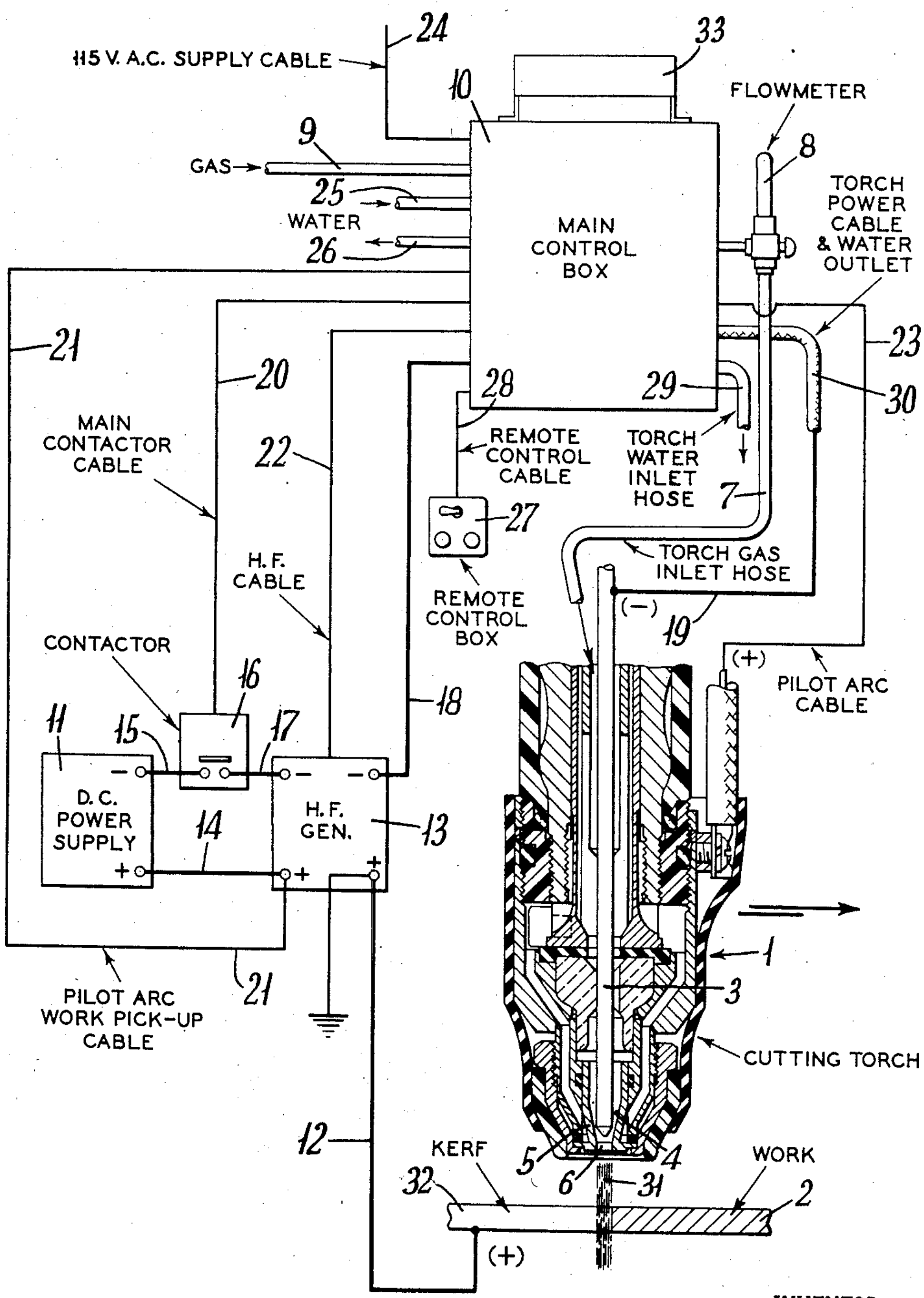
May 12, 1959 G. W. OYLER ET AL 2,886,692

CONSTRICTED ARC METAL REMOVAL

Filed May 23, 1956



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United States Patent Office

2,886,692

Patented May 12, 1959

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CONSTRICTED ARC METAL REMOVAL

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Application May 23, 1956, Serial No. 586,689

7 Claims. (Cl. 219—69)

This invention relates to metal removal with a constricted arc torch of the type disclosed by Robert M. Gage in his application, Serial No. 524,353, filed July 26, 1955, now Patent No. 2,806,124, for Arc Torch and Process; and more particularly to the removal of non-ferrous metals and stainless steels with a high-pressure arc effluent composed of nitrogen alone or nitrogen mixed with hydrogen.

