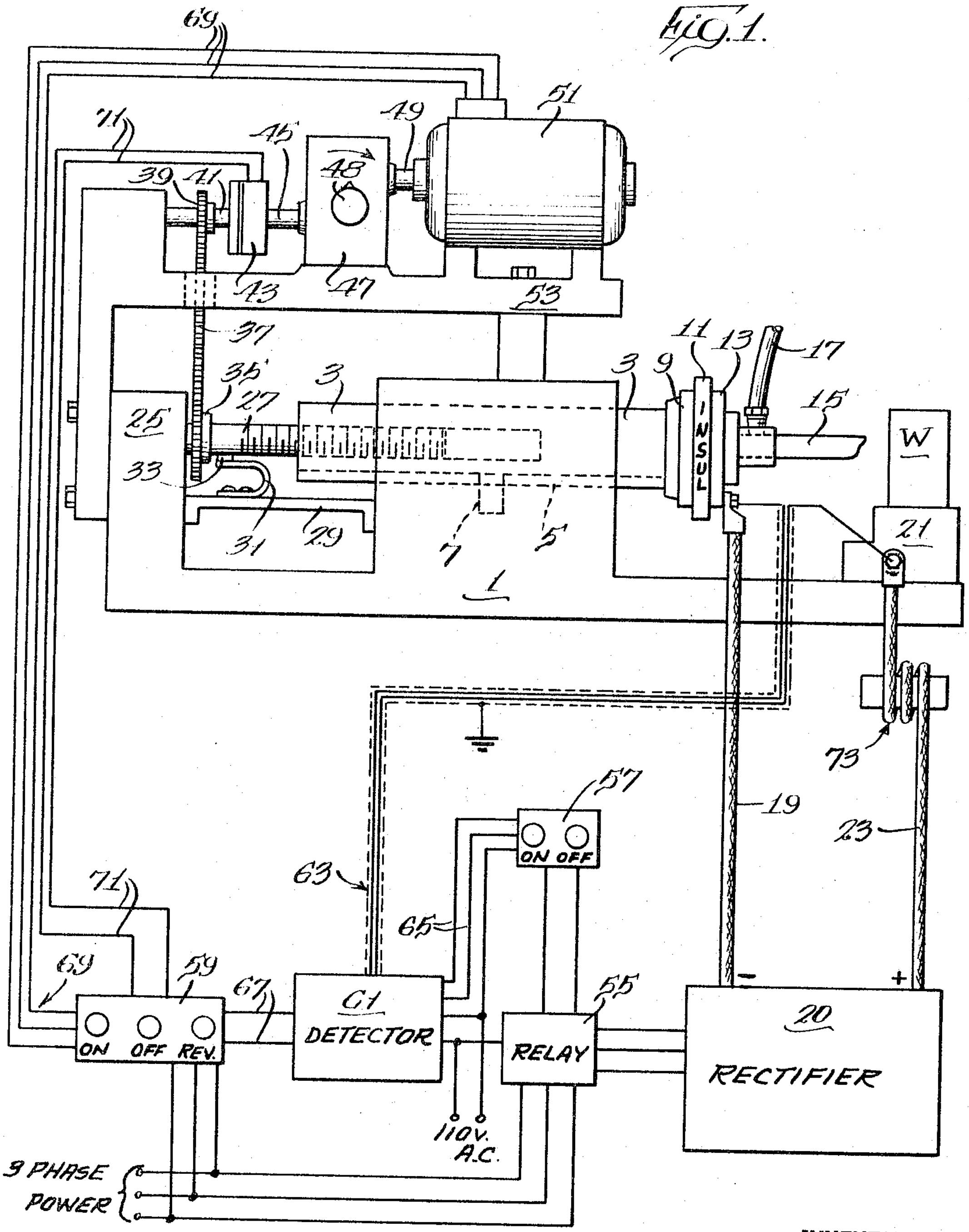
June 27, 1967 | L. A. WILLIAMS ETAL | 3,328,279

CONTROL AND OPERATING SYSTEM FOR ELECTROLYTIC HOLE SINKING

Original Filed Dec. 31, 1959 | 2 Sheets-Sheet 1

Fig. 1.



