June 13, 1950 F. G. DANHIER 2,510,960

METAL CUTTING ROD AND PROCESS

Filed Nov. 17, 1947 3 Sheets-Sheet 1

Fig. 1.

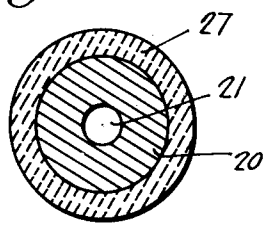


Fig. 2.

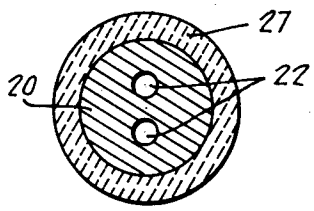


Fig. 3.

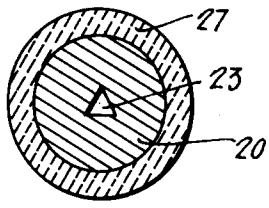


Fig. 4.

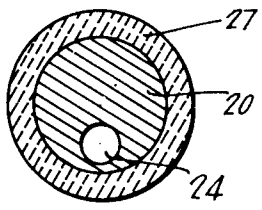


Fig. 5.

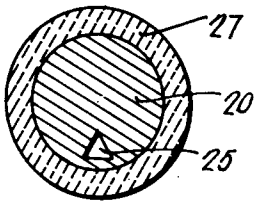


Fig. 6.

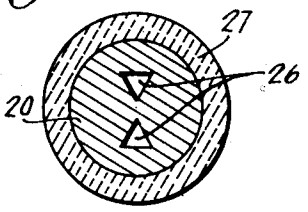


Fig. 7.

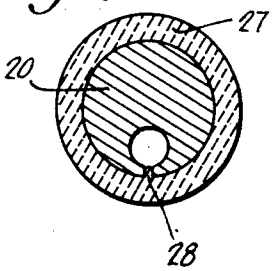
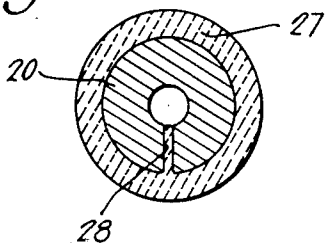


Fig. 7a.



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METAL CUTTING ROD AND PROCESS

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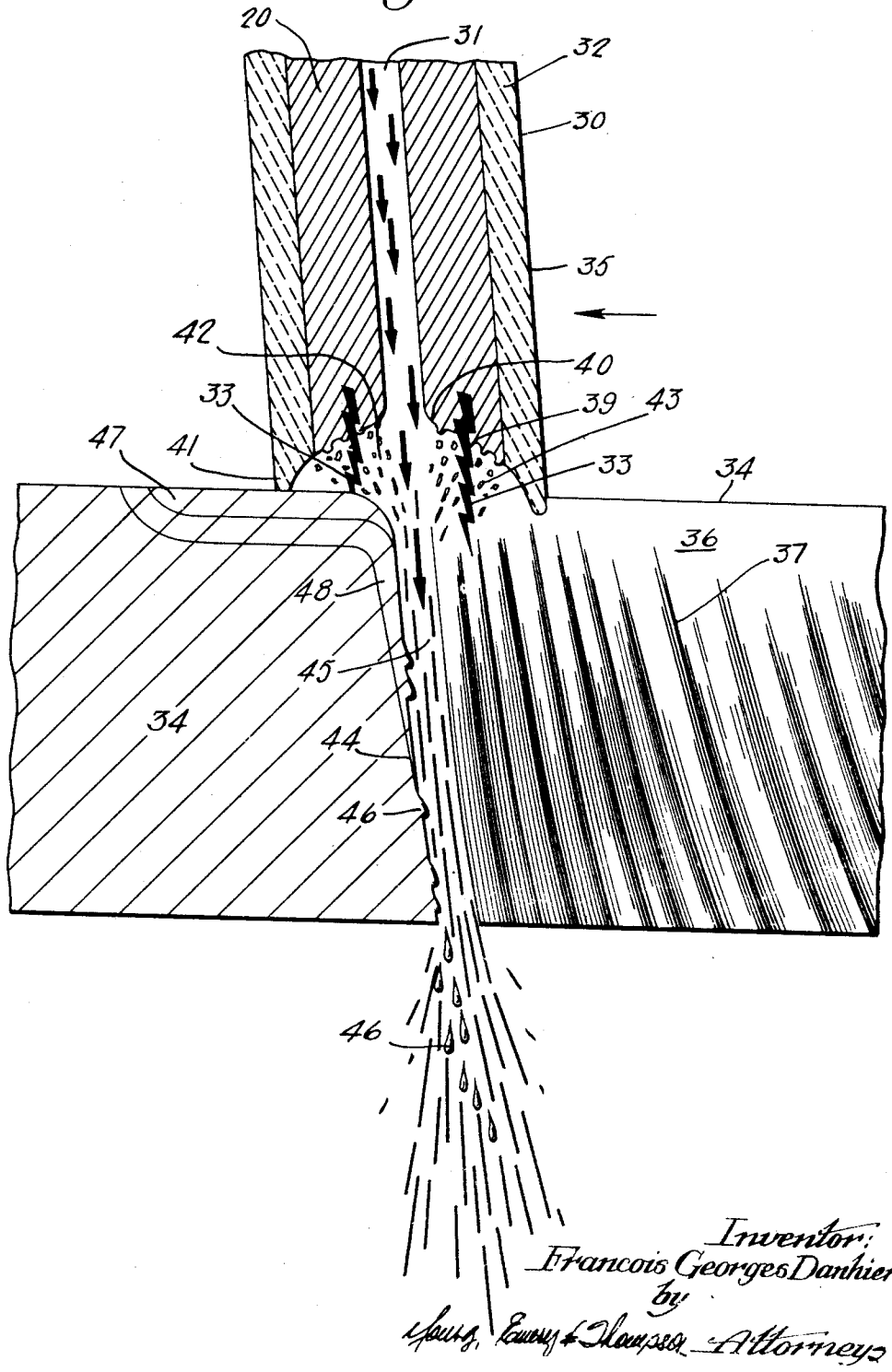
Fig. 8.



