June 30, 1964 A. K. LITTWIN Re. 25,607

APPARATUS FOR AND METHOD OF DEMAGNETIZING

Original Filed April 1, 1957 2 Sheets-Sheet 1

Fig. 1

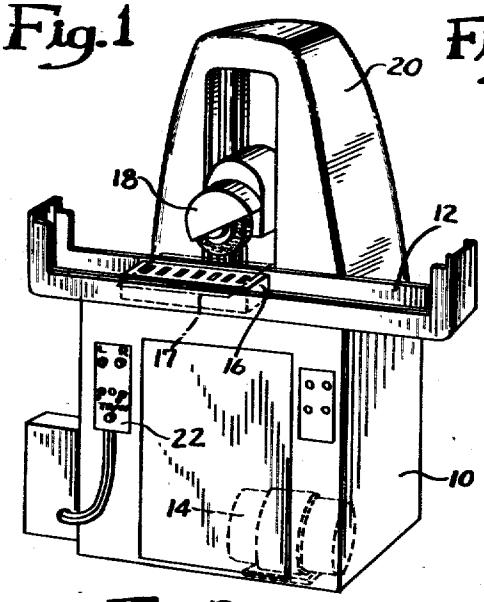



Fig. 4

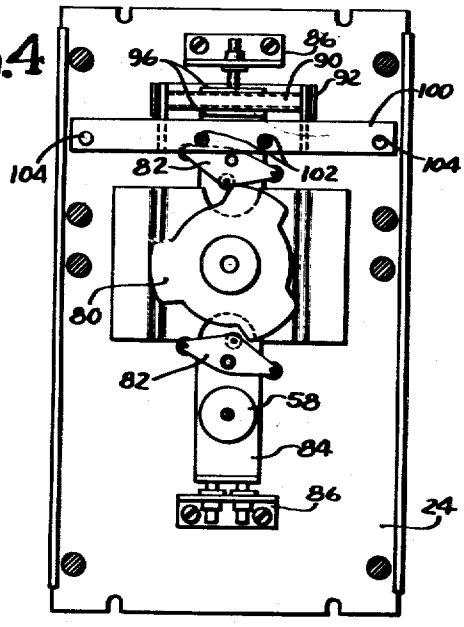



Fig. 2

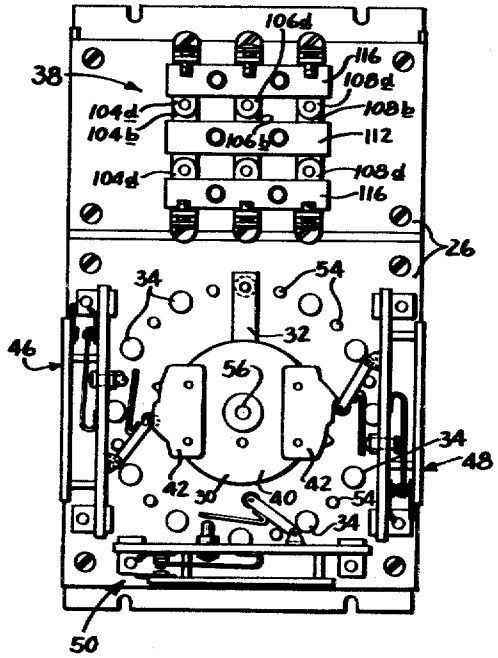
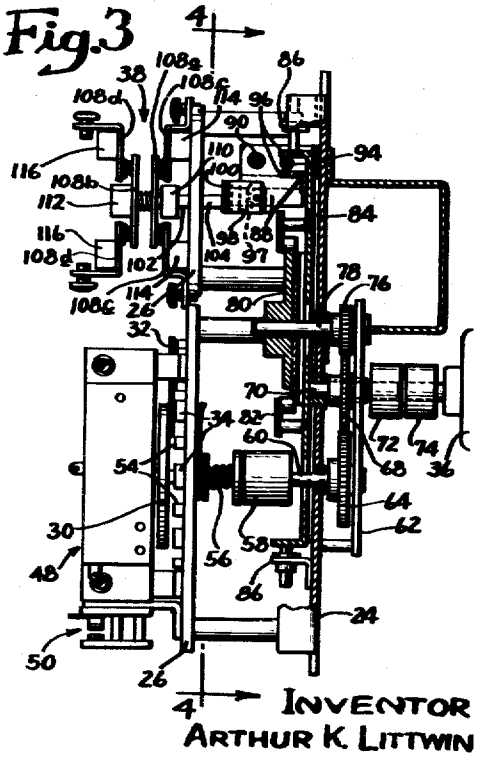