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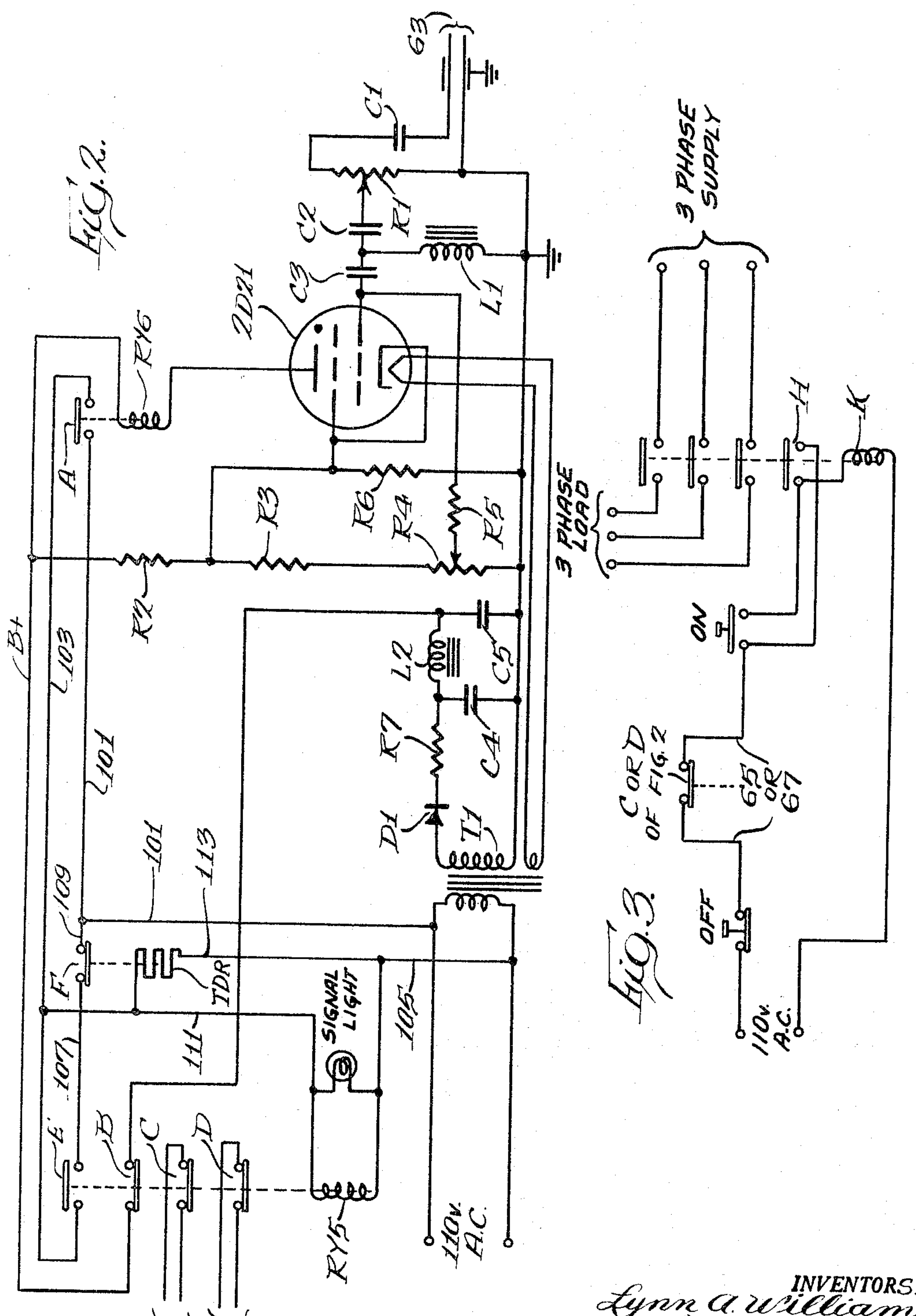

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CONTROL AND OPERATING SYSTEM FOR ELECTROLYTIC HOLE SINKING

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Continuation of applications Ser. No. 863,246, Dec. 31, 1959, and Ser. No. 436,383, Dec. 23, 1964. This application June 23, 1966, Ser. No. 560,013

3 Claims. (Cl. 204—228)

This application is a continuation of copending application 436,383, filed Dec. 23, 1964, and now abandoned, and abandoned application 863,246, filed Dec. 31, 1959.

