United States Patent [19]
Isnard

[11] 3,793,509
[45] Feb. 19, 1974

[54] METHOD AND APPARATUS FOR COUNTING WORK CYCLES OF ELECTRICALLY DRIVEN DEVICES

[75] Inventor: Theophile Isnard, Pont de Claix, France

[73] Assignee: Caterpillar Tractor Co., Peoria, Ill.

[22] Filed: Dec. 23, 1971

[21] Appl. No.: 211,247

[30] Foreign Application Priority Data
Feb. 17, 1971 France .............................. 71.05427

[52] U.S. Cl. ....... 235/92 EL, 235/92 R, 235/92 FP, 235/92 PD
[51] Int. Cl. .............................................. G06m 1/27
[58] Field of Search......235/92 PD, 92 EL, 92 FQ, 235/92 CA, 92 EC, 92 FP

[56] References Cited

UNITED STATES PATENTS

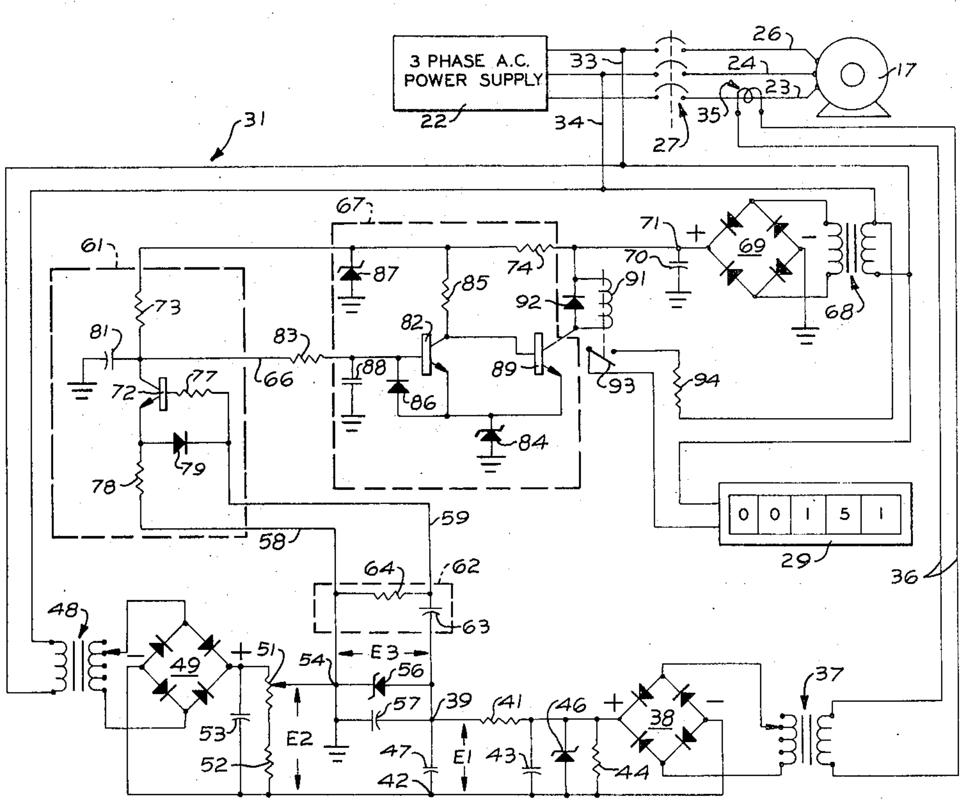

| | | | |
|---|---|---|---|
| 3,329,806 | 7/1967 | McCauley | 235/92 R |
| 3,346,725 | 10/1967 | Allured | 235/92 PD |
| 3,604,904 | 9/1971 | Stiebel | 235/92 PD |
| 1,744,840 | 1/1930 | Strieby | 235/92 EL |


*Primary Examiner*—Maynard R. Wilbur
*Assistant Examiner*—Robert F. Gnuse
*Attorney, Agent, or Firm*—Fryer, Tjensvold, Phillips & Lempio

[57] ABSTRACT

An accurate count of the number of workpieces processed on an electrically driven machine tool is maintained by a counter controlled by a circuit which responds to the changes of drive motor current in the course of each work cycle. As the counting system is not dependent upon detection of any mechanical movement, critical elements of the system may be inaccessibly located to avoid possible tampering with the count. The system can be adapted to counting work operations which involve more than one motor current peak in connection with processing of a single workpiece and is insensitive to supply current fluctuations arising from other causes such as motor starting surges and the like.