Fig. 3




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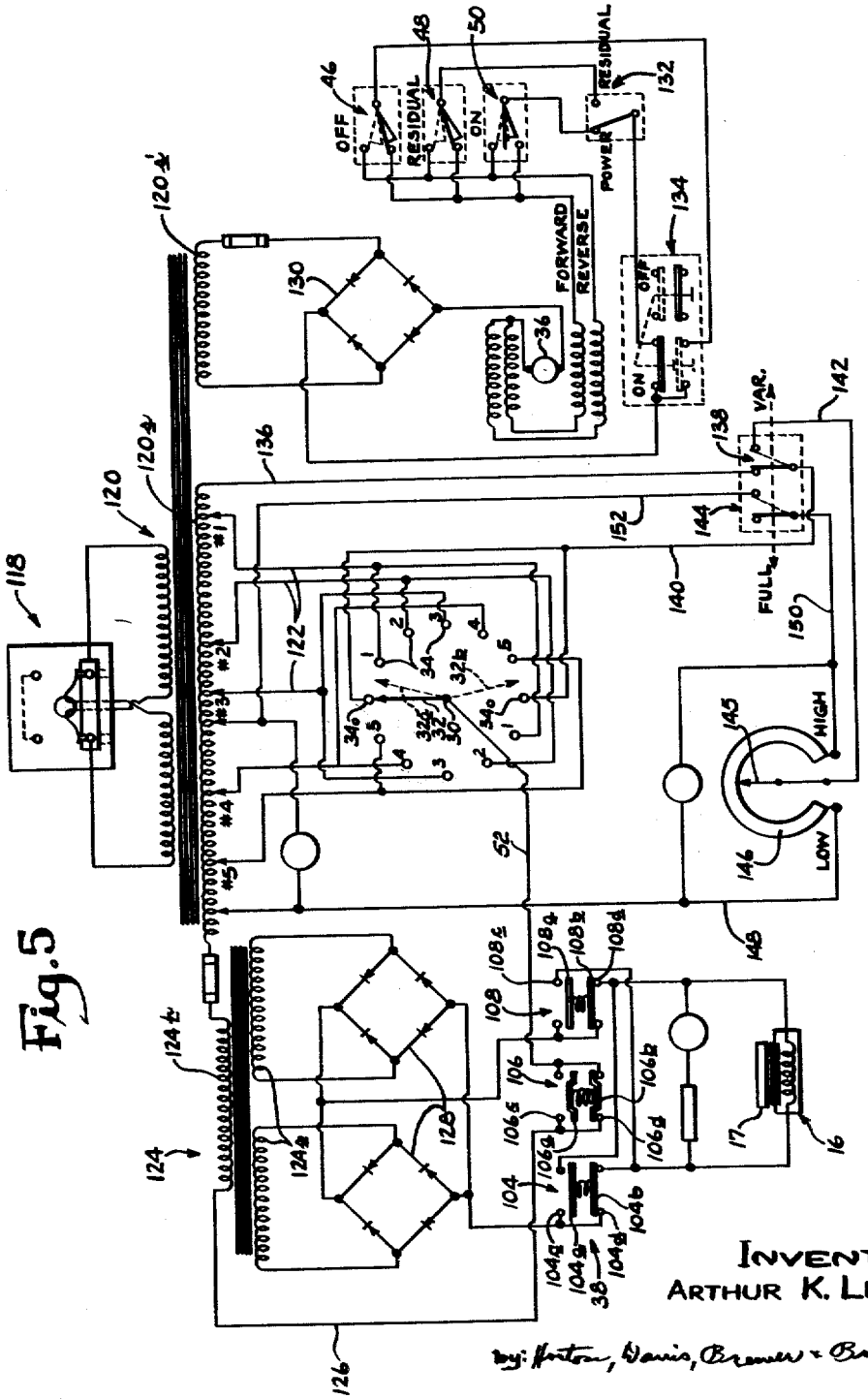



Fig. 5

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# APPARATUS FOR AND METHOD OF DEMAGNETIZING

Arthur K. Littwin, Lincolnwood, Ill., assignor, by mesne assignments, to Robert L. Littwin, Horace A. Young, Arthur K. Littwin, and Donald F. Littwin, trustees of the Littwin Family Trust No. 1

Original No. 2,825,854, dated Mar. 4, 1958, Ser. No. 650,032, Apr. 1, 1957. Application for reissue May 15, 1961, Ser. No. 110,620

19 Claims. (Cl. 317—157.5)

**Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.**

The present invention relates generally to means for demagnetizing an electromagnet.

The device has particular adaptation in connection with an electromagnetic chuck used for holding a work piece thereon in a machine for performing an operation on the piece. When it is desired to remove the work piece from the chuck, the chuck, together with the work piece, is demagnetized to facilitate removing the work piece from the chuck. An electromagnetic chuck of the character indicated above may be used, for example, on a machine tool on which a work piece is held on a table or other supporting means for performing a grinding, cutting, or similar operation thereon. For such operation the magnetic holding power is, of course, substantial in order to properly hold the work piece against the strong forces encountered. It is difficult to remove the work piece from the chuck after the operation is completed, because of the residual magnetism remaining after the magnetizing force is terminated. Therefore, the chuck, with the work piece thereon, is demagnetized to eliminate or minimize such residual magnetism.

An object of the invention is to provide a completely novel apparatus and method for demagnetizing a chuck, of the nature indicated above.

The magnetic chuck of the kind herein concerned is demagnetized by imposing thereon current in successively reversed directions and at successively reduced voltage, in a series of steps, the last one of which leaves the chuck with only a relatively small residual magnetism. The direct current supplied through the chuck is provided by a rectifying means from an alternating current source. Heretofore in demagnetizing such chucks, it has been customary to reduce the voltage in the demagnetizing operation by interposing a resistor or potentiometer in the direct current circuit leading to the chuck.

The present invention embodies an entirely new principle in this connection in that the power supply to the chuck is derived from an alternating current source and, instead of reducing the voltage in the direct current circuit by means of interposing a resistor or potentiometer therein, the alternating current source is interrupted, and at the intervals at which it is interrupted the transformer for supplying the desired voltage to the electromagnet is tapped at various voltage value points, with consequent elimination of disadvantages connected with the previous manner of reducing the voltage mentioned above.

Another object therefore of the invention is to provide apparatus and method for demagnetizing an electromagnet which includes supplying power for the demagnetizing operation from an alternating current source, and



interrupting the alternating current source and at periods of such interruption to reduce the voltage imposed on the electromagnet in a series of steps by tapping the alternating current source at successively lesser voltage value points.

A further object is to provide apparatus and method for demagnetizing an electromagnet in fewer steps than has heretofore been practicable with resulting advantages that less time is required for the operation and less wear is occasioned on the mechanical elements utilized in the apparatus.