This invention relates to electrolytic cavity-sinking apparatus, and constitutes an improvement upon the apparatus forming the subject matter of the United States Patent No. 3,058,895, dated Oct. 16, 1962, of one of the present applicants, Lynn A. Williams, for "Electrolytic Shaping."

In the above identified patent, apparatus is shown for sinking cavities by electrolytic means. In general, the apparatus utilizes a hollow electrode connected with a high pressure source of electrolyte so that the electrolyte can be pumped through or around the electrode to the work area. The electrode is mounted upon one or another form of feeding device arranged to feed the electrode toward and into the workpiece as material is removed from the latter. A high capacity, direct current source is connected in such a way as to make the electrode negative and the workpiece positive.

It has been found in practice that in utilizing the apparatus described in the above identified application it is possible that under some circumstances there may be accidental short circuiting between the electrode and the workpiece. This may occur, for example, where a manually adjusted feed mechanism is used and the feed adjustment is set or increased to too high a level with respect to the removal rate. In such cases, the electrode will advance against the workpiece and cause short circuiting. In other cases, short circuiting may occur if there is some misalignment between the electrode and the workpiece, so that as the electrode penetrates into the work a side portion of the electrode is engaged by the side wall of the cavity being formed so that the electrode is deflected sidewardly. Still again, short circuiting may occur with some types of electrodes, particularly those which are thin in section in one or more planes due to lateral vibration set up by the passage of electrolyte under high pressure through the electrode and out at the working tip thereof.

Whenever such short circuiting occurs, there is the likelihood of greater or less degree of damage to the electrode. If the electrode is small in section, the short circuiting current may actually heat the electrode to such a degree that it is destroyed. In other cases, the short circuit may strike an arc, causing a pit mark on some portion of the working tip, either its frontal surface or a lateral surface depending upon the cause of the short circuit. Since it is sometimes the case that the electrodes are difficult to fabricate and, therefore, costly, it is desirable to prevent serious short circuiting and the consequent damage of the kind which cannot be readily repaired; for example, by filing.

Another possibility for electrode or work damage exists in the situation which may arise where the electrode is being positively advanced into the work and where the electrolyzing current supply fails. Under these conditions the electrode or work will soon be crushed, since the work face no longer recedes as the electrode advances.

An object of this invention is to provide novel means for detecting either an incipient or an actual short circuit between the electrode and the work, and thereupon to

arrest further infeed of the electrode and to turn off the electrolyzing current.

Another purpose is to assure nearly instantaneous stoppage of the forward feed of the electrode whenever sparking or arcing occurs between the electrode and the work, or whenever the electrolyzing current fails even momentarily.

Another purpose is to bring about a stoppage of the forward feed of the electrode and a discontinuance of the electrolyzing current at the first spark which occurs and, without awaiting a train of sparks or arcs during which severe damage might be caused.

Another purpose is to arrange for easy restarting of the forward motion of the electrode and of the electrolyzing current after the condition which caused the automatic stoppage has been corrected.

Another purpose is to avoid repetitive cycling of the detector device after it has detected a short circuit between the electrode and the work.

Another purpose is to devise apparatus which will respond to short circuiting between the electrode and the work, or failure of the electrolyzing current over a broad range of electrical current requirements.

In the drawings:

FIG. 1 is a schematic illustration of the mechanism for driving an electrode toward the work and the associated controls including the malfunction detecting system;

FIG. 2 is a diagram of the electrical circuit which responds to short circuiting or electrolyzing current failure and which is shown in FIG. 1 in the block marked "detector"; and

FIG. 3 is a schematic diagram of the essentially conventional basic control circuit used in connection with the apparatus of this invention.

Referring to FIG. 1, there is shown in the upper portion in diagrammatic form, mechanical apparatus driven by an electric motor for moving the electrode toward a workpiece. It should be understood that while the electromechanical system is shown for illustrative purposes, it is also possible to use pneumatic or hydraulic drive means, in which case, of course, valve devices, including electrically actuated valves, may be substituted for the various switches, etc., which are used in the electromechanical system.

More particularly, the mechanical apparatus consists of a base frame member **1** which in its midsection is raised and has a bore therein in which a cylindrical ram **3** is supported and guided to permit motion to the right or left as seen in the diagram. It is necessary to provide against accidental rotational motion of the ram **3**, and such provision is illustrated diagrammatically by a longitudinal slot or keyway **5** cut into the ram which embraces the end of a pin **7** set into the base member **1**.

