FIG_1

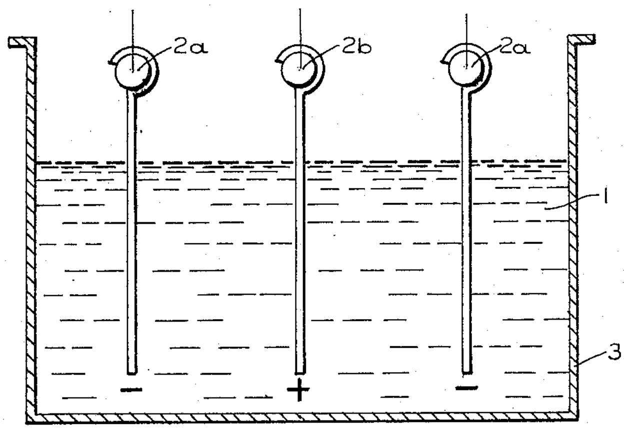

FIG_2

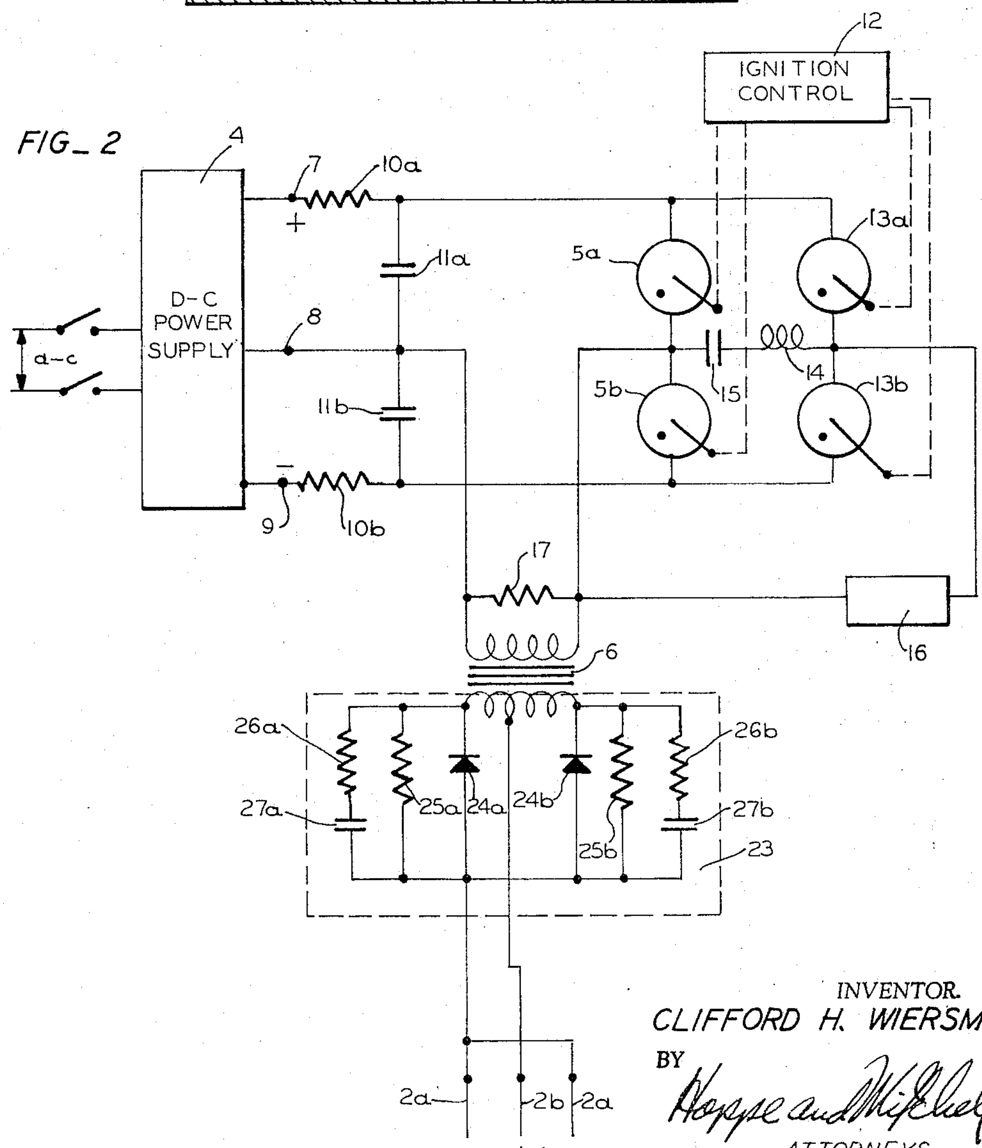