According to our invention gas comprising essentially nitrogen is discharged through an annular space between a non-consumable electrode and the concentric inner wall of a water-cooled nozzle surrounding such electrode and into an arc constricting orifice from which such gas is discharged toward work composed of metal selected from the class consisting of non-ferrous metals and stainless steels which is connected in circuit with a suitable source of electrical power for energizing an arc between the business end of such electrode and the work. The resulting jet-like effluent is used to scarf, gouge, pierce, cut, sever, or otherwise remove selected metal from such work as may be desired.

Prior to our invention it was not possible to kerf-cut aluminum or magnesium with nitrogen in the arc torch at speeds of less than 40 i.p.m. without producing cuts of very poor quality with attached dross. It was, therefore, assumed by those skilled in the art that cutting at higher speeds was impossible. We have discovered, however, that satisfactory cuts unexpectedly can be made which solve such problem, by cutting with such gas at higher speeds and even more unexpectedly regardless of the thickness of the work. By adding hydrogen to the nitrogen we also have discovered that such minimum speed can even be reduced to 10 i.p.m. on thin materials (such as 1/16" thick) and to even lower speeds on thick materials (such as 1") with entirely satisfactory results. Furthermore, the addition of hydrogen to nitrogen in arc torch cutting of non-ferrous metals such as aluminum, magnesium, copper and nickel, according to our invention, results in an increase in cutting speeds over those obtained with nitrogen alone.

A remarkable advantage is that very low flow rates can be employed using nitrogen or mixtures containing predominantly nitrogen and still produce good quality cuts according to our invention. This is unexpected since, when using the conventional 35% hydrogen–65% argon mixture, the minimum flow is approximately twice that when using nitrogen. Flows of nitrogen as low as 25 c.f.h. can be employed without obtaining any deleterious effects. Nitrogen or nitrogen-hydrogen mixtures, which are reducing gases, seem to protect the cut surfaces from excess oxidation. Thus, under conditions in which good quality cuts are obtained, no post cutting preparation is necessary before welding parts cut according to our process.

An additional benefit of nitrogen, as also is the case with hydrogen, is the obtainment of a very high voltage arc. This is the result of these gases having a high electrical resistance. Hydrogen has a somewhat higher resistance than nitrogen, as an open circuit voltage of 100 volts is sufficient to initiate and maintain an arc in nitrogen; whereas, when increasing amounts of hydrogen are added to nitrogen a higher open circuit voltage up to 160 volts is necessary to establish and maintain the arc. The required open circuit voltage is approximately directly proportional to the hydrogen content of the gas mixture. High voltage is essential in our process, especially in the cutting of heavy plate, to force the cutting action to penetrate the thickness of the plate and simultaneously to give excellent quality kerfs that are free of dross. The employment of such relatively high voltage also permits the advantageous use of lower amperage to obtain the necessary heat input. Since the present limitation (double arcing) of the equipment is the current-carrying capacity of the orifice insert or nozzle, it is desirable to have a high heat input with as low an amperage as possible.

Another advantage of using nitrogen or nitrogen-hydrogen mixtures is the minimization of the double arcing phenomenon which is the preference of the arc to establish two independent arcs through the nozzle; the occurrence of which damages or destroys the nozzle. Since nitrogen and hydrogen have very high resistances, an insulating layer is apparently formed between the issuing arc and the inside of the metallic insert; which insulating layer retards the tendency of the arc to jump from the tungsten or copper electrode to the inner wall of the nozzle and then to the base plate.