At the right hand end of the ram, there is provided an enlarged head **9** to which is fastened a block of insulating material **11**. To this, in turn, there is secured an electrode holder **13** into which the electrode itself **15** is fastened by any suitable means. Electrode holder **13** is recessed and adapted to receive connection of a tube or conduit **17** which leads from an electrolyte supply including a high pressure pump. It should be understood that conduit **17** leads high pressure electrolyte through passages provided in electrode holder **13** which communicate with central passages through electrode **15** to the working tip of the electrode. A flexible electrical cable **19** is bolted or otherwise fastened to the electrode holder, and is connected to the negative pole of the output of a low voltage, high current capacity rectifier **20**.

At the right hand end of the base, there is mounted a workholder or fixture **21**, and upon it is clamped the work itself W. For simplicity, the detail of the workholder and the means for fastening the work to it are omitted, as the methods for doing this are conventional. An electrical cable **23** is provided for connecting the fixture and through it the work, or, in some cases, the work directly to the positive pole of the rectifier.

At the left hand end of the base, a riser element **25** journals the back end of a lead screw **27**, and also provides a thrust bearing for the screw. The lead screw **27** is fitted to an internal thread in the ram **3**.

To provide braking action on the lead screw, a cross member **29** is installed carrying a metal spring **31** fitted at its free end with a brake shoe of Teflon or other durable material, identified by reference numeral **33**, which presses against an unthreaded portion of the screw.

To drive the lead screw, a sprocket wheel **35** is fastened to it, this sprocket being connected by a chain **37** to a driving sprocket **39** mounted on a shaft **41** which extends from an electric clutch **43**. The electric clutch is driven by the output shaft **45** of a speed reducer **47** having a speed control knob **48**. The motive power to the speed reducer is supplied through input shaft **49** from electric motor **51**. These drive components for the lead screw are mounted on a suitable base **53** which is rigidly fastened to the main base member **1**.

Turning to the electrical system, the input for the rectifier usually will be taken from a three-phase, alternating current source through a power relay or contactor **55**. It is also possible, of course, to use a well filtered, single phase rectifier system. The contactor **55**, in turn, may be controlled by remote push buttons mounted in a control head **57**. The circuitry for interconnection of the push button controls and the contactor is not shown in detail in this drawing, but is shown in FIG. 3 and is of the conventional type. It may be said here, however, that momentary actuation of the "On" button energizes the contactor and concurrently establishes a holding circuit to hold the contactor in closed circuit position. The "Off" button, when actuated, opens the holding circuit, and causes the contactor to open. The push-button control circuits are normally operated at 110 volt potential in the United States, and assuming that the three-phase line supply is at higher voltage than this, a control transformer connected across one of the phases is used for the 110 volt supply.

Similar remote control circuitry may be used to control the motor **51** and the electric clutch **43**. These controls may be mounted in a control panel generally designated as **59**. If the electric clutch be of the kind which requires direct current for its actuation, it should be understood that an appropriate rectifier may be included within the control panel **59** for this purpose. The control panel will also include switches and an appropriate reversing circuit so that motor **51** may be driven in either direction to advance or retract ram **3** and, with it, the electrode **15**.

The short circuit detector **61** is provided with supply current taken from the electric input lines, and contains one or more relays which, when actuated in response to signal, open the circuits established by control panels **57** and **59** so as to deenergize simultaneously contactor **55**, thereby turning off the rectifier, and motor **51** and electric clutch **43**.

Electric clutch **43** is used instead of relying solely upon the stoppage of motor **51** because it is desired to avoid any coasting which would tend to advance the electrode for some distance into the work even after motor **51** had been deenergized. It will be noted that the electric clutch **43** is mounted on the output side of the variable speed reducer **47** so that the rotary motion transmitted by the clutch is quite slow. Because of this and because of the action of the brake **33**, rotation of the lead screw **27** stops almost instantaneously when the electric circuits to the clutch **43** and the motor **51** are deenergized. Measurements have been made by using a dial type indicator to measure the forward over travel of the ram, and it has been found that with this construction the ram advances less than .001" after the clutch and motor have been deenergized.