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FIG_3

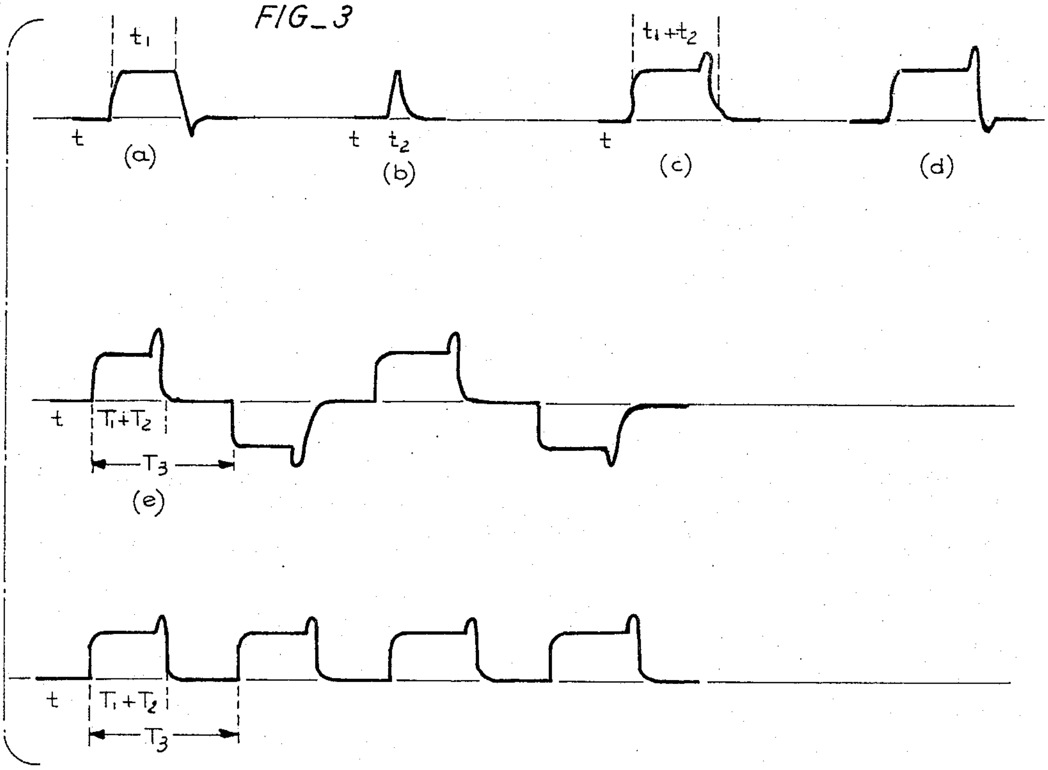
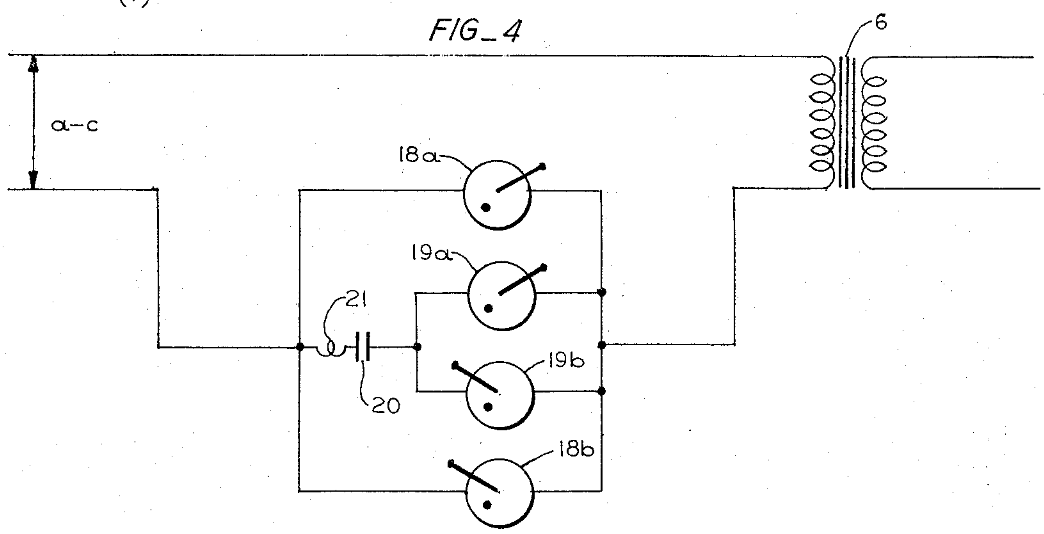


