiating sparking voltage and the time of its application are reduced with the consequent reduction of the consumption of said electrode due to sputtering and the amount of radio interference produced by said sparking voltage, said resistance heating current being supplied through said electrode between current conducting contacts which are in surface engagement therewith and which also serve to supply arc current through the preheated terminal portion of said electrode from said source of arc welding current.

20. The method of initiating a welding arc which comprises positioning a thermionic non-consuming electrode relative to a workpart to provide an operating arc gap therebetween, applying negative voltage to said electrode by connecting across said gap a source of arc welding current which unassisted is insufficient to strike an arc across said gap but which will maintain an arc across said gap after a flow of arc welding current across said gap has been initiated, and supplying resistance heating current through said electrode between current conducting contacts which are in surface engagement therewith to preheat the arc supporting terminal portion of said thermionic electrode to a temperature producing an electron emission therefrom at which current will flow across said gap from said source of arc welding current.

21. The method of initiating a welding arc which comprises positioning a thermionic non-consuming electrode relative to a workpart to provide an operating arc gap therebetween, applying through a pair of contacts which are in surface engagement with and adjacent the arc supporting terminal portion of said electrode a negative voltage of a source of arc welding current which is connected across said gap and whose voltage is insufficient to strike an arc across said gap but which will maintain an arc across said gap after a flow of arc welding current across said gap has been initiated, and supplying resistance heating current through said electrode and between said contacts to preheat the arc supporting terminal portion of said thermionic electrode to a temperature producing an electron emission therefrom at which current will flow across said gap from said source of arc welding current.

22. The method of initiating a welding arc which comprises positioning a thermionic non-consuming electrode relative to a workpart to provide an operating arc gap therebetween, applying negative voltage to said electrode by connecting across said gap a source of arc welding current which unassisted is insufficient to strike an arc across said gap but which will maintain an arc across said gap after a flow of arc welding current across said gap has been initiated, applying sparking voltage across said gap to initiate current flow across said gap from said source of arc welding current, and reducing the energy level of said arc initiating sparking voltage and the time of its application across said gap by resistance heating the arc supporting terminal portion of said thermionic electrode by supplying electric current through said electrode between current conducting contacts which are in surface engagement with said electrode and which also serve to supply the arc current through the preheated terminal portion of said electrode from said source of arc welding current.

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