The detector **61** signal input is connected by leads **63** to the positive and negative supply cables **19** and **23**. The relay contacts within the detector are connected respectively to control panels **57** and **59** by electrical leads **65** and **67** as will appear in greater detail presently.

Electric motor **51** is fed from control panel **59** by electrical leads **69**, and the electric clutch by leads **71**.

The circuitry for the detector **61** of FIG. 1 forms the subject matter of FIG. 2, but before embarking upon a description of this circuit, it should be understood that efforts to achieve the desired control by reference to the current drawn by the electrode can be only partially successful. One might suppose that with a given electrode it would be possible to ascertain the maximum current which might be drawn without sparking or arcing. So long, then, as this current level was not exceeded it might be assumed that the electrode was advancing into the work normally and without short circuiting. All that would be required then, to achieve the desired control, would be an adjustable relay which would be actuated only when the current rose above some predetermined level, the rise above that level being caused by short circuiting.

In fact, however, there are many deficiencies to so simple a system. First, of course, such a system would require adjustment of the current responsive relay for electrodes of different sizes and for different rates of feed, as it will be understood that with faster feed more current is required than with slower feed. Second, the area of the electrode in working relationship to the workpiece may change as the electrode enters the work. This effect will be quite pronounced where the electrode is shaped to provide a bottom in the work cavity which is not flat. As the electrode enters the work, the area between it and the workpiece may be quite small and may then enlarge as other portions of the electrode come successively into working relationship with the workpiece. Under these circumstances, if the maximum acceptable current level were set to accommodate the current for the full working surface of the electrode, then there would not be very good protection against short circuiting when the first part of the electrode reached the work, for considerable arcing might occur without bringing the current level above that which would be absorbed in the normal way by the full working area of the electrode. On the other hand, if the permissible current was set at a low level to give protection as the electrode first entered the work, then the current might well rise above this level in prefectly normal operation, and thereby give a false signal, causing shutdown of the equipment without need for it.

Finally, and contrary to what one might suppose, it has been observed that rather extensive short circuiting may occur without bringing about any very marked change in the mean current level. This seems to happen particularly in the case of accidental short circuiting between the side of the working tip of the electrode and the work. Quite likely, such short circuiting, at least at the outset, is caused by a very light brushing contact which leads to the passage of one or more sparks. Perhaps these erode away a portion of the electrode so that no additional short circuiting will occur immediately.

It would be quite difficult to use a current responsive system which would be sensitive enough to respond to this kind of short circuiting; yet considerable damage to the electrode may result. Sometimes, also, after this type shorting has caused initial damage to the electrode, craters and rough edges which are thus created on the electrode may lead quite suddenly to very severe arcs, which will destroy the electrode's usefulness entirely.

None of the above analysis even considers the related hazard associated with a failure of the electrolyzing current while the drive motor continues to run. Here, of course, the conditions are opposite; that is, the drive should be shut down upon the basis of a current failure rather than excessive current.

Accordingly, in this invention the circuit is arranged to respond to any sudden change in current and, particularly, to any momentary surges. This response, it has been found, can be used effectively at any current level, so that the circuit will operate effectively either for a large electrode or for a small one, or, in the case of an electrode having variable working area as it progresses into the work, this system will function throughout the working advance of the electrode into the work.

In the relatively inexpensive circuit of FIG. 2 which accomplishes the desired result, it will be noted that the input signal is brought to the detector proper by conductors **63**, which are preferably enclosed in a shield. Preferably, the connection of these conductors **63** is taken as close as possible to the electrode and the workpiece so as to minimize attenuation of the signal and to increase the signal-to-noise ratio. The conductor from the negative or electrode side is lead to capocitor C**1** which provides isolation of the direct current. A potentiometer R**1** is connected across the input as shown, so as to permit adjustment of sensitivity. The signal is taken from the potentiometer tap and passed through a high-pass filter consisting of capacitors C**2**, C**3**, and inductance L**1**, and thence to the grid of a gas tube which is shown here as being of the 2D21 type, although, of course, other tube types might be used. The purpose of the high-pass filter is to reject any false signals which might otherwise be induced by the low frequency ripple voltage which is usually present in the rectifier type of power supply commonly used to feed electrolyzing current to the electrolytic gap between the electrode and the work. The high pass filter might be omitted if the power rectifier is well enough filtered to keep the ripple voltage well below the level of the signal to be detected.