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METAL CUTTING ROD AND PROCESS

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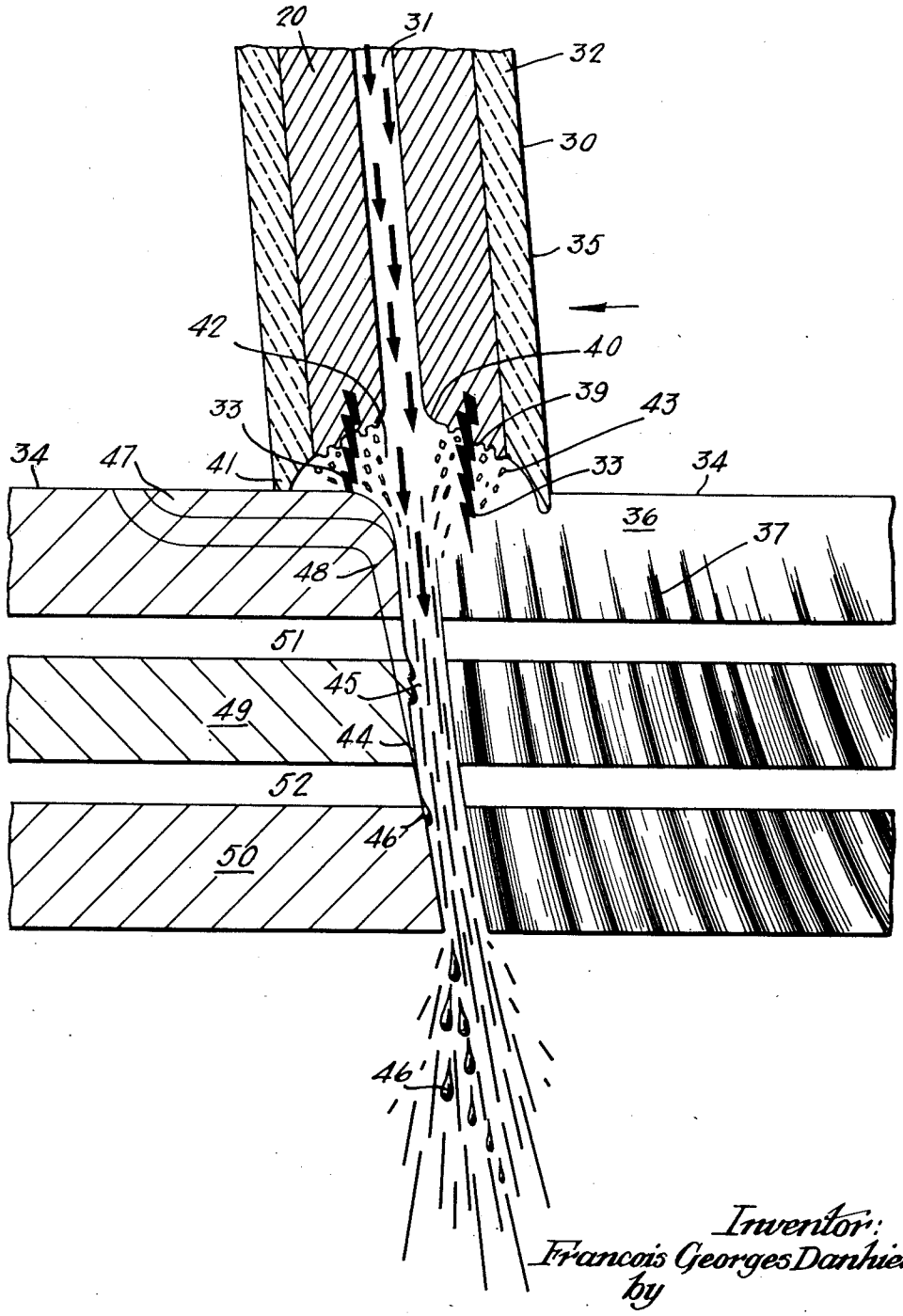
Fig. 9.