A further object is to provide apparatus and method for demagnetizing an electromagnet which is equally effective regardless of the size of the size of the work piece held on the electromagnet and magnetized therewith.

A further object is to provide apparatus and method for demagnetizing an electromagnet in which all counter E.M.F. is effectively eliminated in the electromagnet such as would otherwise be occasioned by reduction of voltage imposed thereon as when a variable resistor is utilized in the direct current circuit.

A further object is to provide apparatus and method for demagnetizing an electromagnet including a novel arrangement for substantially eliminating arc and heat from such arc such as are encountered in breaking circuit in a direct current circuit.

Still another object is to provide apparatus and method for demagnetizing an electromagnet in which the necessary power consumption is substantially reduced relative to apparatus heretofore known.

A further object is to provide an arrangement for demagnetizing an electromagnet utilizing a direct current circuit for producing the magnetizing power, which is free of series resistances for reducing voltage therein, and low impedance is occasioned in the circuit.

Another object is to provide an arrangement for demagnetizing an electromagnet in which a novel mechanical means is provided for producing the reversal of the polarity of the direct current and breaking the aalternating current circuit, as is done in the use of the apparatus as described above.

Other objects and advantages of the invention will appear from the following detailed description taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a general view of a machine tool of a kind utilizing an electromagnetic chuck of the character to which the present invention is particularly adapted;

FIG. 2 is a front view of an instrument incorporating the physical or mechanical device for operating and controlling the demagnetizing means;

FIG. 3 is a side view taken from the right of FIG. 2;

FIG. 4 is a view taken substantially on line 4—4 of FIG. 3; and

FIG. 5 is a diagram of the circuit utilized in the apparatus.

Referring now in detail to the drawings, and particularly to FIG. 1, the device as shown in this figure is a machine tool embodying an electromagnetic chuck. The illustration of this figure is semi-diagrammatic in that most details are omitted for the sake of clarity, since the machine itself does not constitute a part of the present invention. The device or machine may be referred to as a machine tool and is utilized for performing a working operation on a work piece such as is capable of being held by an electromagnetic chuck. The operation may be

a grinding, cutting, or similar operation. The machine includes a suitable base **10** having a table **12** that is arranged for reciprocation back and forth along the base, in direction transverse to the direction of view, and is driven by a suitable driving means such as an electric motor **14**. The table **12** is provided with a chuck **16** of the character indicated above, but which is shown herein in purely schematic arrangement. A work piece **17** such as a metal piece, is held on the chuck **16** and a grinding or similar operation is performed by a grinding wheel **18** mounted in an upstanding portion **20** of the machine. As the table **12** reciprocates back and forth as stated, the grinding wheel **18** performs a grinding operation thereon and the wheel itself moves transversely relative to the direction of reciprocation of the table for performing the operation over the entire surface of the work piece. A control panel **22** is indicated diagrammatically and is located on the machine at an appropriate and convenient location for access by the operator. The panel **22** provides a means for mounting the instrument shown in FIGS. 2, 3 and 4.

Attention is now directed to FIGS. 2, 3 and 4 which illustrate the mechanical device embodying certain of the operating and control parts as well as portions of the control circuit. Attention is also directed to FIG. 5 illustrating the electric circuit and indicating certain mechanical elements incorporated in the instrument of FIGS. 2, 3 and 4. In the following description attention may be directed to FIGS. 2 to 5, unless otherwise specifically indicated. The structure of these figures may be included in an arrangement with other mechanical devices, such as manually operated switches, etc.

The panel structure of FIGS. 2 to 4 includes a back plate **24** and a front plate **26** suitably secured together such as by bolt and spacer assemblies **28** of conventional kind. The structure includes the rotor **30** having an arm **32** arranged for serially or sequentially engaging terminal contact elements or switch elements **34** arranged in a circle on the front plate **26**. The rotor is driven by means of a suitable electric motor **36**. The motor **36** is also arranged for operating a plurality of switches in a switch bank **38**, the details of which will be described hereinbelow. The rotor **30** and associated contact elements, the motor **36**, and the switch bank **38** are all also included in the circuit diagram of FIG. 5.

The rotor **30** includes a circular plate **40** of suitable insulating material and is provided with cams **42** of suitable shape and positioned relatively on the rotor plate for engaging certain limit switches in predetermined positions of rotation of the rotor. The limit switches mentioned are indicated at **46**, **48** and **50**, respectively (also FIG. 5). These switches are of conventional nature, and the details thereof need not be entered into herein. They are so constructed and so positioned relative to the rotor and the cams **42** as to be closed or opened at the desired times for performing certain control operations to be referred to later.

The arm **32** is fixed on the rotor plate **40** in any suitable manner and is made of conducting material or contains a conductor therein and forms a switch member cooperating with counterpart switch elements **34**, for controlling a portion of the circuit. Leading to the arm **32** is a common line **52** (FIG. 5). The elements **34** are mounted on the front plate **26** of the structure, this plate being preferably entirely of insulating material or at least containing insulating material at appropriate places. The elements **34** are connected with certain lines or conductors which will be referred to in detail later in connection with the circuit of FIG. 5. Between each two adjacent elements **34** is a stud or rest **54** for supporting the switch arm **32** when the latter is removed from the elements **34**. The studs **54** are insulated from all other electrical portions of the apparatus and serve merely as a mechanical rest means for maintaining the desired alignment of the arm **32**. It will be noted that the arm **32** is



so dimensioned and the elements **34** are so spaced apart that the switch arm is enabled to assume a position between two adjacent elements **34** amd be entirely out of contact with both of them, completely interrupting the circuit through the elements **34**. The studs **54** aid in maintaining the desired alignment of the switch arm **32**, both in continuous movement between adjacent elements **34** and also when the switch arm is stationarily disposed, temporarily, between the switch elements **34**.