Also of benefit in our process is the breakdown of the nitrogen and hydrogen molecules to their respective atoms. Thus, as pointed out in the application of Oyler, Maier, and Reed, Serial No. 540,951, filed October 17, 1955, two volumes of useful gas are produced for each volume of metered gas, $N_2=2N^+$ and $H_2=2H^+$. This breakdown produces an added jet effect, which is essential to our process for the removal of the molten metal and dross from the kerf walls. In addition, the recombination of the hydrogen and/or nitrogen molecules at the base plate provides a concentration and high transfer efficiency of heat precisely at the desired zone.

As disclosed in application Serial No. 540,951, filed October 17, 1955, the lighter the gas used, the higher the velocity that can be obtained; therefore, since hydrogen is the lightest gas known, it provides an extremely high velocity jet stream which removes the dross and mechanically scrubs the kerf walls. It is desirable, however, to have a certain percentage of a heavy gas present in the mixture to increase the momentum of the stream for the purpose of obtaining satisfactory cuts at substantially lower flows than are required for hydrogen. This can be a relatively heavy gas such as argon, nitrogen, or oxygen. Nitrogen which has a medium molecular weight (28) when mixed with H_2 provides a good balance of molecular weights for obtaining the properties desired in a jet for our purpose. Nitrogen alone produces good quality cuts in most metals. However, in some instances, the addition of hydrogen to nitrogen improves such quality, especially in the cutting of magnesium alloys and aluminum alloys.

Using conventional power supplies which singly have a maximum open circuit voltage of 110 volts, we recommend that pure nitrogen be used to obtain good quality cuts at all speeds in copper and its alloys; and nickel and its alloys; and in aluminum and its alloys; and magnesium and its alloys at cutting speeds above 40 i.p.m. For obtaining good quality at all speeds in cutting aluminum and magnesium and to obtain higher speeds at any selected arc current level, it is desirable to add 15% hydrogen to the nitrogen.

Whereas, prior to our invention, dross-free cuts could not be produced with the conventional argon or argon-hydrogen mixture as the arc gas, excellent quality cuts can be made according to our invention by using an arc atmosphere of pure nitrogen or nitrogen-rich atmospheres in the arc torch cutting of stainless steel. The use of pure nitrogen or nitrogen containing a small addition of hydrogen produces excellent results: the cuts are square, smooth, and free from attached dross. The kerf edges of several cuts made in ¼ in. and ½ in. thick stainless steel at various speeds from 20 to 200 i.p.m., using 70 c.f.h. of pure nitrogen show excellent results. A surprising result with nitrogen is the obtainment of excellent quality cuts at flows as low as 25 c.f.h. (using ⅛″–5⁄32″ I.D. orifices). Similar quality cuts can be made using a small addition (up to about 20%) of hydrogen to nitrogen. However, when larger percentages of hydrogen are employed, the dross bridges the kerf and prevents the obtainment of "drop-cuts."

The quality of the kerf walls in the arc torch cutting of stainless steel is improved using nitrogen over that normally obtained with argon, helium, or argon-hydrogen mixtures. Nitrogen or nitrogen-hydrogen mixtures, which are reducing, protect the cut surfaces from excess oxidation by the air. Consequently, parts with such surfaces can be welded in the "as-cut" condition.

In the drawing the single figure is a diagram illustrating the invention, the arc torch being shown in vertical section.

As shown in the drawing, an arc torch **1**, such as that of Patent No. 2,858,412 manually positioned above the metal work **2** to be cut, or supported by any suitable means, such as a conventional carriage (not shown). Such torch comprises a tungsten electrode **3**, the lower end of which is pointed and centrally located within the tapered inner annular wall **4** of a water-cooled copper nozzle insert **5** that can be readily removed and replaced. Such nozzle insert has an orifice **6** through which the arc and gas pass. Such gas, in this case nitrogen alone, or mixed with hydrogen gas, is delivered to the torch through a hose **7**, from a flowmeter **8** that is connected to a gas supply line **9** by way of a main control box **10**.