9 Claims, 3 Drawing Figures



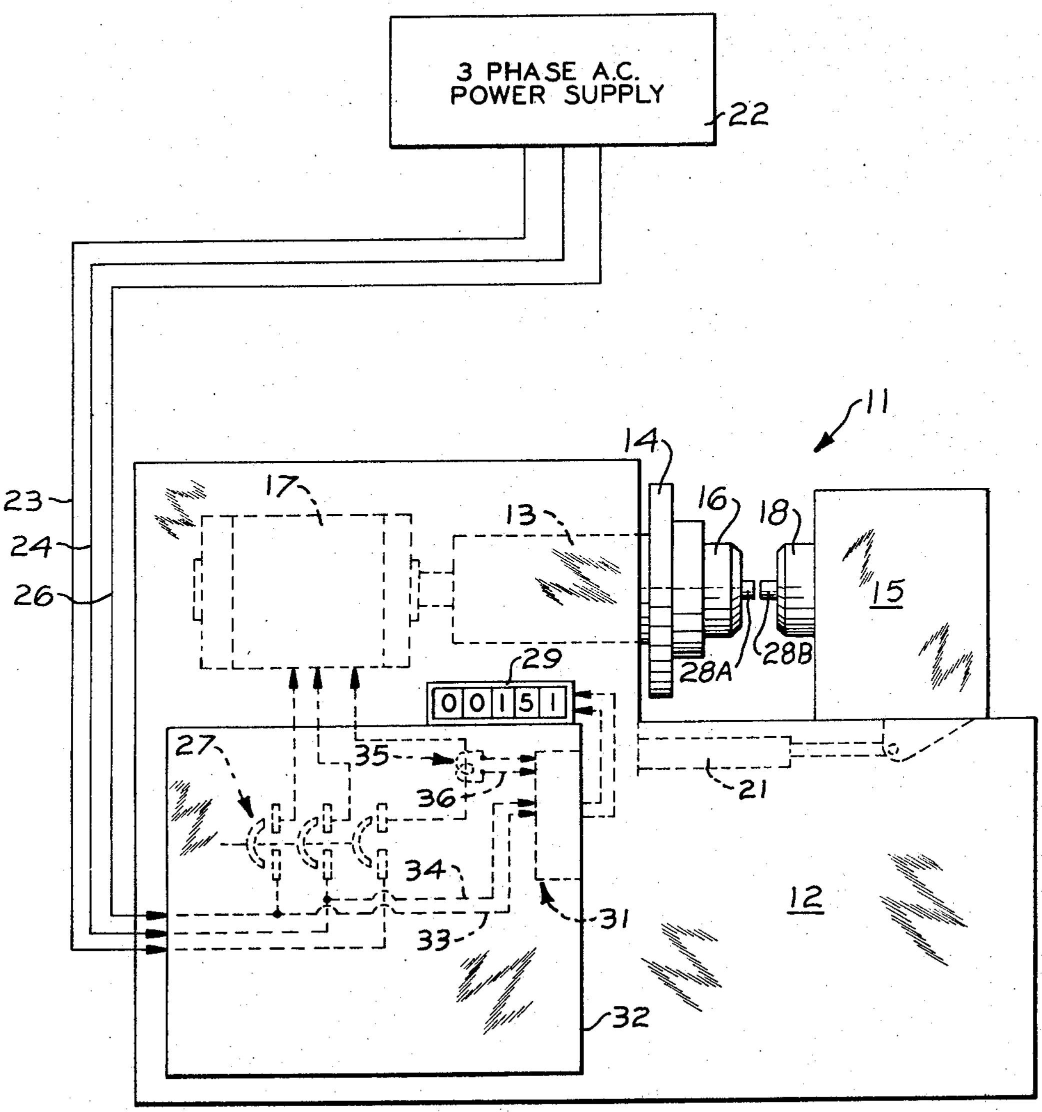



Fig. 1

INVENTOR
THEOPHILE ISNARD

BY
Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

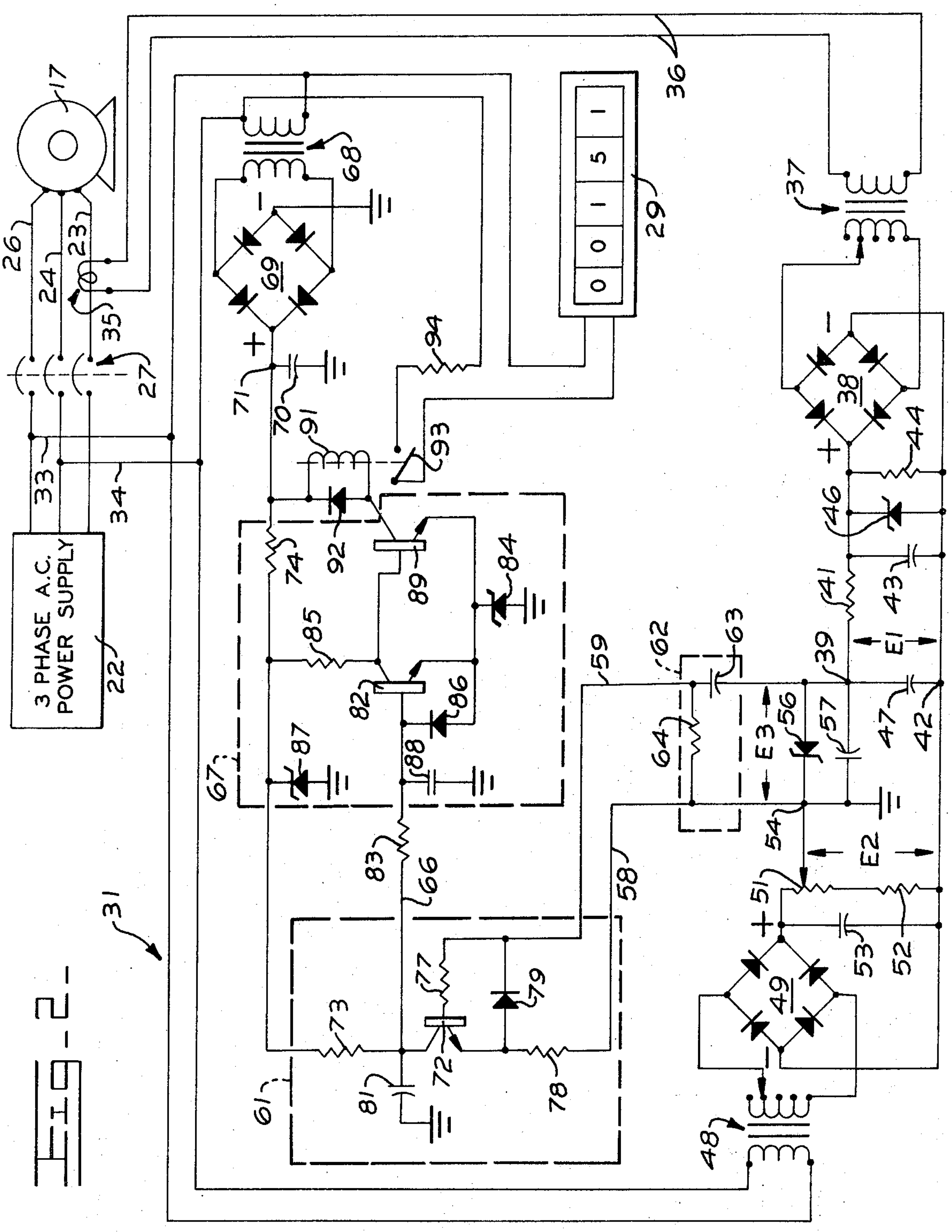



Fig-2

INVENTOR
THEOPHILE ISNARD

BY
Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

PATENTED FEB 19 1974

3,793,509

SHEET 3 OF 3

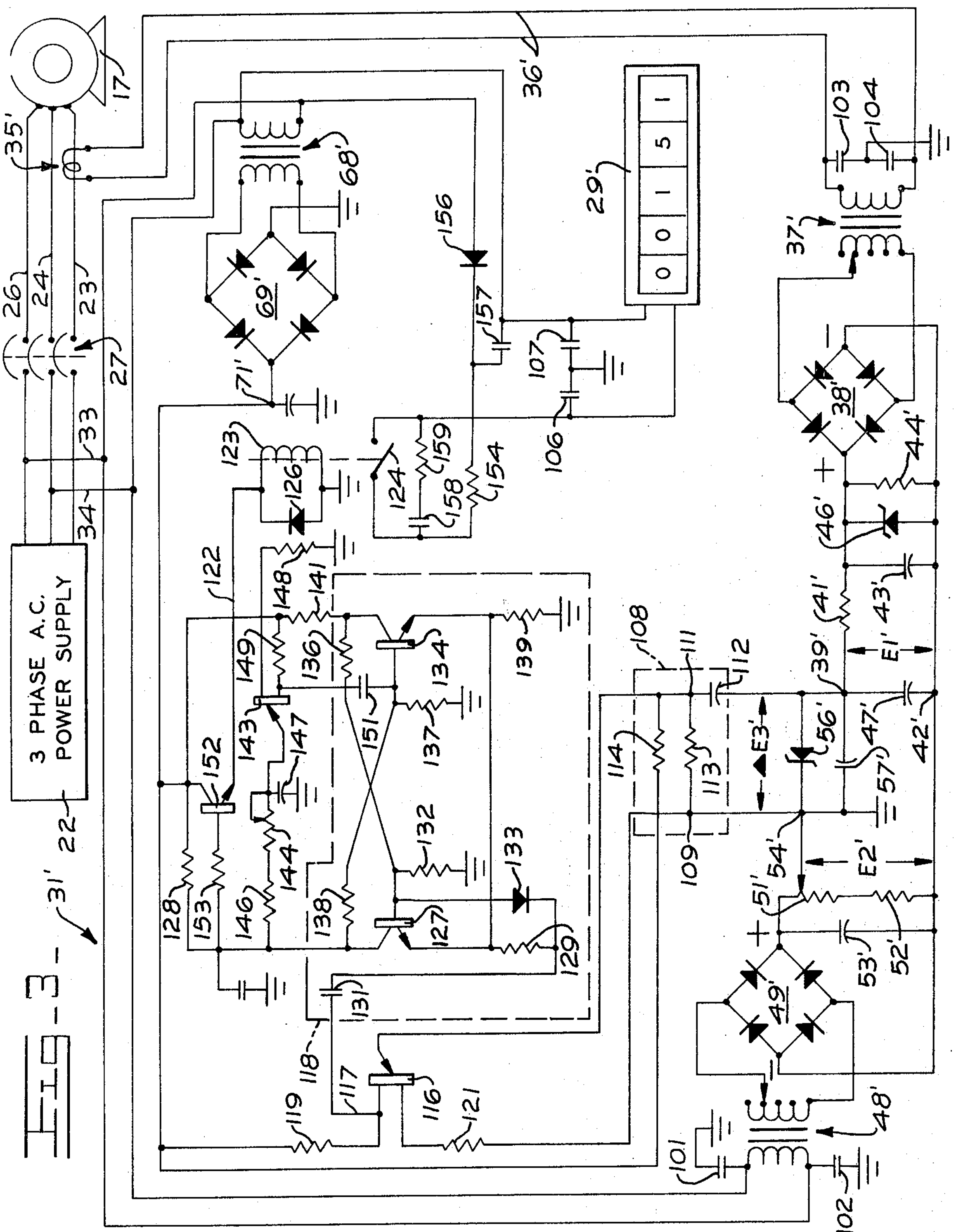



FIG-3

INVENTOR
THEOPHILE ISNARD

BY
Fryer, Tjensvold, Feix, Phillips & Lempio
ATTORNEYS

# METHOD AND APPARATUS FOR COUNTING WORK CYCLES OF ELECTRICALLY DRIVEN DEVICES

## BACKGROUND OF THE INVENTION

This invention relates to the counting of work cycles of an electrically driven device and more particularly to a method and apparatus for electrically counting work cycles at a machine tool or the like in a highly reliable and tamper-proof manner.