The rotor **30** is suitably secured to a shaft **56** appropriately mounted in the front plate **26** of the structure, this shaft being connected through a suitable coupling **58**, which is preferably a flexible coupling, to another shaft **60** mounted in the back plate **24** and another supporting plate **62**, and having secured thereon a gear **64**. The gear **64** is in mesh with another gear **68** secured to a shaft **70** also suitably mounted for rotation on the back plate **24** and the mounting plate **62**. On the outer or rear end of the shaft **70** is a coupling element **72** forming a flexible coupling with another coupling element **74** mounted on the drive shaft of the motor **36**. Thus, upon rotation of the motor **36**, drive is transmitted to the rotor **30** for rotating the latter and sweeping the switch arm **32** over the switch elements **34**.

The switches of the switch bank **38** move in a reciprocating manner and in directions transverse to the line of view of the observer and along a line parallel with the axis of the drive shaft of motor **36**. The drive from the motor **36** to the switches involves a means for converting rotary motion to reciprocating motion in the directions indicated, and includes a third gear **76** in mesh with the gear **68** and secured to a shaft **78** mounted for rotation in the back plate **24** and the mounting plate **62**. On the inner end of the shaft **78**, i.e., on the front side of the back plate **24**, is a cam **80** having preferably a generally triangular shape (FIG. 4) and arranged for engaging cam followers **82** mounted on and carried by vertically reciprocating member **84** which is mounted on the back plate by suitable guide brackets **86**. The guiding action may be provided by pins on the member **84** sliding in apertures in the brackets, or other suitable equivalent arrangement. The cam follower is of conventional kind.

Cooperating with and actuated by the reciprocating member **84** is a bell crank lever **88** pivoted at **90** on a bracket **92** (FIG. 4). The bell crank member **88** may be of any desired transverse dimension and preferably is at least as wide as the switch bank **38** as viewed in FIG. 2, for convenience in operation of the latter. The bell crank lever **88** includes a pin or shaft **94** engaged between fingers **96** of the reciprocating member **84**. The bell crank lever further has suitable pivot elements such as pins **97** pivotally connected with arms **98** on a transverse plate **100**, the latter having pins or rods **102** extending forwardly into the switch bank **38** and connected with certain movable elements of the latter. The transverse plate **100** has suitable guiding engagement with pins or rods **104** at the terminal ends of the plate (FIGS. 3 and 4) for maintaining the necessary alignment of the plate. This plate may actually be in the form of a bar extending transversely the full extent of the structure. From the foregoing it will appear that the member **84** reciprocates in vertical directions and rocks the bell crank lever **88** about the pivot **90**, to cause reciprocation of the arms **98** and rods **102** in transverse directions as noted above.

The switch bank **38** includes three separate switches shown most clearly in FIG. 5, these switches being **104**, **106** and **108**, respectively. Each switch includes bars and terminal elements for certain gang operation. The switch **104** includes contact bars **104a** and **104b** and terminal element sets **104c** and **104d**; the switch **106** includes contact bars **106a** and **106b** and contact terminal sets **106c** and **106d**; the switch **108** includes contact bars **108a** and **108b** as well as contact terminal sets **108c** and **108d**. The contact bars **104a**, **106a**, and **108a** are ganged

for movement in unison and are engaged and actuated by a transverse switch bar **110** (FIG. 3), and similarly the contact bars **104**b, **106**b and **108**b are ganged for movement in unison and are engaged and actuated by a transverse switch bar **112** (FIG. 3). The contact bars *104a, 106a and 108a on one side, and 104b, 106b and 108b on the other side* may be slidably mounted on pins interconnecting the transverse switch bars **110** and **112**. The contact terminal elements **104**c, **106**c, and **108**c are mounted on a pair of transverse bars **114** disposed for convenience above and below, respectively, the transverse bar **110**. In a similar manner the contact terminal elements **104**d, **106**d, and **108**d are mounted on another pair of transverse bars **116** mounted for convenience above and below the transverse bar **112**. The transverse bars **110** and **112** are mounted for movement in tandem relation on the rods **102** (FIG. 4) so that upon movement of the latter the transverse switch bars **110** and **112** are moved together with certain consequent sequential operation of the switch bars connected thereto, as will be explained in detail hereinbelow.

Thus, from the foregoing it will be seen that upon operation of the motor **36** the rotor **30** is rotated with consequent contact make and break operation between the switch arm **32** and the switch elements **34**. The switches in the switch bank **38** are operated in certain synchronized relation thereto. Upon rotation of the rotor **30** the cams **42** actuate the switches **46**, **48**, and **50** in certain timed relationship.

Attention is next directed to the circuit diagram of FIG. 5. A suitable source of alternating current **118** is provided leading to a transformer **120**. The secondary **120**s of the transformer is provided with a number of conductors **122** tapped therein at various voltage points therealong and are connected to various ones of the switch elements **34** as will be explained more fully hereinbelow. Connected with the secondary **120**s is another transformer **124**, the primary **124**p of which is connected serially with the secondary **120**s of the first transformer. At the opposite end of the primary **124**p is another conductor **126** connected through the switch means **106** with the conductor **52**, referred to above, which is a common leading to the switch arm **32** on the rotor **30**. A circuit is thus completed from the secondary **120**s of the first transformer through the primary **124**p of the second transformer, conductor **126**, switch means **106**, conductor **52**, switch arm **32**, and selected ones of the conductors **122** which lead from the switch elements **34** to the secondary **120**s of the first transformer.

