March 2, 1965 B. J. BOURKE ETAL 3,172,027

SEQUENTIALLY ENERGIZED SOLENOIDS RECIPROCATING MOTOR SYSTEM

Filed June 5, 1961 2 Sheets-Sheet 1

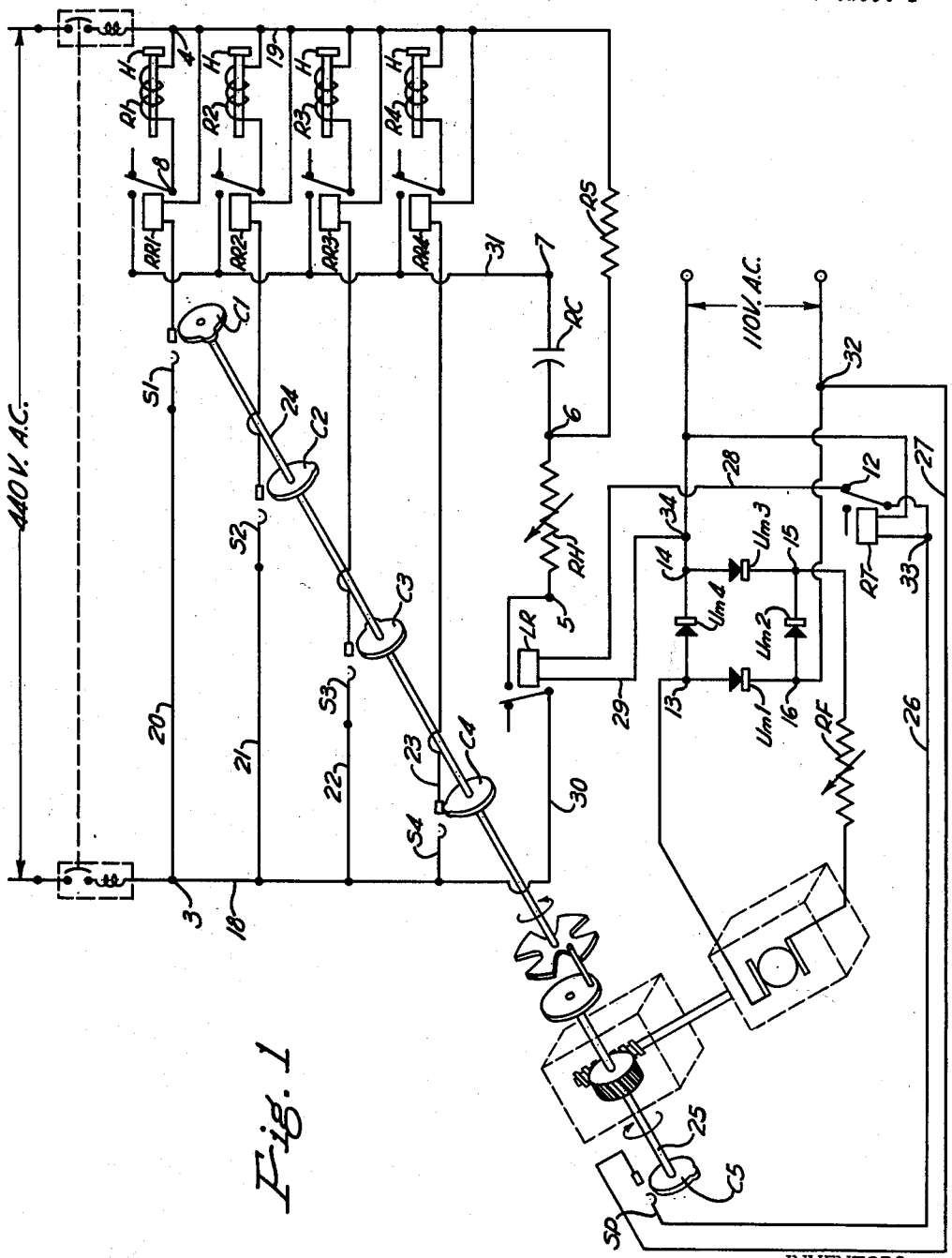


Fig. 1

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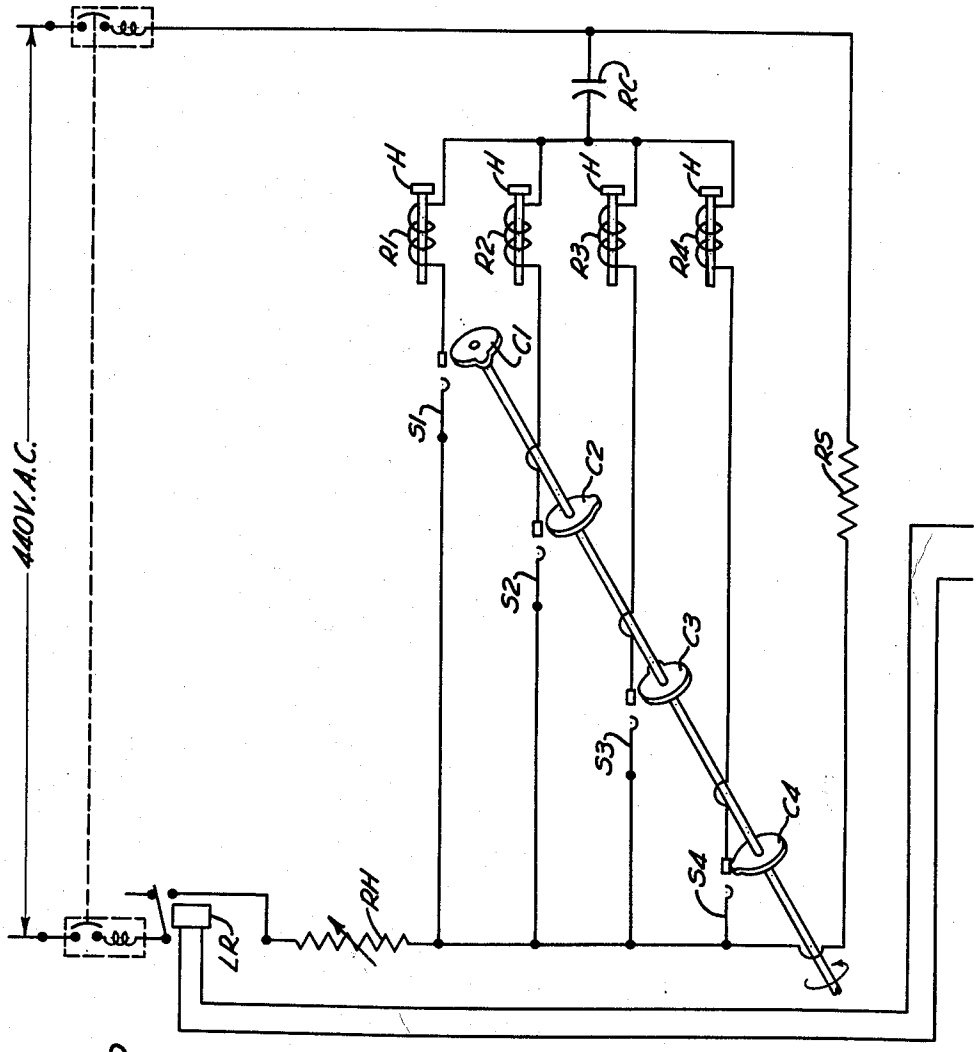


Fig. 2

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SEQUENTIALLY ENERGIZED SOLENOIDS RECIPROCATING MOTOR SYSTEM

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This invention is an improvement in electrically operated rapping systems, particularly in such systems used as rappers to dislodge the collected dust from the electrodes of electrical dust precipitators.

In electrical dust precipitators the dust is caused to collect on collecting electrodes, from whence it falls into collecting hoppers. In many cases it has been customary to supplement the force of gravity by the use of rapping hammers to deliver light impacts to the several collecting electrodes in continuous sequence, thus inducing continuous uniform deposition of dust with minimum re-entrainment of dust in the air stream.

The high voltage discharge electrodes of electrical dust precipitators may tend to collect small quantities of dust. These small quantities of dust interfere with the production of ions and adversely affect the performance of the precipitator. Keeping these small amounts of dust from building up on the discharge wires often requires the use of a high voltage electrode rapping system. For the cleaning of these electrodes, considerations of re-entrainment are unimportant in the light of the small quantities of dust involved. It is, therefore, common practice to impart as high as possible an impact level to these electrodes in order to dislodge as much as possible of the attached material. On these electrodes the impact level is limited only by the capability of the rapping equipment and the avoidance of possible destruction of the electrodes, their supporting frames, and related structure.

In certain situations the collecting electrodes, as well as the discharge electrodes, must be rapped vigorously. Since the impact of the rappers is continuously adjustable from very low intensity to the maximum level, the system may be advantageously applied to this service as well.

It is known to operate these rapping hammers electrically by means of solenoids. In some cases the intensity of rap obtainable in this way has been inadequate. Some attempts have been made to raise the impact level by using high-voltage D.C. power, but this introduces complications in the control system, and increases costs.