The work **2** is connected to the positive (+) side of a D.C. power supply **11**, through a lead **12**, which is connected to the positive (+) side of a high frequency generator **13**, and a lead **14** connecting the positive (+) terminals of the HF generator and D.C. power supply. The negative (−) side of the D.C. power supply **11** is connected to the electrode **3** through lead **15**, contactor **16**, lead **17**, negative (−) terminals of the HF generator **13**, lead **18**, main control box **10**, and lead **19**. The contactor **16** is connected to the main control box by a main contactor cable **20**. The D.C. power supply is also connected to the nozzle **5** of the arc torch through lead **14**, high frequency generator **13**, lead **21**, through control box **10** to lead **23**, then through the torch-to-nozzle insert **5**. Also connected to the control box **10** are a 115 volt A.C. control power supply cable **24**, water inlet and outlet pipes **25** and **26**, and a remote control box **27** by cable **28**. Torch cooling water is conducted between the box and torch by a torch water inlet hose **29**, and a water outlet hose **30**, which also contains the torch power cable **19**.

Our arc torch cutting employs an extremely high temperature, high velocity, constricted arc **31** between the end of the tungsten electrode **3** and the piece **2** of work to be cut. The concentrated and columnated energy of the arc stream rapidly melts and ejects a thin section of metal to form a kerf **32**. Such jet-like action removes the molten metal and the gas atmosphere of the effluent prevents oxidation of the kerf walls. The arc presently is constricted by using a nozzle insert **5** with a ⅛ in. or a 5⁄32 in. diameter opening. An auxiliary circuit including leads **21** and **23**, which is necessary for arc-starting, is used to connect the nozzle to the positive (+) terminal of the power supply through a current limiting resistor **33** located on top of the box **10**.

Two methods of starting are used with nitrogen and/or hydrogen gas. In mechanized cutting, the high frequency unit is used with the pilot arc circuit to initiate the cutting arc. The high frequency spark ionizes a path for pilot arc current between the electrode and the nozzle. The ionized gas from the pilot arc provides a low resistance path for the cutting current between the electrode and the work and the main cutting arc is initiated. In manual cutting, a pilot arc maintained by high frequency is used to start the cutting arc. The illumination provided by the pilot arc permits the operator to locate the edge of the plate at the desired point with his helmet in position. When the starting point of cut is located, the main arc is initiated. At the conclusion of the cut, the arc is extinguished and the nitrogen and/or hydrogen stop flowing.

Excellent quality cuts have been made by us using a cutting atmosphere of pure nitrogen or nitrogen-hydrogen mixtures on aluminum, magnesium, copper, and nickel. Our original work was done with nitrogen on ½-in. thick aluminum at 40 i.p.m. with the result of producing very poor quality cuts with attached dross. Later work indicated that there was a minimum speed at which quality cuts could be produced using nitrogen as the cutting atmosphere. Consequently, an extensive investigation was conducted to determine the limitations associated with the use of nitrogen. Poor quality cuts with black deposits on the kerf walls, most probably aluminum nitride, were obtained at speeds of 20 and 40 i.p.m. Satisfactory cuts, however, were made at speeds above 40 i.p.m. This minimum in speed for the obtainment of good quality cuts was apparently valid irrespective of thickness. The pilot arc could not be maintained in nitrogen using a power supply having an open-circuit voltage of 100 volts; thus for manual operation a different technique (D.C. pilot arc stabilized by high frequency) of starting was employed than that normally used in the conventional arc torch cutting process.

A series of experiments using 85% nitrogen and 15% hydrogen employing a 100 volt open-circuit power supply was made and the minimum speed for obtaining good quality cuts was lowered to 10 i.p.m. on thin materials. Excellent quality cuts were obtained at all speeds on heavy materials.

Good quality cuts can be obtained with aluminum work regardless of the percentage of hydrogen added to the nitrogen. This is clearly shown when 15, 35, 55, and 75% hydrogen additions were added to the nitrogen. The kerf walls are all of equal quality and are comparable to that obtained with the standard H–35 mixture. The unexpected benefit of adding the hydrogen to the nitrogen is the obtainment of much higher cutting speeds with equal quality, regardless of thickness.

A similar investigation was conducted on magnesium as was undertaken on aluminum. Apparently, the same minimum speed of 40 i.p.m. for obtaining good quality cuts using pure nitrogen also holds for magnesium. Below this speed, poor quality cuts with black deposits were obtained; whereas, above this speed good quality cuts resulted. Also as in the case of aluminum, the introduction of hydrogen lowered this minimum speed to that of approximately 10 i.p.m. on thin materials regardless of the thickness of the magnesium being cut.