In production operations at powered machine tools or other electrically driven systems, it is often desirable to maintain an accurate count of work cycles of the system or of the number of workpieces turned out on the tool. This may be desirable, for example, in the course of time and motion studies or in situations where operators are compensated on the basis of quantity of production. Counting devices heretofore employed for this purpose have involved various means for sensing some mechanical movement at the tool or the like which occurs in the course of each work cycle. Such devices are inherently susceptible to tampering or manipulation whereby false counts may be recorded. Moreover, such devices may be complex and bulky, prone to wear and difficult to install on certain machines.

## SUMMARY OF THE INVENTION

This invention is a method and apparatus for counting work cycles in an electrically driven system which is less susceptible to tampering and which may utilize compact economical elements. These results are accomplished by sensing and counting changes of electrical current to the drive motor or the like which occur in the course of each work cycle. An electrical motor, for example, typically draws an increased current each time it is loaded to perform a work operation. In a preferred form, means are provided for discriminating against current fluctuations which arise from other causes, such as the current surges associated with initial starting of a motor, and the system is adaptable to work cycles which may involve a series of current variations in the course of a single cycle.

Accordingly it is an object of this invention to facilitate the obtaining of reliable counts of work cycles performed by an electrically driven device.

It is another object of this invention to provide a method and apparatus for maintaining a count of workpieces turned out on a machine tool or the like which is less susceptible to tampering and which may be compact, economical and durable.

The invention together with further objects and advantages thereof will best be understood by reference to the following description of preferred embodiments taken in conjunction with the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. 1 is an elevation view of an inertia welding machine showing elements of a work cycle counting system associated therewith,

FIG. 2 is a circuit diagram showing electrical elements of the work cycle counting system of FIG. 1, and

FIG. 3 is a circuit diagram showing a modified circuit for use where multiple current peaks may occur in the course of a single work cycle.



## DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to FIG. 1 of the drawings, an inertia welding machine **11** is shown in order to illustrate how the circuit of the present invention may be coupled to a typical machine tool at which a count of work cycles is to be maintained. It will be apparent that the circuit is equally applicable to other forms of machine tool as well as other electrically driven apparatus which would not normally be characterized as a machine tool. Inasmuch as the structure and operation of an inertia welder **11** is known, only those elements of the welder which are necessary to understand the coaction of the present invention therewith will be herein described.

Welder **11** may have a base **12** supporting a rotatable spindle **13** which carries a flywheel **14** and a rotary chuck **16**, the spindle, flywheel and rotary chuck being driven by an electrical motor **17** which is of the three-phase alternating current form in this example. Slidably positioned on base **12** opposite the rotary chuck **16** is a tailstock **15** carrying a non-rotating chuck **18.** Tailstock **15** and chuck **18** may be moved towards the rotary chuck **16** and away therefrom by suitable means such as a hydraulic cylinder **21** within base **12.** The drive motor **17** is coupled to a suitable three-phase alternating current power supply **22** through three conductors **23, 24** and **26** and a switch **27** for selectively energizing the motor.

In order to weld workpieces, which in this example are formed from two short rod-like elements **28A** and **28B**, one such element **28A** is mounted in the rotary chuck **16** and the other is similarly mounted in the chuck **18** is coaxial relation to the first element. Motor **17** is then energized by closing the switch **27** which then accelerates spindle **13,** flywheel **14,** rotary chuck **16** and element **28A** to a high angular velocity with the result that substantial kinetic energy is stored in the several rotating elements. Motor **17** is then deenergized by opening switch **27** although in some other forms of inertia welder the motor remains energized and clutch means are provided to decouple spindle **13** from the motor. In either case, the spindle **13,** flywheel **14,** rotary chuck **16** and element **28A** continue to rotate owing to the kinetic energy stored therein. Hydraulic cylinder **21** is then actuated to shift the element **28B** into abutment with rotating element **28A.** Friction at the resultant contacting ends of elements **28A** and **28B** then acts to rapidly brake the rotating elements with the kinetic energy of rotation being converted into intense heat at the zone of contact of the two elements. This heats the contacting ends of elements **28A** and **28B** to a plastic condition so that when the rotating elements come to rest, the two elements are fused together. Tailstock assembly **15** may then be retracted and the welded workpiece formed of elements **28A** and **28B** is removed.

Of interest relative to the present invention is the fact that the current drawn by motor **17** from power supply **22** is a function of the load on the motor and thus rises during the period that the spindle **13,** flywheel **14,** and other rotating elements are in the process of being accelerated. As is well known in the electrical motor art, there may also be a relatively brief but high amplitude current spike at the time motor control switch **27** is first closed as the motor offers very little impedance to current flow until such time as substantial armature speed has been brought about. In instances where a clutch is employed to decouple the motor 17 from the spindle 13, without deenergizing the motor, there is still a rise of motor current during the period that the motor is accelerating the flywheel 14 and associated elements inasmuch as the current drawn by a motor is a function of the load.