FIG_4



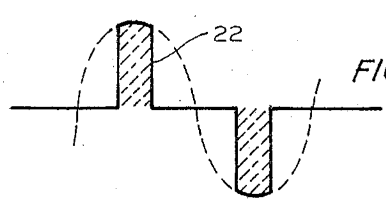


FIG_5

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United States Patent Office

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ELECTROLYTIC TREATING APPARATUS INCLUDING A PULSATING D.C. POWER SOURCE

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1 Claim. (Cl. 204—228)

This invention relates generally to electrolytic treating methods and apparatus and more particularly to an electrolytic method and apparatus for cleaning, anodizing and micromachining electrically conductive objects.

Heretofore electrolytic cleaning or scale and oxide removal has been conducted in baths of electrolyte by employing steady D.-C. power across the electrodes. With prior art processes many oxide scales and foreign materials cannot be removed satisfactorily, particularly at deep internal corners of small radius, without undesirably damaging or removing parent metal in other parts of the object. However, it has been found that by use of the described method employing pulsed D.-C. power extremely deep corners and grooves can be cleaned without injury to the other portions of the object.

One object of this invention therefore is to provide a method and apparatus employing pulsed D.-C. power for electrolytic cleaning of metal objects.

Another object of this invention is to provide a method and apparatus employing pulsed D.-C. power for micromachining electrically conductive objects.

One other object of this invention is to provide a method and apparatus for improving the physical characteristics of metals by subjecting them to electrolysis with pulsed D.-C. power.

The foregoing and other objects and advantages of this invention will become apparent to those skilled in this art upon an understanding of the preferred embodiments described herein and illustrated in the accompanying drawings, wherein:

FIG. 1 is an elevational view in section of an electrolytic bath which may be employed in the described process;

FIG. 2 is one embodiment of means for developing the pulsed D.-C. power employed in the present invention;

FIG. 3 represents the wave forms appearing in various portions of the circuits illustrated in FIG. 2;

FIG. 4 illustrates another circuit for developing the pulsed D.-C. power employed in this invention; and

FIG. 5 represents the wave form developed with the circuit of FIG. 4.

The method of this invention includes immersing the object to be treated in a bath of electrolyte. The object is then electrically connected to one electrode of a pulsed D.-C. power source. At least one other electrode of opposite polarity is also immersed in the bath. Application of the pulsed D.-C. power across the electrodes causes remarkably improved cleaning of the object. The method, if carried further, micromachines the base metal of the object itself.

The described method can be performed with various electrolytic solutions. As is well-known in this art the electrolyte generally will vary as a function of the type of material to be treated. For chrome-nickel steel alloys, including various stainless steels, or for pure iron, stabilized phosphoric acid solutions have been found to be extremely satisfactory. Use of such solutions imparts a high polish to the material in addition to removing scale or oxides.