According to the present invention a capacitor is placed in series with the common conductor leading to the individual solenoid coils of the rapping hammers. This capacitor is selected so that it will produce a resonant circuit with the inductance of the rapper solenoid. This makes possible a substantial increase in the surge current to the rapper solenoid in a simple and efficient manner.

This, and other objects and advantages of the invention will become apparent as the description proceeds.

In the drawings,

FIG. 1 is a schematic diagram illustrating the invention;

FIG. 2 is a schematic diagram illustrating a modification.

Referring to FIG. 1, the rapping hammers H are adapted to engage corresponding high voltage discharge electrodes in a well-known manner. These hammers are actuated by the solenoid coils R1, R2, R3 and R4, which are energized by corresponding rapper relays RR1 through RR4.

A supply voltage, usually 440 volts, single phase, 60-cycle, is applied through a circuit breaker to the points 3 and 4, and thence to lines 18 and 19. This voltage is impressed on the rapper relays RR1 through RR4 by way of lines 20, 21, 22 and 23 when the switches S1 through S4 are closed. These switches are operated in sequence by mechanism which will now be described.

These switches are operated by cams C1 through C4 carried by shaft 24 which is driven intermittently through the Geneva gear from shaft 25. A variable speed motor drives the shaft 25 through reduction gears as illustrated.

The motor is energized by D.C. received from points 13 and 15 of the rectifier system, which includes rectifiers *Um*1 through *Um*4 and is supplied with 110 v. A.C. applied to points 14 and 16.

When the system has been turned on, the motor rotates continuously, and the rapping hammers H are operated in sequence in a manner now to be explained.

When the lobe of cam C1 closes switch S1, a circuit is set up through point 3, conductor 20, switch S1 and rapper relay RR1 to conductor 19 causing rapper relay RR1 to close, thus setting up the solenoid coil R1 for energization by the 440 v. A.C. current.

Immediately thereafter cam C5 carried by shaft 25 closes the firing switch SP. The closing of switch SP closes a circuit through load relay LR as follows: from point 32 on the 110 v. supply, conductor 27, switch SP, conductor 26, point 33 on timer relay RT, contact 12, conductor 28 to relay LR, conductor 29 to point 34 on the 110 v. supply.

The completion of this circuit energizes load relay LR, causing it to close and apply the 440 v. current through intensity adjustment rheostat RH and capacitor RC to the solenoid coil R1.

This circuit through capacitor RC extends through conductor 18, conductor 30, contacts of relay LR to point 5, adjustable rheostat RH to point 6, capacitor RC to point 7, conductor 31, contacts of rapper relay RR1, point 8, and solenoid coil R1 to point 4.

During the period of enerization a very high current at high voltage is forced through the solenoid coil R1 obtaining a high level of impact of the rapping hammer H on its corresponding electrode. This action will be explained more fully below under "Theory of operation."

After a short period of energization of solenoid coil R1, usually about two tenths of a second, the timer relay RT operates to break the circuit through load relay LR, thereby de-energizing the solenoid coil R1.

Due to the continuous rotation of the motor, the solenoid coils R2, R3 and R4 are energized in continuous sequence in exactly the same manner as that just described for solenoid coil R1.

The adjustable rheostat RF located in the power circuit to the motor permits control of the speed of the motor, and hence the frequency of operation of the rapping hammers.

Resistor RS, located in shunt around the capacitor RC and the solenoid coils R1 through R4, is a surge limiting resistor which is utilized in order to avoid voltage surges

which may occur upon the interruption of current in the solenoid coils.

Theory of operation

During its period of energization, solenoid coil R1 is connected in series with capacitor RC across the 60 cycle power line. Capacitor RC is selected so that its capacitive reactance equals, or substantially equals the inductive reactance of solenoid coil R1. Since these two reactances cancel each other, the only effective impedance in the system is its resistance. In large measure this resistance is made up of the resistance of solenoid coil R1, plus whatever resistance is inserted in the system by means of the adjustable rheostat RH. The result is that this series circuit is substantially resonant.

For a given supply frequency (f) the condition required for a series circuit to be resonant is for the inductive reactance X_L to be equal to the capacitive reactance X_C.