Essentially a similar situation occurs in many other forms of electrically driven tools, other than the inertia welder herein shown for purposes of example. In lathes, drill presses, milling machines and diverse other apparatus, an electrical motor draws a varying amount of current from the power supply in a predictable manner in the course of processing each individual workpiece.

The present invention maintains a reliable count of the number of workpieces which are processed, by detecting a current change associated with processing of each workpiece and by operating a counter in response to each such current change. In the present example, the counter 29 is a visually readable type mounted on the cabinet 32 of the welder 11 which contains other electrical control elements of the welder. The circuit 31 which drives the counter is within the closed cabinet 32 where it is relatively inaccessible to the operator. In some instances the circuit 31 may be situated remote from the welder 11 as it operates wholly through electrical connections to the conductors 23, 24 and 26 which supply electrical current to the motor and these conductors may extend a considerable distance away from the welder.

Operating power for the counter circuit 31 is obtained through conductors 33 and 34 which connect to two of the motor supply current conductors 26 and 24 respectively. In order that the circuit 31 remain energized when the motor control switch 27 is open, this connection is preferably made between that portion of the conductors 26 and 24 which extend between switch 27 and power supply 22. To provide a means for detecting current changes in the motor conductors, a pair of conductors 36 extend from the circuit 31 and are connected to the secondary of a current sensing transformer 35 having the third motor power supply lead 23 as a primary.

Considering now a suitable detailed configuration for the counter circuit 31, reference should be made initially to FIG. 2. The two conductors 36 connect to opposite ends of the primary coil of an adjustable transformer 37. The secondary winding of transformer 37 is in turn connected across the input terminals of a full wave diode bridge rectifier 38. One output terminal of rectifier 38 connects to a terminal 39 through a resistor 41 while the other output terminal of the rectifier connects directly with a terminal 42. Thus a DC voltage E–1 appears between terminals 39 and 42 and has a magnitude proportional to the current in motor power supply conductor 23. To filter out the ripple which might otherwise be present in the output of a bridge rectifier 38 of this form, a capacitor 43 and resistor 44 are connected across the output terminals of the rectifier. To limit the maximum voltage differential between terminals 39 and 42, a zener diode 46 is also connected across the output of the rectifier.

Accordingly, when the load on motor 17 increases in the course of a work cycle, the resulting increase of alternating current in motor conductor 23 inductively increases the amplitude of the alternating current at the output of transformer 37. DC voltage E–1 therefore increases in magnitude at that time. An additional capacitor 47 is connected between terminals 39 and 42 to that the voltage E–1 does not rise abruptly when the current drawn by motor 17 increases, the delay in the rise of the voltage being determined primarily by the time constant of the R C network defined by resistor 41 and capacitor 47. This avoids any pronounced increase of voltage E–1 in response to very brief current surges such as may occur as motor 17 is first energized or from other causes.

While the above described means protect against an erroneous work cycle signal arising from very brief motor current increases, it is also desirable to discriminate against current changes which arise from variations in the voltage of the power supplied to motor 17. Accordingly, voltage E–1 is continually compared with a second voltage E–2 derived from the motor power supply conductors and a work cycle count is initiated only when a rise of voltage E–1 is unaccompanied by a corresponding rise of voltage E–2. To obtain the comparison voltage E–2, the primary winding of a second adjuatable transformer 48 is connected between the previously described power conductors 33 and 34 which connect to motor power conductors 26 and 24 respectively and the secondary winding of the transformer 48 is connected across the input terminals of a second full wave diode bridge rectifier 49. A potentiometer 51 and resistor 52 are connected in series across the output terminals of rectifier 49 and a ripple smoothing capacitor 53 is also connected across the output terminals in parallel relationship with the potentiometer and resistor. The movable contact of potentiometer 51 is connected to a ground conductor 54 and the negative output terminals of both rectifiers 38 and 49 are connected to terminal 42. Thus a DC voltage E–2 is present between the terminal 42 and ground conductor 54 and varies as a function of any voltage changes in the power supply leads to motor 17. Voltage E–2 thus constitutes a reference voltage against which voltage E–1 may be compared to detect increased current to motor 17 as a result of loading of the motor as distinguished from current increases due to fluctuations of the motor power supply voltage. As voltage E–1 appears between terminals 39 and 42 while voltage E–2 appears between ground conductors 54 and terminal 42, a difference voltage E–3 is present between terminal 39 and the ground conductor. To limit this difference voltage E–3 to a predetermined magnitude, a zener diode 56 and a protective capacitor 57 are connected between terminal 39 and ground conductor 54.

When motor 17 is not loaded, difference voltage E–3 remains essentially constant at the value determined by zener diode 56. When voltage E–1 rises due to motor loading, voltage E–3 decreases and this decrease is caused to initiate a work cycle count. For this purpose, input conductors 58 and 59 of an amplifier 61 are connected to ground conductor 54 and terminal 39 respectively through a differentator circuit 62. In particular, amplifier input 59 connects to terminal 39 through a capacitor 63 while amplifier input 58 connects directly with ground conductor 54 and a resistor 64 is connected across the amplifier input conductors whereby the capacitor 63 and resistor 64 differentiate the decrease of voltage E–3 accompanying a work cycle and apply the differentiated signal to the amplifier input. Amplifier 61 in turn, applies an amplified signal to the input 66 of a Schmitt trigger circuit 67.