In addition, the pulsed D.-C. power of this invention has been found to be a superior anodizing medium. In some instances exposure to pulsed D.-C. electrolysis also improves the physical properties of metallic objects. For

example, exposure to pulsed D.-C. of type 4340 stainless steel test tabs for one minute in a stabilized phosphoric acid bath increased the yield and ultimate strengths of the tabs some 1–4 percent and the ductility by 20 percent. The D.-C. power was 10 amperes at 2 volts (average) and 35 volts (peak) with a pulse repetition rate of 114 pulses per minute and a pulse width of 20 milliseconds.

FIG. 1 illustrates a bath of electrolyte **1** in which the electrodes **2***a*, **2***b* employed in the method are immersed. The object to be treated is affixed for example to electrode **2***b* of positive polarity and equally spaced from the negative electrodes **2***a*. A vessel **3** contains the electrolyte. The electrodes generally are heavy copper bars; however, other conductors are satisfactory for use with various electrolytes.

FIG. 2 schematically represents means for developing pulsed D.-C. power useful in the method. The apparatus comprises a load transformer; means supplying a pulsed signal of alternating polarity and controlled pulse width to the primary of the load transformer; and means for rectifying a corresponding high amperage-low voltage current induced in the transformer secondary to produce a pulsed electrode supply of uniform polarity with predetermined pulse widths.

A D.-C. power supply **4** provides anode-cathode potential for a pair of high capacity mercury discharge tubes **5***a*, **5***b* of the type disclosed in U.S. Letters Patent No. 3,089,053 issued on May 7, 1963 to Alfred Vang. These tubes, sometimes called trignitrons, through separate loops supply pulses of alternating polarity to the primary winding of load transformer **6**. The D.-C. power supply has a positive terminal **7**, an intermediate or common terminal **8**, and a negative terminal **9**. Trignitron **5***a* in series with the primary winding supplies power from terminals **7**, **8** through current limiting resistor **10***a* and filter condenser **11***a*. Tube **5***b* also in series with the primary supplies power from negative terminal **9** and common terminal **8** through a similar limiting resistor **10***b* and filter condenser **11***b*.

Ignition control **12** supplies a sequence of pulses at predetermined values, intervals and repetition rates to alternately fire and disable trignitrons **5***a*, **5***b*. The ignition control **12** first supplies a firing pulse to the ignitor of trignitron **5***a* for example. The pulse ionizes some of the mercury within the tube and initiates conduction through the tube as is more particularly described in Patent No. 3,089,053. The current flow supplies power to the primary winding of load transformer **6**.

The duration of the tube firing time and hence the width of the pulse which trignitron **5***a* supplies to transformer **6** is determined by a second trignitron tube **13***a* referred to herein as a "blow-out" tube. This blow-out tube is connected in series with inductive means **14** and capacitor **15** across the trignitron **5***a*. The blow-out tube acts as a switch to discharge condenser **15** in opposition to the current flow in trignitron **5***a*. The applied reverse voltage deionizes it and terminates current flow through the tube **5***a*. The blow-out tube **13***a* is made conducting by a second pulse from the ignition control **12**. This permits condenser **15** to discharge across trignitron **5***a*, deionize the tube and interrupt the current flow through it to form a pulse as illustrated in FIG. 3(*a*).

The condenser discharge forms a second pulse represented in FIG. 3(*b*) at the transformer primary. The total pulse is a composite of these two waveforms as represented in FIG. 3(*c*). The waveform sometimes appears as the variant illustrated in FIG. 3(*d*), depending upon the inductance of the transformer **6**.

Trignitron **5***b* then is similarly ignited by a third pulse from the ignition control **12**. Conduction through tube **5***b* is terminated by a fourth pulse from the ignition control supplied to the ignitor of a second blow-out tube

13*b* connected in series with capacitor **15** and conductor **14** across tube 5*b*. When blow-out tube **13***b* conducts the condenser **15** discharges and applies a reverse voltage to trignitron 5*b* as described in connection with tube 5*a*. The resulting pulse supplied by tube 5*b* to the transformer primary is similar to the waveform of FIG. 3(*c*) but of opposite polarity. The entire waveform in the transformer primary is represented in FIG. 5(*e*). By varying the interval between ignition control pulses the pulse width and repetition rate can easily be adjusted for varying operating conditions.