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Patented June 13, 1950

2,510,960

UNITED STATES PATENT OFFICE

2,510,960

METAL CUTTING ROD AND PROCESS

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Application November 17, 1947, Serial No. 786,408
In Belgium January 16, 1945

6 Claims. (Cl. 219—15)

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The cutting of iron and steel by oxidation by means of an oxygen jet, the reaction of oxidation being started and maintained by the heat developed by an electric arc is a well known process.

The present application is a continuation-in-part of my copending application, Serial No. 597,508, filed in the United States June 4, 1945, based upon a convention date in Belgium of January 16, 1945, now abandoned.

Generally the oxygen was supplied through a hollow carbon electrode, the arc being struck between the extremity of the electrode and the piece to be cut. This old process had also been improved by the adjunction of an aluminum rod as a flux.

It has also been known to cut metals under water by a hollow metallic rod through which an oxygen jet is passed, employing on the rod a carbonaceous coating which produces an envelope of gas.

It could also have been proposed to use, as a hollow electrode, a simple steel pipe, in which the oxygen stream passes and to cause the electric arc to be struck between the extremity of the pipe and the piece to be cut. This process would not be able to be developed industrially: firstly, on account of the great consumption of oxygen and pipes, with the resulting frequent interruption of the cutting operation to change the electrode, and especially because the slot or cut obtained would be very wide.

After many experiments the applicant has finally realized a process giving practical and unimpeachable results, in which no commercial pipes are used, but which consists in utilizing an oxygen jet through an inner passage reserving in a metal electrode, with respect to a given total cross section of said electrode, a greater metal section, so that for a sufficient strength of the electric current, a minimum of electrode length is consumed in the time unit for a maximum cutting length.

In other words, in the process according to the invention, an electrode of given and necessarily limited length, but responding to the above defined condition, makes it possible to operate a cutting of relatively great length, all conditions being fulfilled to make the electrode able to resist high oxygen pressures, which, combined with a suitable strength of electric current, allows a very rapid progression of the cutting with the contemplated low consumption of electrodes.

The electrode or metal rod used according to the invention is provided in principle with an inner passage for the oxygen gas in form of one

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or several narrow channels, the total cross section of which in the preferred embodiment is smaller than the quarter of the net metal cross section of the electrode.

It has been found that the best ratio of the cross section of the passage for the oxygen to the total cross section of the metal and bore of the rod is between 4 and 20 per cent.