In a typical installation, the values of the condenser and coil would be as follows:

Condenser (C)=.0001255 farad

Then

$$x_c=\frac{1}{2\pi fC}$$

$$=\frac{1}{2\pi\times 60\times .0001255}$$

$$=21.1 \text{ ohms}$$

Coil (L)=.056 henry

Its resistance R=4 ohms

Then

$$X_L=2\pi fL$$

$$=2\pi\times 60\times .056$$

$$=21.2 \text{ ohms}$$

From the above it will be seen that the impedance of this coil,

$$Z=\sqrt{R^2+X_L{}^2}$$

$$=\sqrt{4^2+21.2^2}$$

$$=21.6 \text{ ohms}$$

However, when the coil and condenser are connected in series, X_C cancels out X_L so that the impedance (Z) is equal to the resistance:

$$Z=R$$

$$=4 \text{ ohms}$$

In this case, the quality factor (Q) of the coil is

$$Q=\frac{X_L}{R}$$

$$=\frac{21.2}{4}$$

$$=5.03$$

This low Q factor produces a broad resonant curve of current flowing in the circuit as frequency is varied. Therefore, because of this low Q factor, it is not essential for the two reactances X_C and X_L to be perfectly equal.

It will be noted that the voltage applied to the system remains at 440 volts, and since the effective impedance of the rapper coil has been reduced from 21.6 ohms to 4 ohms, the current through the rapper coil has been increased by approximately five times.

FIG. 2 illustrates a modification in which the relays RR1 through RR4 are omitted. This form operates in substantially the same manner as the form of FIG. 1. However, in this case the switches S1 through S4 must withstand the high resonant coil voltages during periods when they are open. This necessitates using heavier and more expensive switches for the parts S1 through S4, but this modification may be preferred in some cases.

Advantages

(1) By arranging the system so that the capacitive reactance of capacitor RC cancels out the inductive reactance of the solenoid coil, it is possible to force a very high current through the solenoid coil. This current is limited only by the resistance of the coil, and not by its inductance. In this manner a much higher impact level can be obtained from a given solenoid coil than could be obtained if it were energized simply from the A.C. power line. This improvement can be more than 5 times the previous impact level.

As stated above, the advantages of the invention can be substantially attained while utilizing a capacitor which does not entirely equal the inductive rectance of the solenoid coil. In this case the force of the impact of the rapping hammer would be somewhat reduced.

It is also possible by adjusting the variable resistor RH to vary the impedance of the circuit which delivers current to the solenoid coil, and thus vary the intensity of the blow delivered by the rapping hammer to any preferred level.

(2) In the system of the present invention high voltages occur only in that portion of the system between the capacitor RC and the solenoid coils. This distance can be made relatively short, thus avoiding the use of long runs of expensive high voltage wiring.

(3) Since the high voltage components are few, it is possible to sectionalize the rapper control into a high voltage section and a low voltage section. The high voltage section, which includes only the capacitor RC and the conductors leading from it to the solenoid coils R1 through R4, can be made very compact. The remainder of the system is subject to low voltage only, and can therefore be made of less expensive components.

This arrangement also makes it easier to provide safety protection for the small, compact high voltage section.

(4) By avoiding the need for rectification to produce D.C., the present invention utilizes relatively simple circuitry, which reduces original cost, maintenance, etc.

(5) The intensity adjustment rheostat RH permits a continuous adjustment of the intensity of the rappers over a range from very low intensity to the maximum level.

Conclusion

It will be understood by those skilled in the art that the present invention provides a simple and efficient device for raising the impact level in an electrically operated rapping system. While the device has been described in connection with an electrical dust precipitator, it may be used wherever a similar rapping system is desired.

According to the provisions of the patent statutes, we have explained the principle of our invention and have illustrated and described what we now consider to represent its best embodiment. However, we desire to have it understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

We claim:

1. In an electrically-operated rapper system of known type which comprises elements (a) to (e) inclusive and defined as follows:

Element (a): a series of rapping hammers;

Element (b): a series of solenoid coils individual to the rapping hammers;

Element (c): an electrical circuit furnishing alternating current to the solenoid coils of element (b);

Element (d): a series of switches adapted to sequentially set up a circuit from the circuit of element (c) to the individual solenoid coils of element (b);

Element (e): a firing switch which is closed whenever one of the switches of element (d) is closed, and which closes contacts to complete the circuit of element (c);

The improvement which comprises:

Element (*f*): a capacitor placed in the circuit of element (*c*); the capacitor having a capactive reactance which substantially equals the inductive reactance of the individual solenoid coils of element (*b*).

2. A system as specified in claim 1 in which an adjustable rheostat is placed in the circuit, element (*c*), in order to provide adjustment of the force of the blow delivered by the rapping hammers.

3. A system as specified in claim 1 in which a relay is connected in circuit between each of the switches of element (*d*) and its related solenoid coil of element (*b*),

whereby the switch sets up a circuit through the solenoid prior to the closing of the firing switch.

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