Good quality cuts have also been made using nitrogen on various thicknesses of copper. Quality cuts can be made at all speeds using nitrogen and there apparently is no minimum speed required as is the case with aluminum and magnesium. Good quality cuts can likewise be made with varying additions of hydrogen to the nitrogen with comparable increase speeds as noted for magnesium and aluminum.

Excellent quality cuts were made in various thicknesses of nickel even at very slow speeds. Excellent kerf walls with no attached dross were obtained. The additions of varying percentages of hydrogen did not affect the quality of the cuts but again results in the obtainment of increased cutting speeds. Thus, the use of nitrogen or nitrogen-hydrogen mixtures produced good quality cuts in all thicknesses of nickel at all speeds checked.

It will be understood that, while a D.C.–S.P. (straight polarity) power supply for energizing the arc is shown by way of example, the invention is not limited thereto inasmuch as D.C.–R.P. (reverse polarity) as well as A.C. power supplies are also satisfactory for such purpose.

Subject matter disclosed herein is claimed in the co-pending applications mentioned above which, together with the present case, are all owned by the Union Carbide and Carbon Corporation of New York.

What is claimed is:

1. Process of removing metal from work composed of metal selected from the class consisting of stainless steels and non-ferrous metals with a constricted-arc torch effluent which includes the use of arc gas selected from the class consisting of nitrogen and mixtures of nitrogen and a trace to 75% hydrogen, by flowing such gas first through an annular space between a non-consumable electrode and the concentric inner wall of a water-cooled nozzle, and then discharging such gas through a central arc-constricting orifice in such nozzle in line with such electrode, energizing in such flowing gas a high-pressure arc between such electrode end and such work, and melting and removing selected metal from such work with the resulting intense, directional and stable jet-like effluent that is discharged from such nozzle and applied to such work, characterized in that the adjacent surface of the work from which selected metal has been so melted and removed is clean, smooth, and of excellent quality.

2. Process as defined by claim 1, in which the operation is kerf-cutting at a minimum cutting speed of 40 i.p.m. in the case of work composed of magnesium, aluminum, and alloys thereof with an arc gas consisting of pure nitrogen which has the beneficial effect of increasing the range of cutting speed regardless of the thickness of the work being cut at substantially decreased arc gas flows.

3. Process as defined by claim 1, in which the operation is kerf-cutting work composed of stainless steel and the arc gas consists of pure nitrogen which has the beneficial effect of increasing the range of cutting speed regardless of the thickness of the work being cut at substantially decreased arc gas flows.

4. Process as defined by claim 1, in which the operation is kerf-cutting work composed of copper or an alloy thereof with an arc gas composed of a mixture of nitrogen and a trace to 75% of hydrogen.

5. Process of cutting a body of metal selected from the class consisting of non-ferrous metals and stainless steels, which comprises removing metal from such body by melting the metal to be removed to form a kerf in such body with a constricted electric arc comprising a jet of gas selected from the class consisting of nitrogen, and a mixture of nitrogen and a trace to 75% of hydrogen, which jet of gas carries an electric arc energized by current flowing through a circuit that includes such body of metal characterized in that the so-cut metal is clean, smooth, and of excellent quality.

6. Process as defined by claim 1, in which the operation is kerf-cutting metal composed of nickel and the alloys thereof with arc gas selected from the class consisting of pure nitrogen and mixtures of nitrogen and a trace to 75% of hydrogen characterized in that the so-cut metal is clean, smooth, and of excellent quality.

7. The improvement in the wall-stabilized arc-cutting process for removing metal from stainless steels and non-ferrous metals or alloys by discharging a gas stream through an annular space between a non-consumable electrode and a concentric inner wall of a cooled nozzle and directing such stream about a high-pressure arc maintained at the end of the electrode in such gas characterized in that, to obtain cuts having smoother wall surfaces in the workpiece and to obtain a wider range of cutting speed, the gas is selected from the class consisting of nitrogen, and a mixture of nitrogen and hydrogen containing from 15% to 75% by volume of hydrogen.

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