An important aspect of the invention is the character of coating which is employed to facilitate the cutting and minimize the consumption of rods. In accordance with the invention the coating which surrounds or extends along the metallic core of the rod consists practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature. This avoids the undesirable effects of substantial evolution of fixed gases such as are obtained from conventional welding rod coatings and from the underwater cutting rod coatings.

The drawings show a few only of the numerous embodiments in which the invention may appear, the forms shown having been chosen from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figures 1 to 7a inclusive are enlarged diagrammatic cross sections of metal cutting rods in accordance with the invention.

Figures 8 and 9 are diagrammatic sectional illustrations of the cutting operation.

In carrying the invention into effect, the combustible metal electrode may be made of iron, for instance cast iron, but it can also be made of steel.

In a special embodiment, the oxy-electric cutting electrode according to the invention is made, for instance, of a steel strip or band 20 folded one or several times on itself and suitably compressed or drawn, in such a manner that one inner channel 21 (Figure 1) or several inner channels 22 (Figure 2) for the passage of the oxidizing gas (preferably at least commercially pure oxygen) will be formed.

Comparative tests have shown that for an equal area of the cross section of the passage for the oxygen and provided the above specified relation between the metal to be burned and the oxygen passage is maintained, good results can be obtained with various forms of passage cross sections other than the circular form, especially with passages of triangular cross section as shown at 23 (Figure 3).

For preventing the displacement of the arc at the extremity of the rod forming the gas electrode, the single or multiple channel may be distinctly eccentric with respect to the section of the electrode as at 24 or 25, in order to leave on one side a bigger mass of metal supporting the electric arc (Figures 4 and 5).

The bore may also take the form of two triangular longitudinal passages 26 as shown in Figure 6.

The core 20 is surrounded by a coating 27 as shown in Figures 1 to 7, which performs a number of different functions as later explained. In accordance with the invention the coating is of mineral type and differs from the conventional arc-welding mineral coatings in that it consists practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature. In other words, the coating does not evolve substantial quantities of fixed gases such as carbon monoxide, carbon dioxide or the like which are so generally desired and widely used to surround arc-welding operations and are accordingly formed from ingredients included in conventional arc-welding coatings. The presence of such fixed gases in the cutting operation in accordance with the present invention definitely slows up the cutting by diluting the stream of at least commercially pure oxygen which passes through the arc, thereby reducing the calorific intensity of combustion of the rod and work, and also carries away sensible heat needlessly in such fixed gases. In general the gaseous components of the combustion of the rod of the present invention will be limited to vapors of metals, silicon, etc., which may be formed in the arc, and minor contents of vapor or gas from water or other impurities which may be unintentionally or undesirably present.

In the underwater cutting rods substantial amounts of carbonaceous material have been included in the coatings so that any mineral, if present at all, was not effective in aiding cutting. The coating of the present invention is for all practical purposes entirely mineral, providing a heavy liquid or solid which is projected forward by the arc and the oxygen stream into the cut. This stream of mineral from the coating aids cutting in a number of respects. Many of the alloys cut such as chromium alloys, form refractory oxides at the surface of the cut and thus tend to form a refractory skin which impedes further cutting. When carbonaceous and other coatings are employed in cutting in air this refractory skin is difficult to remove, and operations are delayed until it can be fused or cracked by striking or rubbing. On the other hand, with the strictly mineral coating of the present invention there is an abrasive and scouring action exerted by the liquid and solid from the coating projected into the cut which aids in removing the skin of refractory oxide such as chromium oxide, and also a chemical fluxing action exerted particularly by silicates and the like in the coating. Furthermore solid products of combustion result from the burning of the core and work in the oxygen stream, and these tend to clog the kerf, whereas the mineral ingredients from the coating aid in fluxing away such products of combustion. The net effect of the mineral coating is to produce a much narrower kerf than would be possible were a carbonaceous containing coating used as in the prior art practice with underwater cutting or the conventional arc-welding practice.

There is a tendency also for the oxygen stream and the arc to project or propel metal from the rod into the work, and the propulsion of this metal stream also contributes to the propulsion of the coating products and has a tendency to break up the refractory oxide skin and carry away products of combustion from the kerf.

A further important function which will be emphasized in consideration of Figures 8 and 9 is the effect of the coating in sealing the oxygen jet to the work and forming a crucible, since the core of the rod will burn out more rapidly than the mineral type coating.