The second transformer **124** includes one or more secondary windings **124**s leading to rectifying means **128** which converts the alternating current provided from the transformer **124** to direct current, and delivers it to the chuck **16** through the switches **104** and **108**, these two switches being reversing switches for reversing the polarity of the direct current delivered to the chuck **16**, shown in this diagram in direct current circuit with those switches.

Another secondary winding **120**s' is provided in the transformer **120** and leads to rectifying means **130** providing direct current to the motor **36** which is of reversing type. This motor, as shown in the circuit, is controlled by the switches **46**, **48** and **50**, referred to above, the switches in turn being actuated by the cams **42** on the rotor **30**. Manually operated switch means **132** is provided for controlling the switches **48** and **50**, and selectively placing them in circuit. Serially arranged with the switch **132** is another manually operated switch **134** which is arranged for on-off switching, and consequent placing of the switches **132** and **46** selectively in circuit.

Attention is directed next to that portion of the circuit of FIG. 5 in the center thereof and derived from the secondary **120**s of the transformer **120**. A common line or conductor **136** leads from the secondary **120**s from the end opposite the transformer **124** to a switch **138** which connects the common conductor selectively with conductors **140** and **142**. The switch means **138** is arranged for cooperation with an associated switch **144**, and are operated in gang or in tandem between the full and dotted line positions indicated. Referring first to the conductor **140** which is connected with the conductor **136** when the switch **138** is in full line position, this conductor (**140**) leads to a certain two of the switch elements **34**. These two elements to which the conductor **140** is connected are indicated, for convenience, as $34_0$. The switch elements **34** are arranged in two series. They number twelve in all, and each series includes six. The elements in each series are arranged serially relative to the element $34_0$, which may be referred to as the main or home element, and, with relation to the latter, are numbered 1 to 5 inclusive. The switch elements, namely, Nos. 1 to 5, are connected, respectively, with the conductors **122**, referred to above and which are connected to the secondary **120**s at various voltage value points therealong. The two series of these elements **34**, as will be obvious, are parallel, each serving the same purpose as the other series or sets, and the switch arm **32** in its contact or sweeping motion engages the one or the other set of elements depending upon its starting position.

When the switch means **138** is in its opposite or dotted line position, the conductor **142** is connected with the conductor **136**. The conductor **142** is connected with an arm **145** of a potentiometer or variable resistance **146** from the remote end of which a conductor **148** leads to the secondary **120**s. The end of the potentiometer opposite the said remote end is connected through a conductor **150** which, in turn, is connected through the switch **144**, when the latter is in its dotted line position, to a conductor **152** leading to the secondary **120**s at a point spaced from the connection of the conductor **148** thereto.

The switches **138** and **144**, as mentioned above, are arranged for tandem operation and may be arranged in a suitable mechanical control knob located conveniently on the panel **22**. Assuming first the switch means as being in the full line position as indicated, the following is a description of the operation when it is desired to demagnetize the electromagnet in a series of steps of opposite polarity current of successively reduced value.

Assume first a condition in which the switch arm **32** and the switches **104** and **108** are in the full line positions indicated in the diagram. In such position, the present circuit remains simply in an "on" position, and the electromagnet is energized to hold the work piece in position thereon. The current delivered to the electromagnet is at full voltage value according to the capacity of the transformer **120**. In such condition the circuit is as follows: from the secondary **120**s to the primary **124**p of the second transformer **124**, conductor **126**, switch **106**, conductor **52**, switch **32**, the associated switch element $34_0$, conductor **140**, switch **138**, and conductor **136** to the secondary **120**s. The direct current circuit to the chuck, as will be understood, in this condition is closed through the switches **104** and **108**, which are in corresponding positions such as the lower position of the two possible indicated in the diagram. So long as the operation is being performed on the work piece, the circuit is permitted to remain in the closed position as described. In the normal operation of the machine tool of FIG. 1, and without the use of the demagnetizing apparatus, the switch means **134** and **132** remain in the full line positions indicated in the diagram. The switch **134** is in the "on" position, and the circuit continues from this switch through the switch **132** to the switch **50** which is in open position. The circuit to the motor **36** is therefore open and the motor is idle, and, consequently, the switch arm **32** remains stationary in engagement with the contact terminal element $34_0$.

Next, assume it is desired to demagnetize the electromagnet. The operator moves the switch **134** from the full line "on" position to the dotted line "off" position. This

closes the circuit from the switch **134** to the switch **46**, [the] *and* the latter closes the circuit to the motor **36** for driving the motor in forward direction. It will be understood that the switches **46**, **48** and **50** are normally biased to their position corresponding to the forward drive of the motor **36** which is in the lower position as the elements are arranged in FIG. 5. The switches are moved in opposite direction to the other extreme for closing the circuit for reversing the motor **36** by the cams **42** in accordance with the rotation of the latter and the relative spacing or positioning of the cams on the rotor **30** relative to the positions of the switches **46**, **48** and **50**. The motor in so driving forward rotates the switch arm **32** in clockwise direction (as viewed in FIG. 5), and it is brought to rest at the dotted line position **32**b at an open circuit position immediately after passing the element **34** at position No. 5 of the series relating to the home terminal element $34_0$, from which the switch arm started.

The circuit is successively opened and closed in the sweep of the switch arm **32** over the elements **34**, and each time that the circuit is opened between two adjacent contacts, the polarity of the direct current delivered to the chuck **16** is reversed. This is accomplished by the switch means **104**, **106**, and **108**. These switches, as was explained above, are actuated by mechanism driven by motor **36** and are timed with respect to the switch arm **32** so that the circuit is broken through the switch arm **32** intermittently, and when this circuit is broken, the direct current to the chuck is reversed in polarity. Upon the switch arm **32** moving toward, for example, a first open circuit position such as between the element $34_0$ and the next station No. 1, the switch **106** is opened before the switch arm leaves the terminal element $34_0$. The switch **106** opens the A.C. circuit which includes the switch arm **32**, and while this circuit is open, the switch means **104** and **108** are reversed by moving the respective bars **104**a and **104**b in the one switch, and **108**a and **108**b in the other switch, from the position they happen to be assuming (such as the lower position in FIG. 5) to the opposite position, from which it will be seen that the polarity of the current delivered to the chuck **16** is reversed. After the switch bars have engaged the opposite contact elements, the switch means **106** is closed. This latter switch is closed after the switch arm **32** engages the next element **34**, e.g., the No. 1 element.