DC operating voltage for both the amplifier **61** and Scmitt triger **67** is obtained through a third transformer **68** having a primary winding connecting to the previously described conductors **33** and **34** respectively and having a secondary winding connected across the input terminals of a third full wave diode bridge rectifier **69.** The negative output terminal of rectifier **69** is grounded while the positive output terminal connects with a power terminal **71** for the Schmitt trigger circuit **67** and amplifier **61.** To smooth ripple from the output of rectifier **69** a capacitor **70** is connected between the positive output terminal and ground.

The collector of transistor **72** of the amplifier **61** connects with power terminal **71** through a resistor **73** and an additional resistor **74** of the Schmitt trigger. In addition to the transistor **72,** amplifier **61** may consist of a resistor **77** connecting the base of the transistor with amplifier input **59** and a resistor **78** connecting the transistor emitter with grounded input **58.** A protective diode **79** is connected between the transistor emitter and input **59** and a capacitor **81** is connected between the collector and ground to suppress transient voltage spikes.

When voltage E–3 decreases due to an increased motor current, differentiator **62** applies a momentary voltage to the base of transistor **72** through base resistor **77** causing the transistor to conduct. The input **66** of Schmitt trigger **67** is connected to the collector of transistor **72** and thus the momentary conduction of the transistor causes a momentary voltage decrease at input **66.**

Schmitt trigger **67** may consist of a transistor **82** having a base connected to input **66** through a resistor **83** and having a collector connected to the power supply terminal **71** through a resistor **85** and resistor **74.** A zener diode **84** is connected between the emitter of transistor **82** and ground and diode **86** is connected between the emitter and base of the transistor. Accordingly transistor **82** is normally conductive and becomes non-conductive when the previously described momentary voltage drop is applied to the base through input **66.** To assure that a predetermined constant operating voltage is applied to the collector of transistor **82,** another zener diode **87** is connected between power supply terminal **71** and ground through resistor **74.** Zener diode **87** also has the effect of providing a constant operating voltage to amplifier **61.** A capacitor **88** connected between the base of transistor **82** and ground avoids stopping of conduction through the transistor in response to brief spurious voltage transients.

Schmitt trigger **67** further includes a second transistor **89** having a base connected to the collector of transistor **82** and having an emitter connected to the emitter of transistor **82** and thus to ground through zener diode **84.** The collector of transistor **89** connects to power supply terminal **71** through a relay driver coil **91** and also through a diode **92** which protects the transistor against transient voltages arising from the collapse of the magnetic field of coil **91.**

Thus transistor **89** is nonconductive as long as transistor **82** is in conduction. While transistor **82** ceases to conduct in response to a signal at input **66** a positive voltage rise occurs at the base of transistor **89** which then conducts to energize coil **91.**

Energization of coil **91** closes normally open relay contacts **93.** Relay contacts **93** are connected between one input of counter **29** and power conductor **34** in series with a load resistor **94,** the other input of the counter being connected directly to power conductor **33.** Accordingly each momentary closing of contacts **93** initiated by the current increase at motor **17** applies one pulse count to counter **29** which displays the total of pulse counts received and thus visually indicates the number of work cycles which have been performed by motor **17.**

The above described circuit configuration is readily adjustable to accommodate to specific conditions at the particular machine tool with which the motor **17** is associated. The magnitude of the voltage E–1 and the magnitude of the reference voltage E–2 may be selected to provide sensitivity to the major current change accompanying a work cycle, while discriminating against minor current changes by appropriate adjustments of the variable transformers **37** and **48** and potentiometer **51.** Once these adjustments are made to accommodate to the specific tool, further changes are unnecessary. Of particular significance with respect to forestalling tampering and attempts to register false counts is the fact that the entire circuit **31** need connect only to the power leads to the motor **17.** These connections are readily made inaccessible.

The form of the circuit described above with reference to FIG. **2** was designed for use with a machine tool or the like wherein there is a single substantial current increase with each work cycle to be counted. In some instances, a machine tool may exhibit several current increaseof more or less similar magnitude in the course of a single work operation. FIG. **3** illustrates a modified form of the circuit in which the counter **29** will record a single additional count for each work cycle of a machine of this kind wherein several current increases may occur during the work cycle.

As in the previously described embodiment of the invention, the circuit **31'** of FIG. **3** includes power supply conductors **33** and **34** which connect to two of the three conductors **26** and **24** respectively between motor power supply **22** and the three-phase motor **17** and further includes a current sensing transformer **35'** having the third motor current conductor **23** as a primary, no other connections to the motor and power supply being necessarily required. Certain portions of the modified circuit **31'** of FIG. **3** are essentialy similar to corresponding portions of the previously described circuit and accordingly will not be redescribed in detail, the elements of these unmodified portions of the circuit being identified in FIG. **3** by primed reference numerals corresponding to the reference numerals used in FIG. **2** for similar elements. These essentially unmodified portions of the circuit of FIG. **3** include a transformer **68'** and rectifier **69'** coupled to conductors **33** and **34** to provide DC operating power at a terminal **71'** and an additional transformer **48'** and rectifier **49'** for providing a reference voltage E–2' between a terminal **42'** and grounded conductor **54'.** Another transformer **37'** and rectifier **38'** provide a voltage E–1' between terminal **42'** and a terminal **39'** that is a function of the magnitude of current in the motor power conductor **23** as previously described. As in the previous instance, a zener diode **56'** is connected between terminals **39'** and **54'** to limit the difference between voltages E–2' and E–1' to a predetermined maximum. Accordingly, a differential voltage E–3' is present across the zener diode **56'** and when voltage E–1' increases due to an increased current in the conductor 23 to motor 17 voltage E–3′ undergoes a decrease.