The oxygen jet exerts substantial cooling effect and has a marked tendency to extinguish the arc even when direct current is used. It is, therefore, very desirable on direct current, and most important on alternating current, to include an ionizing substance in the coating, to stabilize the arc and prevent extinguishing of the arc notwithstanding the effect of variation in the arc length and of the oxygen jet.

The coated rod of the present invention, unlike the underwater cutting rods, is capable of effective use in air with alternating current.

The coating also performs an important function of insulating the core at all times. For example, in piercing it insulates the side wall from the edge of the hole being pierced. Likewise when cutting is accomplished in a space close to side walls, the coating insulates from such side walls. Furthermore, the coating insulates from the kerf walls in deep cutting of thick members, and permits re-establishing the arc at the bottom of the kerf when several rods are used in a single cut. Due to the fact that the core burns off more rapidly than the coating, the coating automatically holds a suitable arc spacing, and it is merely necessary for the operator to hold the end of the coating in contact with the work at all times. Thus there is in ordinary cutting no conscious effort involved in holding the arc.

To summarize some of the important effects of the coating of the invention, it will be seen that it aids in cutting by removing refractory oxide and by fluidifying combustion products, by sealing the oxygen jet to the work, and by stabilizing the arc in the presence of oxygen and particularly on alternating current. The arc stabilizing effect is evident in spite of the use of low currents, which are favorable for slower combustion of the rod.

When the electrode according to the invention is, for instance, constituted by a steel band or ribbon simply formed into a roll, so as to form a single narrow channel for the passage of the oxygen gas under pressure, this coating may also serve the purpose to secure the tightness of the electrode channel at 28 (Figure 7). Figure 7a is similar to Figure 7 except that the bore is eccentric in Figure 7 and concentric in Figure 7a.

The coating will be made from inorganic materials, a wide variety of which are suitable. Inorganic materials such as the carbonates which under the arc in oxygen yield a material which is gaseous at ordinary room temperature should be avoided, and likewise carbonaceous combustible materials such as cellulose should be eliminated. Suitable coating materials include silicates of calcium, magnesium, potassium, sodium, zirconium and iron and complex silicates

of two or more of the same, titanates of potassium, sodium, strontium and iron; metallic oxides such as titanium dioxide (rutile), manganese dioxide, and magnetite; silicate glasses such as alkaline powdered silicate glass; monazite sand (cerium phosphate), clay in minor proportions to aid extrusion or in larger proportion to act as a flux and oxidizable metal powders with insulating ingredients.

Of the materials referred to, it is preferable to include an ionizer in each coating. Suitable ionizers are potassium titanate, titanium dioxide, manganese dioxide, potassium zirconium silicate, sodium silicate, calcium silicate and potassium silicate.

It will also be desirable to include a flux such as one of the silicates or silica.

It will also be desirable to include in the coating a conductor of the second class which will be insulating at moderate temperature and therefore will permit the coating to be insulating except at the hot end, and will be conducting in the hot end to aid in re-establishing the arc by bringing the hot end of the coating in contact with the work. Suitable conductors of the second class are ilmenite and magnetite.

The following are examples of coating compositions which are suitable to use with a core of iron, steel or stainless steel for cutting iron, steel, stainless steel, high chromium and high nickel alloys, brass, bronze and other ferrous and nonferrous structural metals and alloys.

Example I

	Per cent
Magnetite	22
Wollastonite	26
Anhydrous clay	22
Potassium titanate	18
Potassium silicate	12
	100

In this case the magnetite acts as a conductor of the second class as well as a flux, and the wollastonite acts as an ionizer and a flux, while the potassium titanate acts as an ionizer.

Example II

	Per cent
Ilmenite	31
Potassium zirconium silicate	22
Powdered silicate glass	18
Anhydrous clay	17
Sodium silicate	12
	100

Here ilmenite acts as a conductor of the second class and a flux, potassium zirconium silicate, powdered silicate glass and sodium silicate act as ionizers and fluxes, and clay aids extrusion, acts as a binder (with sodium silicate) and acts as a flux.

Example III

	Per cent
Ilmenite	26
Haussmannite (Mn_3O_4)	26
Wollastonite	22
Iron silicate	14
Potassium silicate	12
	100

Here ilmenite acts as a conductor of the second class and a flux, and the remaining ingredients act as ionizers and fluxes.