This operation is repeated at each of the elements **34** and the spaces therebetween until the switch arm **32** reaches, or closely approaches, the position indicated in the dotted line position at **32**b. To stop the switch arm at the latter position, the respective cam means **42** moves away from the switch **46** and enables the switch to close in the opposite direction (FIG. 5) to reverse the motor **36**. The momentum of the motor tends to carry the switch arm past station No. 5 and on to the next terminal element $34_0$, but the reversal of the motor prevents this overthrow. The reversal of the motor also reverses the rotor **30**, and the cam means **42** also reverses and moves the switch **46** to an intermediate position in which the circuit to the motor **36** is open. The motor is brought to a standstill at the desired position in which the switch arm **32** is at the dotted line position indicated at **32**b and prevents its making circuit through the element $34_0$ at the bottom.

In the operation just described, the voltage value of the current imposed on the chuck is successively reduced. This will be seen from the fact that the switch elements **34**, at stations Nos. 1, 2, 3, etc., are connected with the secondary **120**s at successively lesser voltage values as indicated at the tapped connections on the secondary as indicated at No. 1, No. 2, etc.

The invention provides for interrupting the current at its source. The source is alternating current, and this can be interrupted with facility and without the disadvantages associated with interrupting direct current, such as arcing, with objectionable heat resulting therefrom, etc. Each time the source is interrupted the switch arm **32** closes the circuit successively in different circuit portions representing successively lesser values of voltage according to the tappings of the secondary **120**s. Each time the circuit is so interrupted, the switch means **104** and **108** reverse the direct current imposed on the chuck **16**.



*In order to effectively eliminate counter E.M.F. in the electromagnet, and for substantially eliminating arc and heat from such arc such as are encountered in breaking circuit in a direct current circuit, as referred to above, the switches 104 and 108 are of the make-before-break type and the operation of those two switches in conjunction with the switch 106 is such that the sequence of operating steps in the interrupting and reversing operation is as follows, the mechanical structure for accomplishing these steps being clearly shown in FIG. 3; a starting point as illustrated in FIG. 5 is assumed: (a) first the switch 106 is moved so as to be opened to all its contacts; (b) in the switches 104 and 108 the contact bars 104a and 108a are then moved to engage the respective contacts 104c and 108c while the other contact bars 104b and 108b remain in engagement with the respective contacts 104d and 108d; (c) the contact bars 104b and 108b then are moved from the respective contacts 104d and 108d; and (d) thereafter the switch 106 is closed to the contacts 106c; as clearly shown in FIG. 3 these operating steps resulting in the condition that while the A.C. circuit is open the polarity of the D.C. is reversed, and in the reversing operation the D.C. circuit remains closed to the electromagnet.*

The demagnetization of the electromagnet of the chuck **16** may be achieved by imposing constant voltage thereon for varying intervals of time or varying voltages for constant intervals of time. The latter method is utilized in the present instance. The rotation of the switch arm **32** is of constant speed, whereby the voltage imposed on the electromagnet at each of the stations **34** No. 1, **34** No. 2, etc., is for the same interval of time, but the value of the voltage varies. Accordingly, if, for example, 115 volts originally should be imposed on the electromagnet for magnetizing it for holding the work piece, this value is reduced uniformly in six steps so that the residual magnetism remaining after the last step is of relatively small value. The operator may then easily lift the work piece from the chuck. It will be understood that the polarity of the current imposed on the electromagnet at any stage in the operation explained, completely neutralizes the magnetism imposed in the opposite direction at the period previous thereto so that after the last step in the demagnetizing operation the residual magnetism is no greater than that represented by the tapping No. 5 on the secondary **120**s, and in practice is usually less than that.

When, after such a demagnetizing operation, it is desired to connect the circuit for magnetizing the chuck for holding a work piece thereon, the operator moves the switch **134** from the "off" position to the "on" position. This closes the circuit through the switch **132** to the switch **50**. The latter switch was at normal position, closing the circuit for driving the motor **36** forwardly, but so long as the switch **134** was open to the switch **50**, as was the case when the latter was in the "off" position, the motor remains at a standstill. However, upon turning the switch **134** to "on" position as just explained, the circuit being closed to the motor **36**, the latter rotates the switch arm **32** from the position indicated at **32**b, which it assumed after the demagnetizing operation to the lowermost position in engagement with the contact terminal element $34_0$, i.e., the lower one, opposite to that assumed above in the description of the operation. Since the switch arm moves only a short distance which is half the distance between two adjacent switch elements **34**, the inertia of the motor is not so great and does not carry the switch arm **32** beyond the associated switch element $34_0$. However, if it should, the appropriate cam

means 42 on the rotor would throw the switch blade of the switch 50 to the reversing position to reverse the motor the appropriate amount for positioning the switch arm on the element $34_0$. It will be understood that the cam means and the blade of the switch 50 are so related that when the switch arm 32 is on the element $34_0$, the blade of the switch 50 is in an intermediate open position. After the switch arm 32 thus engages the element $34_0$, the apparatus remains at rest until it is again desired to demagnetize the electromagnet. When that is desired, the operator repeats the demagnetizing cycle described above. In this cycle the switch arm 32 sweeps from its lower position to an upper position just short of the uppermost switch element $34_0$.