While the portions of the circuit of FIG. 3 which have been referred to up to this point are similar to the corresponding portions of the previously described circuit, the FIG. 3 circuit is somewhat more susceptible to false counts from brief voltage transients if appropriate corrective measures are not taken. To guard against such erroneous counts, anti-interference capacitors are provided at various points in the circuit. This includes capacitors 101 and 102 each connected between ground and a separate end of the primary of transformer 48′ and a pair of capacitors 103 and 104 similarly connected between opposite ends of the primary of transformer 37′ and ground. For similar purposes, still another pair of capacitors 106 and 107 connect between ground and separate ones of the inputs to counter 29′.

Considering now the portions of the circuit 31′ which accommodate to a motor work cycle which includes two or more current peaks, voltage E–3′ is applied to a differentiator circuit 108 of modified form. In particular, one input terminal 109 of differentiator 108 is connected to the previously described grounded conductor 54′ while terminal 39′ is connected to a terminal 111 of the differentiator through a capacitor 112. A first differentiator resistor 113 is connected between terminals 109 and 111 while a second resistor 114 is connected between terminal 111 and the DC power terminal 71′. When voltage E–3′ decreases in response to an increase of current in motor power conductor 23 as previously described, the differentiating action of the capacitance and resistance produces a pulse at terminal 111. The pulse is detected by a unijunction transistor 116 which then transmits a set signal to the input 117 of a flip-flop (bistable multivibrator) circuit 118 to set the flip-flop. For this purpose, one base electrode of unijunction transistor 116 is coupled to DC power terminal 71′ through a resistor 119 while the other base electrode of the unijunction transistor is coupled to differentiator terminal 109 through a resistor 121. The emitter of unijunction transistor 116 is coupled to the terminal 111 of the differentiator whereby a decrease of voltage E–3′ causes the unijunction transistor to become conductive for a brief period. Input 117 of flip-flop 118 is connected to the junction between resistor 119 and the unijunction transistor 116 and thus a positive voltage at input 117 is momentarily decreased each time transistor 116 conducts.

Flip-flop 118 has an output conductor 122 connected to ground through a relay driver coil 123 which controls a set of normally open relay contacts 124. A diode 126 is connected across relay driver coil 123 to protect against inverted voltage surges which may accompany deenergization of the coil. As will hereinafter be described in greater detail, closing of the relay contacts 124 supplies a count signal to the counter 29′. In the normal, reset condition of flip-flop 118 output 122 is unenergized and thus relay coil 123 is also unenergized and the contacts 124 remain open. Upon receipt of an input pulse at input 117 as previously described, the flip-flop 118 assumes the alternate condition at which output 122 is energized thereby closing the contacts 124 to transmit a count to counter 29′. In the course of a work cycle of motor 17 this action occurs when the first of a series of major current peaks associated with a work cycle is detected. Subsequent current peaks associated with the same work cycle do not produce additional count signals to counter 29′ in that the flip-flop 118 is arranged to remain in the set condition and therefore to be insensitive to additional input pulses for a predetermined period corresponding to a time just slightly less than the period required for a full work cycle of motor 17.

Considering now suitable internal structure for the flip-flop 118 whereby these results are accomplished, a transistor 127 has a collector connected to power supply terminal 71′ through a voltage dropping resistor 128 with the emitter being connected to input 117 through a resistor 129 and capacitor 131. The base of transistor 127 is connected to ground through a resistor 132 and to the junction between resistor 129 and capacitor 131 through a diode 133 and also to the collector of an additional transistor 134 through a resistor 136. The base of transistor 134 is connected to ground through a resistor 137 and cross coupled to the collector of transistor 127 through resistor 138 to provide the desired multivibrator action. The emitter of transistor 134 is connected to ground through resistor 139 and to the emitter of transistor 127. The collector of transistor 134 is coupled to power supply terminal 71′ through a resistor 141. The above described cross couplings of the transistors 127 and 134 result in a bistable action wherein conduction of one transistor 127 or 134 precludes conduction of the other. With transistor 127 initially in a conducting condition, transistor 134 is biased into a non-conducting state. Receipt of the previously described set pulse at input 117 momentarily lowers the base voltage of transistor 127. This cutoff conduction through transistor 127 causing the potential at the base of transistor 134 to rise whereby transistor 134 becomes conductive and thereby holds transistor 127 in the non-conductive state until such time as a reset pulse is applied to the base of transistor 134. At that time, conduction through transistor 134 is stopped and the circuit assumes the original stable reset state.

To generate the reset pulse a predetermined time after the flip-flop 118 is set by an input pulse, a unijunction transistor 143 has an emitter connected to the collector of transistor 127 through a selectively variable resistance 144 and fixed resistance 146. The emitter of unijunction transistor 143 is also coupled to ground through a capacitor 147 which in conjunction with resistances 144 and 146 forms a time delay circuit of selectable time constant. When transistor 127 turns off in response to an input pulse as previously described, the voltage on capacitor 147 begins to rise and reaches a potential sufficient to trigger unijunction transistor 143 after a period of time determined by the adjustable time constant of the R C network defined by resistors 144, 146 and capacitor 147. One base electrode of unijunction transistor 143 is coupled to ground through a resistor 148 while the other base electrode of the unijunction transistor connects to power supply terminal 71′ through a resistor 149.