Example IV

	Per cent
Magnetite	44
Rutile	31
Powdered silicate glass	13
Potassium silicate	12
	100

In this case magnetite acts as a conductor of the second class and a flux, and the remaining ingredients act as ionizers and fluxes.

It will be evident, of course, that other coatings may be made up using entirely other inorganic materials which will not form any product which is gaseous at room temperature.

The operation will be better understood by reference to Figures 8 and 9 which show an electric-arc oxygen open air metal cutting rod **30** having an interior bore **31** through which at least commercially pure oxygen is passing under suitable pressure (for example 5 to 200 p. s. i.) and suitable rate of flow. The bore is formed in the interior of a core **20** in this case of steel, preferably of plain carbon low-carbon grade. The outside of the core is provided with a coating **32** surrounding the core. The coating is entirely inorganic and free from materials which would produce products which are gaseous at room temperatures. An arc **33** has been established at the end in contact with a metal plate or other work **34** which is being cut. The metal plate or other work here shown may be iron, steel, stainless steel, high chromium or high nickel alloy, brass, bronze or the like. The direction of travel of the rod **35** is from right to left and a kerf **36** has been formed in cutting through the plate. Serrations **37** on the edge of the kerf are typical of the very slight irregularities which may be produced. The arc acting at **39** has burned away the core more rapidly than the coating and more rapidly at the center **40** than at the edge. The coating then extends beyond the core at the end at **41**, and portions of the core at **42** and the coating at **43** are melted and projected forward into the cut, tending to cut away the leading edge **44** and carry oxide, slag and molten metal away from the combustion zone **45** in globules **46**. The surface pre-heated by the arc alone is shown at **47** and the layer pre-heated by the arc and combustion of the core is shown at **48**. The products of the combustion are substantially entirely solid or liquid at room temperature, since substantially no carbonaceous material is available in the coating and the carbon in the work will ordinarily be a negligible factor. It will be noted that the coating aids in the cutting by removing the skin of refractory oxide which forms on the leading edge and by carrying away products of combustion through erosion and fluxing. As shown, the coating seals the jet around the arc at **41**, preventing loss of gas and loss of heat. Coating also as shown at **41** automatically tends to restrict and concentrate the arc and in case of piercing or contact with walls of the work at the side will prevent undesired side arcing.

Thus as shown, a metallic arc with direct or alternating current is established to the work, a stream of oxygen is passed through the interior of the arc to the work, and the mineral coating consisting practically entirely of inorganic ingredients, which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature,

is fused and the fusion products are projected into the cut.

The coating also preferably ionizes to aid in maintaining the arc and to stabilize the arc.

That the coating is very effective in aiding cutting is shown by Figure 9 which is similar to Figure 8 except that it exhibits stack cutting. With the underwater type of rod it is impossible to cut through a stack in air in this manner due to the fact that the aid of mineral coating in projecting the cutting into the layers of the stack beyond the first layer is not present. In this form the coating particles tend to carry the cut through the subsequent plates 49 and 50 and beyond the gaps 51 and 52.

The following comparative tests have been run using rods as follows:

1. The rod of the present invention.
2. The underwater cutting rod with a Scotch tape coating according to Ronay U. S. Patent 2,410,461.
3. A standard gas shielded arc-welding electrode coating on a steel tubular core.

3a. A standard gas shielded arc-welding electrode coating with a waterproof vinyl resin coating following Jensen U. S. Patent 2,394,550.

4. A complete vinyl resin type coating following Jensen U. S. Patent 2,394,550.

The rod according to the present invention was an open seamed tubular steel core rod covered with a non-gas forming silicate type coating as herein described.

All the other experimental rods were made with the same tubular metallic core as that used for the rod of the present invention. The Ronay type rod was covered according to the procedure recommended by the U. S. Navy for the preparation of Ronay type rods for underwater cutting, using Scotch tape of type MHS as recommended by the Navy.

The Jensen type rod using a standard arc-welding electrode coating plus a waterproof vinyl resin coating was prepared in the manner of the rods manufactured for the U. S. Navy for underwater cutting. The standard welding electrode formula used for the slag forming portion of the coating was of the limestone type used for arc-welding electrodes. This coating produces a gaseous shield to protect the weld metal in its transfer across the arc and a protective slag to protect the weld bead while it is cooling. The waterproof covering was a vinyl resin known as Ucilon (United Chromium Company) reinforced with lime in the manner recommended by Jensen for producing underwater cutting rods.