The apparatus includes a further control that may be utilized in certain situations, such as when the operator wishes to test a piece that is being worked upon without putting the demagnetizing apparatus through a complete cycle. This control is effected through the "residual" switch 48, and to put this switch into circuit, the operator manually moves the switch 132 from the "power" position indicated in the circuit, to the opposite or "residual" position. The circuit is then closed from the switch 134 through the switch 132 to the switch 48. The switch 48 up to this time has assumed the position indicated in full lines in which the circuit is closed to the motor 36 in forward direction. Upon throwing the switch from "Power" to "Residual" position, the motor 36 is rotated to move the switch arm 32 from the "home" position (which may be either upper or lower extreme positions, but assume for convenience the upper position shown in full lines in the diagram). Upon rotation of the motor 36 as just indicated, the switch arm 32 is rotated clockwise, and when it reaches the position indicated in dotted lines at 32a between the starting element $34_0$ and the next adjacent one at station No. 1, the cam 42 on the rotor engages the switch blade of the switch 48 and moves it from the position in which it was resting, as explained above. If the inertia of the motor should be sufficient to carry the switch arm 32 beyond the desired position, the switch blade of the switch 48 would close the circuit in the opposite direction for reversing the motor and hence reversing the rotor for consequently reversing the switch arm 32 so that it stops at the desired position indicated. The operator, rather than being required to completely cycle the demagnetizing apparatus, may, after performing the operation just described, move table 12 (FIG. 1) from an operating position for exposing the work piece on the chuck 16. He may then want to remove, for example, one of a number of pieces held thereon for checking its dimensions, and replace it for further operation, without removing all of the pieces on the chuck. This operation, therefore, provides a quick and convenient method of opening the demagnetizing circuit temporarily for performing the test indicated, without the necessity of completely cycling the apparatus.

If it should be desired to impose a lesser voltage on the chuck than the full voltage allowable, the operator may desire to set the potentiometer 146 at a selected voltage less than the full voltage of the transformer. To do this he moves the switch means 138 and 144 from the full line position to the dotted line position, whereupon the circuit is from the secondary 120s, through the primary 124p of the transformer 124, conductor 126, switch means 106, conductor 52, switch arm 32, contact terminal element $34_0$, conductor 140, conductor 142, potentiometer 146, and conductor 148 to the secondary 120s. The potentiometer 146 enables the operator to impose a selected voltage value on the chuck rather than, for example, the full voltage of the transformer secondary 120s.

Advantages of interrupting the current through the A.C. supply circuit are numerous. There is substantially no counter E.M.F. such as has been encountered heretofore in arrangements in which the D.C. circuit has been varied for varying the voltage imposed on the electromagnet. In interrupting the A.C. circuit, the transformer connected thereto may be easily and conveniently tapped at selected different voltage value points. The demagnetizing operation is extremely fast. Appreciably less power is required than in the case of previous instances in which, for example, a resistance is imposed in the D.C. circuit. In such previous cases, an additional reserve of power was required for producing the revese magnetization effect whereas in the present case, only that power necessary for producing the initial given magnetization is required, and only the voltage according to the nominal voltage of the magnetization at any step in the series of voltage values.

Because of the less time required for demagnetization, the wear imposed on the physical and mechanical elements is reduced to a minimum. The absence of a resistance in series with the electromagnet and the low impedance in the circuit, results in completion of the reversing demagnetizing steps in a minimum time interval with consequent minimum overall time required for the demagnetizing operation.

While I have shown herein a preferred embodiment of the invention, it is understood that changes may be made therein within the scope of the appended claims.

I claim:

1. Apparatus for demagnetizing an electromagnet comprising a source of alternating current including first circuit means, rectifying means for converting the alternating current to direct current, circuit means for transmitting the direct current to the electomagnet, cycling means operable through a predetermined cycle, means controlled by said cycling means and operable at a predetermined number of intervals in a cycle of operation for interrupting said first circuit means and thus the alternating current at full voltage value of the alternating current and re-establishing it, and [maintaining the alternating current so established for such period of time and at such value of voltage at the respective ones of said intervals that the magnetization imposed on the electromagnet is progressively decreased in successive ones of said] *decreasing the value of the voltage of the alternating current in successive ones of said intervals and thereby progressively decreasing the magnetization imposed on the electromagnet in those successive* intervals, and means operable during each interruption for reversing the polarity of the direct current transmitted to the electromagnet.

[2. The apparatus set out in claim 1, in which the means for decreasing the magnetization imposed on the electromagnet is operative for so decreasing it by decreasing the value of the voltage of the alternating current in successive ones of said intervals.]

3. The apparatus set out in claim [2], *1* in which transformer means including a secondary winding is included in the first circuit means of the alternating current source as a serial portion thereof, and the means for decreasing the value of the voltage includes, and is operative for so decreasing the value of the voltage by means of, means for tapping the secondary winding of the transformer at different points.

4. The apparatus set out in claim 3 in which the transformer means includes a first and second transformer, circuit means is provided connecting the primary of the second transformer serially with the secondary of the first transformer so that the former derives its current from the latter, the rectifying means and electromagnet are connected with and derive their current from the secondary of the second transformer, and the tappings are made in the secondary of the first transformer for connecting the primary of the second transformer at corresponding voltage value points therewith.

5. Apparatus for demagnetizing an electromagnet comprising, a source of alternating current, cycling means for intermittently interrupting the alternating current at the source, at full voltage value, a predetermined num-

be of times in a cycle of operation, said cycling means including means for decreasing the value of the voltage of the alternating current at successive ones of said times in the cycle of operation, means for converting the alternating current to direct current, circuit means of low impedance for transmitting direct current to the electromagnet, whereby to effect maximum reverse magnetization with minimum voltage current source and less than that required to produce the next previous magnetization, and means for reversing the polarity of the direct current at the intervals of interruption.