In some cases, it may be desirable in order to augment the signal to introduce inductance into one or more of the power cables as shown schematically in FIG. 1 at **73**, where one of the cables is wrapped for several turns around an iron core. This introduces a high impedance back through the rectifier to any high frequency transients, but of course offers very low impedance to the passage of direct current. Most commonly, this is not used and is unnecessary. However, a heavy bank of capacitors having a value of 24,000 to 50,000 microfarads will sometimes be connected across the direct current output at the rectifier for smoothing the ripple.

The control grid of the gas tube 2D21 is biased to a negative potential relative to the cathode by a voltage dividing network which includes resistors R**2**, R**3** and potentiometer R**4** connected between B+ and ground. Resistor R**5** is interposed between the arm of the potentiometer R**4** and the control grid to complete the grid bias connection. The grid signal appears across R**5** and a portion of R**4**. The screen is tied to the cathode as is conventional for this type of tube.

In the absence of signal, the negative bias on the control grid prevents the gas tube from firing. However, if a signal is received consisting of a sharp transient resulting from the passage of a spark between the electrode and the work, the positive spike of the transient will raise the potential of the control grid relative to the cathode to the point where the tube will fire and conduct current supplied by the plate current B supply system. The B supply system is substantially conventional and consists of a transformer T**1**, a diode D**1**, a dropping resistor R**7**, and a shunt capacitor input filter system consisting of condensers C**4** and C**5** and inductance L**2**.

The B supply is connected to the plate of the tube through normally closed contacts B of relay RY**5** and through the control coil of a sensitive relay RY**6**.

Upon receiving a signal, the desired control operation is first to open the holding circuits which maintain energization of the mechanical feed of the electrode, and also to interrupt the principal power supply which feeds current to the electrolytic work gap. Subsequently it is desired to recondition the control system so that when the entire apparatus is set in operation again the detector will be ready to function. These results are accomplished in the following manner.

When the sensitive relay RY**6** is energized, its normally open contacts are closed, and they establish a circuit through conductors **101**, **103**, and **105** to supply 110 volt alternating current to the control coil of relay RY**5**.

Relay RY**5** includes not only normally closed B+ supply contacts previously referred to, but also two other sets of normally closed contacts C and D. Upon actuation of relay RY**5**, all of these normally closed contacts are opened, and contacts C and D open the previously mentioned holding circuits so as to cause deenergization of the input supply to the main rectifier and the electric clutch **43** and the electric drive motor **51**.

The actuation of relay RY**5** also closes a set of normally open contacts which are connected to establish a holding circuit for relay RY**5** through delay relay TDR, which is shown here as being of the thermal type.

The holding circuit may be traced as follows: Starting with conductor **105**, current is supplied to the control coil of relay RY**5**, thence to one of the contacts E, thence from the other contact E by conductor **107** to one of the contacts F of the time delay relay TDR, thence by conductors **109** and **101** back to the other side of the alternating current power line. Thus contacts E and F as a series unit are in parallel with contacts A.

Accordingly, even though relay RY**6** drops open when the plate power supply is broken by the opening of contacts B, the closure of contacts E maintains relay RY**5** in its energized position, since contacts F are normally closed, but without any plate current being supplied to the gas tube 2D21. The cessation of plate supply permits the gas tube to be extinguished and to become nonconductive.

The heater element of time delay relay TDR is connected in parallel with relay coil RY**5** by leads **111** and **113** and is energized simultaneously therewith. When the heating element has been warmed to its predetermined level, it causes the opening of contacts F, which thus breaks the holding circuit of relay RY**5**, which then returns to its deenergized position, closes contacts B, and restores the plate supply to the gas tube 2D21. It should be noted, however, that this last step does not reenergize either the mechanical feed of the electrode or the main rectifier for supplying electrolyzing current.

To do this, it is necessary to actuate the control buttons shown at **57** and **59** in FIG. 1. Before doing this, however, it is prudent ordinarily to operate the drive motor **51** in reverse direction to retract the electrode **15** three or four thousandths of an inch in the cavity, so that whatever caused the short circuit will not cause an immediate short circuit upon restarting. After thus backing the electrode away from the work a bit, both the infeed mechanism and the main rectifier are started again by pushing the "on" buttons at **57** and **59**.