The condenser **15** during operation of the device is charged alternately by blow-out tubes **13***a* and **13***b*. However, upon startup the charge across the condenser is developed by a D.-C. source **16** generally referred to as a "trickle charger." The source **16** connects one end of load resistor **17**, which is in parallel with the transformer primary, and charges condenser **15** through inductor **14**. The trickle charger may be, for example, a single wave rectifier operating from line power with a filter network to supply a relatively steady D.-C. voltage in the order of 600 volts.

With the foregoing arrangement a high voltage alternating signal with controlled pulse widths supplies the primary of the load transformer. Other means for supplying a similar signal also may be employed. For example, solid state devices such as silicon controlled rectifiers, may replace the trignitrons in some applications. However, the described circuit employing the mercury discharge tubes of Patent No. 3,089,053 has been found to provide extremely large system capacity and close control over the pulse width which generally is not obtainable with other pulse generating system.

One alternate means employing single phase alternating line power is illustrated in FIG. 4. In this system one side of the A.-C. line directly energizes the primary of the load transformer **6**. The other side is connected through a pair of trignitron tubes **18***a*, **18***b* with their corresponding blow-out tubes **19***a*, **19***b* connected in series with capacitor **20** and inductance **21** in a manner somewhat similar to that described in connection with FIG. 2. An ignition control with an output of selectively spaced pulses controls ignition and cut-off of trignitrons **18***a*, **18***b* in a manner somewhat similar to that described in connection with FIG. 2 to provide the transformer primary with a pulse input signal of alternate polarity as illustrated in FIG. 5 as at **22**. The dotted waveform in FIG. 5 is the input A.-C. signal. In the described system the ignition control is synchronized with the input A.-C. waveform so that the ignition pulses are supplied to tubes **18***a*, **18***b* and to blow-out tubes **19***a*, **19***b* only during that part of the A.-C. cycle when their respective anodes are positive relative to the corresponding cathode.

A waveform of pulses alternating in polarity similar to that illustrated in FIG. 3(*e*) is induced in the secondary winding of the load transformer **6**. This signal is of generally high amperage and low voltage. It is rectified by rectifying means referred to generally as **23** so that the power supplied to electrodes **2***a*, **2***b* is a series of pulses as illustrated in FIG. 3(*f*) of the same polarity. The rectifying means comprises, for example, diodes **24***a*, **24***b* connected respectively to the ends of the secondary winding and the common negative electrode **2***a*; a filter network for each diode comprising a parallel resistor **25***a*, **25***b* and a parallel resistor **26***a*, **26***b* and capacitor **27***a*, **27***b*, respectively, for each diode. The positive electrode connects to a center tap on the secondary winding of the transformer **6**.

Thus, the rectified output signal is a series of pulses of the same polarity as illustrated in FIG. 3(*f*). The pulse repetition rate and pulse duration is determinable by the control pulses from the ignition control. In this manner the average current in the electrolyte can easily be varied and controlled within close limits. The pulse waveforms of the rectified output are nearly identical to those in the transformer secondary, but of one polarity. Each pulse is a composite of T_1, the firing time of each firing trignitron and T_2, the discharge time of the blow-out condenser. The composite pulse and a variable period of no current flow complete the repetitive waveform.

The ignition control is a pulse generator having a variable repetition rate. Various forms of such generators useful in the described circuit will be familiar to those in this art and therefore the circuit details of suitable apparatus are not shown.

The foregoing detailed description has been given for clearness of understanding only and no unnecessary limitations should be understood therefrom, for certain modifications will be obvious to those skilled in this art. The invention is defined in the following claim.

I claim:

In an apparatus for electrolytically cleaning metal objects having a bath of electrolyte and spaced electrodes of opposite polarity in said bath, an improved source of power connected across said electrodes comprising a center tapped D.-C. power supply; a first mercury discharge device connected across the center tap and one side of said supply; a second mercury discharge device connected across the center tap and the opposite side of said supply; separate igniter means for making each of said mercury discharge devices conductive; separate means for terminating conduction of each of said mercury discharge devices; and ignition control means selectively igniting and terminating conduction of said mercury discharge devices in preselected sequence and time relationship.

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