6. Means for demagnetizing an electromagnet comprising, a source of alternating current including a transformer connected serially therein, means for tapping the secondary of the transformer including a plurality of conductors connected at successively decreasing voltage value points along the transformer, terminal contact elements connected with the respective conductors, a rotor for serially contacting the contact elements and moving off of each contact element before contacting the next, means including a switch completing circuit with the transformer and contact elements and rotor, rectifying means for converting the alternating current from the transformer to direct current, circuit means for delivering the direct current to the electromagnet, reversing switch means in the latter circuit means for reversing the polarity of the direct current, and driving means including a common movable member for rotating said rotor and serially placing the contact elements in the associated circuit portions and operating the reversing switch means at each interval between contacts.

7. The apparatus set out in claim 6 in which the driving means includes means operable for sequentially opening the switch in the circuit between the transformer and contact elements and rotor while the rotor is in contact with each contact element, operating the reversing switch means after the said switch is open, and, after the rotor contacts the next succeeding contact element, then closing the switch.

8. The apparatus set out in claim 6 in which the driving means including an electric motor, and a limit switch is provided, controlled by the rotor, for stopping the motor after the rotor has passed the last of the contact elements.

9. The apparatus set out in claim 8 in which the motor and rotor are normally at rest in a position in which the rotor is in contact with one of the contact elements, a first limit switch is provided, manually settable and controlled by the rotor, for stopping the motor after the rotor has passed the last of the contact elements, and a second limit switch is also provided, manually settable and controlled by the rotor, for actuating the motor for moving the rotor from its rest position to an adjacent open-circuit position between the contact elements.

10. The apparatus set out in claim 9 in which the motor is reversible, and an additional limit switch is provided, controlled by the rotor, for reversing the motor after the rotor passes the last of the contact elements and moves a predetermined distance toward the first of the contact elements whereby it is prevented from again correlating with the first of the contact elements in a next rotation and whereby to stop the motor at an open circuit position after the last of the contact elements.

11. The apparatus set out in claim 6, in which the driving means is of uniform speed.

12. The method of demagnetizing an electromagnet comprising, supplying alternating current, converting the alternating current to direct current and transmitting it to the electromagnet, intermittently interrupting the alternating current at full voltage value at a predetermined number of periods in a cycle, reversing the polarity of the direct current at each interruption of the alternating current, and [varying the ratio between] *reducing* the voltage value of the current [and the time interval of the period] *at successive periods* of interruption so as to produce progressively decreased magnetization in the electromagnet in successive ones of said periods.

[13. The method set out in claim 12 in which magnetization is decreased by decreasing the voltage value of the alternating current.]

14. The method set out in claim [13] *12* in which the periods are maintained constant and the voltage values are decreased sufficiently to produce the decrease in magnetization.

15. The method of demagnetizing an electromagnet comprising, supplying alternating current, converting the alternating current to direct current and transmitting it to the electromagnet, intermittently interrupting the alternating current at full voltage value at a plurality of periods in a cycle, reversing the polarity of the direct current at each interruption of the alternating current and [varying the ratio between] *reducing* the voltage value of the current [and the time interval of the period] *at successive periods* of interruption so as to produce progressively decreased magnetization in the electromagnet in successive ones of said periods.

*16. Apparatus for demagnetizing an electromagnet comprising a source of alternating current including first circuit means, rectifying means for converting the alternating current to direct current, circuit means for transmitting the direct current to the electromagnet, cycling means operable through a predetermined cycle, means controlled by said cycling means and operable at a predetermined number of intervals in a cycle of operation for interrupting said first circuit means and thus the alternating current at full voltage value of the alternating current and re-establishing it, and maintaining the alternating current so established for such period of time and at such value of voltage at the respective ones of said intervals that the magnetization imposed on the electromagnet is progressively decreased in successive ones of said intervals, and means including switch means operable during each interruption for reversing the polarity of the direct current transmitted to the electromagnet, said switch means including a make-before-break switch for maintaining the direct current circuit means closed in the switching operation of reversing the polarity of the direct current.*

*17. The method of demagnetizing an electromagnet comprising, supplying alternating current, converting the alternating current to direct current and transmitting it to the electromagnet, intermittently interrupting the alternating current at full voltage value at a predetermined number of periods in a cycle, reversing the polarity of the direct current at each interruption of the alternating current and maintaining a direct current circuit through the electromagnet during such reversing operation, and varying the ratio between the voltage value of the current and the time interval of the period of interruption so as to produce progressively decreased magnetization in the electromagnet in successive ones of said periods.*

*18. The method of demagnetizing an electromagnet comprising, supplying alternating current, converting the alternating current to direct current and transmitting it to the electromagnet, intermittently interrupting the alternating current at full voltage value at a plurality of periods in a cycle, reversing the polarity of the direct current at each interruption of the alternating current and maintaining a direct current circuit through the electromagnet during such reversing operation, and varying the ratio between the voltage value of the current and the time interval of the period of interruption so as to produce progressively decreased magnetization in the electromagnet in successive ones of said periods.*

*19. The invention set out in claim 1 wherein said means for reversing the polarity includes switch means and that switch means includes a make-before-break switch operative for maintaining the direct current circuit means closed in the switching operation of reversing the polarity of the direct current.*

*20. The invention set out in claim 12 wherein a direct current circuit is maintained through the electromagnet during each interruption of the alternating current.*

*21. The invention set out in claim 15 wherein a direct current circuit is maintained through the electromagnet during each interruption of the alternating current.*



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