If the cause of the short circuiting signal was of a temporary or incidental nature, for example, a piece of conductive dirt which the filter (not shown) in the electrolyte supply system failed to arrest, then the operation will proceed normally. If, however, the cause of the short circuiting is of a more persistent nature, for example, excessive lateral vibration of the electrode or an excessive feed rate, then short circuiting will occur again, and again the entire system will be shut down.

It has been found convenient to bring one or both of the control knobs for potentiometers R**1** and R**4** to a position convenient to the operator, for when the detector is set for high sensitivity the operation of various control relays may cause false signals to actuate the detector even though it be shielded as shown and even though the pickup conductors **63** are shielded as well as is possible. Thus, when not actually doing any electrolytic work, the operator may easily desensitize the detector as much as is desirable by attenuating the input signal by adjustment of the potentiometer R1 or by increasing the negative bias on the control grid by adjustment of potentiometer R4.

The values of the electrical components successfully used in the detector circuit are as follows:

Component designation:	Value
C1	.002 μf.
C2	.002 μf.
C3	.002 μf.
L1	.75 h.
R1	10K.
R2	25K.
R3	5K.
R4	10K.
R5	3.9K.
R6	1K.
R7	50 ohms.
C4	20 μf.
C5	40 μf.
D1	75 ma.
L2	35 h.
RY6	10,000 ohm-5 ma.

The time delay relay TDR is chosen to have a time constant of the order of two to three seconds. An indicator light signal S is connected across the control coil of relay RY5 as illustrated to show the attendant that the detector has operated and so that he will know that this is the cause of the shutdown of the apparatus.

So that there will not be any misunderstanding, there is shown in FIG. 3 a schematic circuit diagram which typifies the holding circuits used in control boxes **57** and **59** shown in block form in the diagram of FIG. 1. Ordinarily, such control systems are supplied on the control side by 110 volt alternating current usually derived by a step-down transformer connected across one pair of the three phase power lines which most commonly are at 220 or 440 volts. The power relay or contractor K ordinarily includes three sets of contacts for a three phase power system. In the case of control box **59**, there is also included a standard reversing switch circuit to transpose two of the three phase lines for the purpose of reversing the motor **51**. There is also included a rectifier for supplying direct current to electric clutch **43** if the clutch be of the DC type, which is usual. In the case of control box **57**, the reversing switch and the rectifier are not needed, and thus the diagram of FIG. 3 accords precisely with the elements of control box **57** shown in FIG. 1 and it accords with the elements of control box **59** shown in FIG. 1 except for the omissions of the conventional circuits noted above.

The contactor or power relay K of FIG. 3 controls the three phase power supply through three normally open contacts. The connections marked "3-Phase Load" will lead to the main rectifier if the circuit shown in FIG. 3 is thought of as corresponding with control box **57**, and in this case, the three phase load conductors shown in FIG. 1. If the circuit of FIG. 3 is thought of as corresponding with that of control box **59**, then the three phase load conductors correspond with conductor **69** of FIG. 1. The control conductors shown as **67** or **65** in FIG. 3 correspond with the similarly numbered conductors of FIG. 1.

The actuator coil of relay K is energized from the 110 v. supply by way of a series connection comprised of the normally closed "Off" switch, the normally open "On" switch and the normally closed relay contacts C or D (FIG. 2) as the case may be. A set of normally open relay holding contacts H, actuated by the coil of relay K, are also connected across the "On" switch contacts.

When it is desired to energize contactor K, the momentary contact button "On" is pushed, thereby closing its normally open contacts and sending electric current to the actuating coil of contactor K by way of normally closed contacts C or D of FIG. 2. When contactor K is energized, not only are the normally open power contacts closed, but so also are the holding contacts H. Since the holding contacts bridge the "On" switch, the latter may now be opened without disturbing the energization of the coil of power relay K. Accordingly, once contactor K has been actuated by a momentary push on the "On" button, the above described holding circuit will maintain the contactor energized so that all of its contacts remain closed.

The contactor K is opened by any momentary break in the holding circuit. Thus, by pushing the "Off" button, the holding circuit is broken or, alternatively, the opening of normally closed contacts C or D in the detector as shown in FIG. 2 will cause the same result.