The completely vinyl resin type of covering according to Jensen was prepared with the vinyl resin and lime mixture as recommended by Jensen. The thicknesses were adjusted to give the most favorable performance of this rod.

The four types of arc oxygen cutting rods above described were tested under identical conditions, but adjustments to produce the conditions most favorable to Ronay and Jensen were required. All cuts were made in open air at normal room temperature. Oxygen was supplied from a standard tank through a reducing valve at 75 pounds per square inch when cutting mild steel and at 10 pounds per square inch (except for two instances at 20 pounds per square inch) when cutting stainless steel. The current supplied to the arc was obtained from a standard welding source. The direct current was supplied by a motor generator set and the alternating current was supplied by a welding transformer. The current was approximately 200 amperes in each test. The machine settings were identical in each case but because of different characteristics in the rods some operated on less current than others. As shown in the accompanying table the currents ranged from 160 to 208 amperes and the voltages varied from 28 to 50 volts, but most of the tests fell in the range from 160 to 200 amperes and 30 to 35 volts. The materials cut were ¾" thick mild steel plate, $\frac{5}{16}$" thick mild steel strips stacked three high with a $\frac{1}{64}$" air gap between the strips and ¾" thick type 347 (18% Cr, 9% Ni, 1% Cb) stainless steel plates.

Cutting of mild steel

The following table shows the result in cutting mild steel:

	Rod	Cutting Data for ¾" Mild Steel			
		Current Ranges		Ave. Speed, in./min.	Burn-off Ratio, in. cut/in.
		Amps.	Volts		
1	Present invention	190–204	31–35	25.4	1.19
2	Scotch tape–Ronay	160–200	44–50	22.9	0.96
3	Gas shielded	200	34	22.2	1.06
3a	Gas shielded and water-proofed-Jensen	190–208	29–34	17.4	0.75
4	All vinyl resin-Jensen	175–208	28–35	14.3	0.73

Under the conditions of these tests the rod of the present invention shows definite superiority in cutting mild steel. The speed in cutting ¾" mild steel plate is 10 to 77% faster than the speed with other types of rod. The efficiency of the rod of the present invention as measured by the distance cut per unit length of rod is 10 to 60% better than the efficiency of the other rods. The closest approach to the rod of the present invention in efficiency is neither the Ronay nor Jensen types but the gas shielded welding rod type of coating.

Cutting stainless steel

The following table shows the result of comparative tests in cutting stainless steel:

	Rod	Cutting Data for ¾" Stainless Steel			
		Current Ranges		Ave. Speed, in./min.	Burn-off Ratio, in. cut/in.
		Amps.	Volts		
1	Present invention	190–200	33–35	3.4	.19
2	Scotch tape–Ronay	200	-------	2.0	.12
3	Gas shielded	180–200	32–40	3.0	.16
3a	Gas shielded and waterproofed-Jensen	200	-------	2.0	.12
4	All vinyl resin-Jensen	160–192	30–44	3.0	.12

As shown in the table, the rod of the present invention was more rapid and more efficient in cutting of type 347 stainless steel than any of the other rods.

Stack cutting

Because of the unsatisfactory performance of the Jensen type rods on solid mild steel in open air, only the rod of the present invention, the rod with the gas shielded mineral type welding rod coating and the Scotch tape Ronay type rod were tested in stack cutting. $\frac{5}{16}$" thick and 2" wide mild steel strips were stacked three high separated by $\frac{1}{64}$" to leave two air gaps between the three strips. Cuts were attempted while dragging the rod across the upper surface of the top strip as though the plate were solid, but with

both the Scotch tape and gas shielded rod it was necessary to work the rod down into the kerf to cut the lower pieces. The following results were obtained:

	Rod	Cutting Data for Stack Cutting			
		Current Ranges		Ave. Speed, in./min.	Burn-off Ratio, in. cut/in.
		Amps.	Volts		
1	Present invention	180–200	36–43	7.1	0.35
2	Scotch tape–Ronay	120–160	22–64	3.0	0.24
3	Gas shielded	185–200	34–40	4.2	0.19

With the rod of the present invention there was no trouble in stack cutting, the power of the arc-oxygen stream and the coating bridging the gaps with ease. The amperage and voltage were normal. With the gas shielded arc-welding type of coating without waterproof layers, the performance was fair but the speed was definitely lower. The operating amperage and voltage were normal. With the Scotch tape type of Ronay coating, the performance was quite unsatisfactory. The voltage and amperage swung violently from low to high values, so much so that the arc was extinguished briefly about seven times during 40 seconds of operation. The speed of cutting was slow.