Accordingly the unijunction transistor 143 is triggered a predetermined interval after the flip-flop 118 is set thereby producing a reset pulse across resistor 149. The reset pulse is transmitted to the base of transistor 134 by a capacitor 151 to turn off transistor 134 and thereby cause the flip-flop 118 to revert to the initial reset state.

The flip-flop 118 controls the relay driver coil 123 in that conductor 122 to the coil is connected to the emitter of a control transistor 152 having a collector connected to the power supply terminal **71**′. A resistor **153** is connected between the base of the control transistor **152** and the collector of transistor **127.** Thus transistor **152** is held in a nonconductive condition while the flip-flop is in the reset condition and becomes conductive to energize relay coil **123** when the flip-flop is set since transistor **127** becomes nonconductive at that time as previously described. To deliver a count signal to counter **29**′ each time that relay coil **123** is energized, one input to the counter is connected to AC power conductor **33** while the other counter input connects to AC power conductor **34** through relay contacts **124**, a resistor **154** and a diode **156.** Resistor **154** and diode **156,** together with a capacitor **157** act to rectify the count signal voltage transmitted to counter. A capacitor **158** and resistor **159** are connected across relay contacts **124** to suppress arcing at the contacts.

Accordingly, the circuit **31**′ of FIG. **3** provides for reliable counting of work cycles of motor **17** without regard to number of motor current peaks in the course of a single cycle provided all peaks occur within a predetermined normal work cycle interval.

While the invention has been described with respect to certain preferred embodiments, it will be apparent that many modifications are possible and it is not intended to limit the invention except as defined in the following claims.

What is claimed is:

**1.** A device for counting work cycles performed by an electrically operated apparatus having conductor means for connection to a source of electrical power, comprising:

a counter having input means for receiving count signals and having means for recording the number of said count signals received at said input,

current sensing means coupled to said conductor means to sense current changes therein and having means for producing a first continuous voltage which changes in response to said changes of said current,

voltage sensing means coupled to said conductor means independently of said current sensing means for producing a second continuous voltage which is proportional to the voltage being applied to said apparatus by said source,

means for comparing said first and second voltages for producing an output signal as said first voltage reaches a predetermined relationship to said second voltage, and

circuit means coupled to said comparing means and to said counter input and having means for transmitting count signals to said counter input in response to output signals from said comparing means.

**2.** A device as defined in claim **1** wherein said current sensing means comprises a first transformer inductively coupled to said conductor means which connects said electrically operated apparatus with said source of electrical power and a first full wave rectifier connected to said transformer to produce said first voltage, and

wherein said voltage sensing means for producing said second voltage comprises a second transformer having primary and secondary windings and having said primary windings connected between a pair of conductors of said conductor means which connects said electrically operated apparatus with said source of electrical power, a second full wave rectifier connected across the secondary winding of said transformer, and an adjustable potentiometer connected across said rectifier.

**3.** A device as defined in claim **1** wherein said circuit means comprises a Schmitt trigger circuit having an output which changes between a first and a second predetermined fixed electrical states in response to said output signals from said comparing means, and means controlled by said output of said Schmitt trigger for transmitting a count signal to said counter upon each change of state of said Schmitt trigger output.

**4.** A device as defined in claim **1** wherein said circuit means comprises a bistable multivibrator flip-flop circuit having an output which changes state in response to said output signals from said comparing means to assume a set condition, means coupled to said output of said flip-flop for transmitting a count signal to said counter each time said flip-flop assumes said set condition, and means for resetting said flip-flop circuit a predetermined time interval after said flip-flop circuit is set.

**5.** A device as defined in claim **1** wherein said means for producing said first voltage has filter means for supressing any significant change of said first voltage when said change of said current is of less duration than a predetermined interval.

**6.** A device for counting work cycles performed at a machine tool or the like which is driven by an electrical motor having conductors which connect with a source of alternating electrical current and wherein at least one increase of current in said conductors occurs in the course of each work cycle due to increased loading of said motor, comprising:

current sensing transformer means inductively coupled to at least one of said conductors for sensing said current increase therein,

variable voltage means including a first rectifier coupled to said transformer means and having a pair of output terminals across which a first continuous voltage is generated which varies in response to said current changes,

comparison means connected between a pair of said electrical conductors independently of said transformer means and having a second rectifier and output terminals across which a second continuous voltage is produced which is proportional to the voltage supplied to said motor through said conductors,

conductive means interconnecting one output terminal of said variable voltage means with one output terminal of like polarity of said comparison means whereby a third voltage is present between the other terminals of said variable voltage means and said comparison means which third voltage varies in response to said changes of current in said conductors,

voltage change detector means coupled between said other terminals of said variable voltage means and said comparison means and having an output for transmitting a signal when said third voltage is reduced to a predetermined value by an increase of said first voltage relative to said second voltage,

a counter having input terminals for receiving count signals and having means for recording an accumulated total of said count signals, relay means connected between said input terminals of said counter and said source of electrical current for transmitting said count signals to said counter in response to actuation of said relay means, and

circuit means for actuating said relay means in response to said output signals from said detector means.

**7.** The combination defined in claim **6** wherein said circuit means has time delay means for blocking reactuation of said relay means for a predetermined interval

after a prior actuation thereof.

**8.** The combination defined in claim **6** further comprising a breakdown device connected between said other terminals of said variable voltage means and said comparison means for limiting said third voltage to a predetermined maximum value.

**9.** The combination defined in claim **6** further comprising a differentiator circuit coupling said other terminals and said voltage change detector means.

* * * * *