It should be understood that this holding circuit arrangement is entirely conventional and is used very widely in machine tool electrical controls and it is not suggested that this arrangement in itself constitutes invention. The overall safety control circuit for the electrolytic machining apparatus here shown has as one of its merits the fact that it is adapted to coact with the normally accepted "On-Off" push button controls used in machine tool practice.

By use of the gas tube type detector arranged with a triggering circuit as shown in FIG. 2, it is possible to bring the grid bias very close to the triggering point so that a very small signal will fire the tube, thereby providing adequate current to actuate sensitive relay **RY6**. Accordingly, a single tube without any amplifiers has been found to function quite satisfactorily. By use of the circuit shown, it has also been found very convenient to restart the operation without difficulty or undue delay.

Above all, the circuit permits elimination of a servo control with the attendant complications of a modulated electrode feeding system. Moreover, the detector will respond not only to overspeeding but also to any other cause of short circuiting, such as dirt of a conductive sort or vibration of the electrode, either of which may cause short circuiting and consequent damage to the electrode and possibly to the work.

Moreover, if the rectifier system which supplies the electrolyzing current should fail, or blow a separate fuse which controls its energization, the transient thus produced in leads **63** will actuate the detector in the same manner that a short circuit will, thereby shutting down the system. This is important because a failure of the electrolyzing current supply will lead to collapse of the electrode or the work if the drive to the feed screw is not immediately shut down, since, without the electrolyzing current, the work face no longer will recede in front of the advancing electrode. The control system, since it is sensitive to a transient across the electrode to work interface, rather than simply to excessive electrolyzing current, is thus seen to provide full protection for the work and for the electrode.

A complete power failure, even though momentary, will of course deenergize the coil of power relay K and open holding contacts H—H, thereby shutting down the system until it is purposely restarted.

It will be understood that the particular embodiments above described are subject to considerable variation without departing from the spirit of the invention, and it is not intended to limit the invention to the specific embodiments shown and described.

What is claimed as new and useful and desired to be secured by Letters Patent is:

1. In an electrolytic machining apparatus having a tool electrode, means for positioning a workpice, electrically energized means for relatively moving the workpiece positioning means and the electrode, means for supplying electrolyte to the work gap between the electrode and the workpiece, and an electrical system of high current capacity connected to supply a low voltage direct current between the workpiece and the electrode in a sense to make the electrode cathodic, the combination comprising

(a) manually operable switch means connected to initiate operation of the moving means and the electrical system,

(b) an electron discharge device and circuit therefor,

(c) circuit means connected for establishing potentials upon said discharge device to render said device normally nonconducting,

(d) means for changing the potentials upon said discharge device to render said device conducting,

(i) said potential changing means having a pair of input terminals connected to the workpiece and electrode, respectively, and

(ii) being actuated by a rapid change in the potential difference between said terminals caused by a spark passed between the workpiece and the electrode,

(e) normally closed second switch means connected in series with said manually operable switch means and which when opened deenergizes the moving means and the electrical system,

(f) relay means connected to receive current from said electron discharge device and to be energized thereby,

(i) said relay means when energized being connected to open said normally closed second switch means and to open said circuit which includes said electron discharge device,

(g) and a time delay relay connected to be operated by the energization of said relay means and being connected to prevent closing said discharge device circuit for a predetermined time period.

2. The combination set forth in claim 1, wherein

(b) said electron discharge device comprises an electron discharge tube,

(d) (iii) said potential charging means also includes circuit means connecting one of said input terminals to the workpiece and the other of said input terminals to the electrode,

(f) and said relay means comprises

(ii) first relay means connected to receive current from said electron discharge tube and to be energized thereby, and

(iii) second relay means connected to be energized upon energization of said first relay means,

(iv) said second relay means when energized opening said normally closed second switch means and opening said electron tube circuit which includes said electron discharge tube,

(g) and said time delay relay means is connected to be operated by said second relay means.

3. The combination set forth in claim 1, wherein

(d) said potential changing means includes

(iv) a capacitor to provide direct current isolation and

(v) a high pass filter to minimize the effect of ripple voltages,

and the combination includes

(h) means connecting said manually operable switch means in circuit with said relay means and said time delay relay means,

whereby said manually operable switch means must be manually closed to energize said moving means and said current supply system once said relay means has been energized to open said normally closed second switch means.

No references cited.

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