Alternating current

Of all of the rods described the type of the present invention was far superior in operation with alternating current. The speed and efficiency of cutting was so nearly equivalent to the speed and efficiency with direct current that all data for direct and alternating current were combined in obtaining the average speed and average burn-off rate of this rod. The rod with the gas shielded arc welding type of coating was unsatisfactory for operation with alternating current, since the arc was so unstable that a simple dragging operation was not possible and see-saw action was necessary to keep the arc going. The same coating protected with the outer waterproof layer according to the Jensen patent showed a stability of arc increased only enough so that drag cutting was barely possible. The Ronay Scotch tape coating operated about as well with alternating current as with direct current but in each case it was unsatisfactory in open air cutting. The operator experienced great difficulty in restriking the arc after the rod and the plate being cut became heated since the coating softened and burned off at the tip to expose the bare core which froze fast to the plate. Moderate overheating caused the Scotch tape coating to soften and be blown completely off the rod.

The presence of gas forming ingredients in these other coatings is believed to be an essential reason for the deficient behavior in the tests described. The completely inorganic character of the coating of the present invention is of significant importance in accomplishing stack cutting.

In view of my invention and disclosure variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of my invention without copying the structure and process shown, and I therefore claim all such insofar as they fall within the reasonable spirit and scope of my claims.

Having thus described my invention what I

claim as new and desire to secure by Letters Patent is:

1. An electric-arc oxygen open-air metal cutting rod comprising a tube-like metallic core having an interior longitudinal oxygen bore and a mineral non-oxygen-liberating type coating, fusible in the cutting arc, supported on and extending longitudinally along the core and the coating consisting practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature, the coating comprising an ionizing substance.

2. An electric-arc oxygen open-air metal cutting rod comprising a tube-like metallic core having an interior longitudinal oxygen bore and a mineral non-oxygen-liberating type coating, fusible in the cutting arc, supported on and extending longitudinally along the core and the coating consisting practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature, the coating comprising a conductor of the second class.

3. An electric-arc oxygen open-air metal cutting rod comprising a tube-like ferrous metal core having an interior longitudinal oxygen bore of diameter between 4 and 25 percent of the net metal cross section and a mineral non-oxygen-liberating type coating, fusible in the cutting arc, surrounding the core and consisting practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature.

4. The process of cutting metal in open air, which comprises establishing an alternating current metallic arc from a core to the work, passing a stream of oxygen in open air through the interior of the alternating current arc to the work, fusing in the arc the core and an ionizing mineral non-oxygen-liberating coating consisting practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature and projecting the fused products of the coating and core into the cut under the action of the arc and the stream of oxygen.

5. The process of stack cutting metal in the open air, which comprises establishing a metallic arc to a stack of work having gaps between the work and directed across the stack, passing a stream of oxygen through the interior of the arc directed against the stack in the direction across the stack, fusing in the arc a mineral non-oxygen-liberating coating consisting practically entirely of inorganic ingredients which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature, ionizing the coating in the arc and projecting the fused products of the coating into the cut and across the gaps of the stack to cut across such gaps.

6. The process of stack cutting metal in the open air, which comprises establishing an alternating current metallic arc to a stack of work having gaps between the work and directed across the stack, passing a stream of oxygen through the interior of the arc directed against the stack in the direction across the stack, fusing in the arc a mineral non-oxygen-liberating coating consisting practically entirely of inorganic ingredi-

ents which in the arc in the presence of oxygen form practically only products which are solid or liquid if considered at room temperature, ionizing the coating to maintain the arc in the presence of the oxygen stream and of the alternating current and projecting the fused products of the coating across the gaps of the stack to cut across such gaps.

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