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CONTROL FOR RECIPROCATING MAGNETIC ACTUATORS

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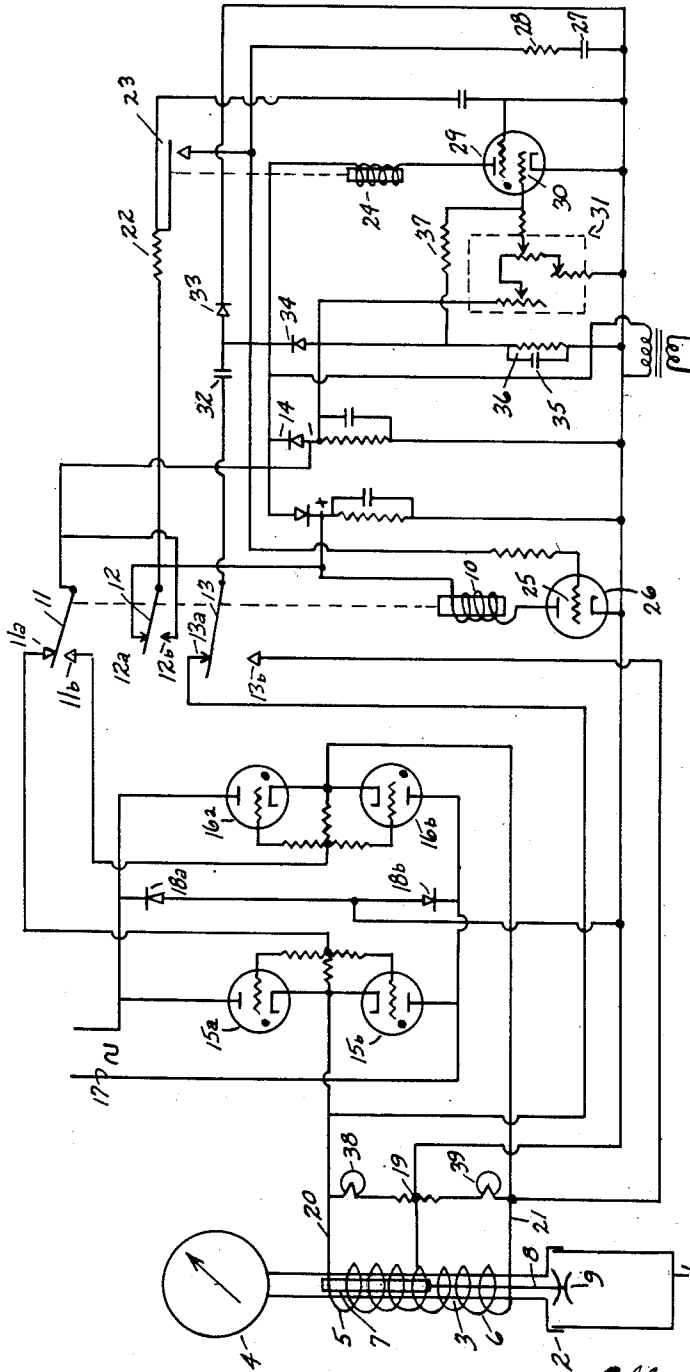


FIG. 1

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CONTROL FOR RECIPROCATING MAGNETIC ACTUATORS

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In high pressure autoclaves, external magnetic coils have been used to reciprocate an internal armature carrying an agitator, thereby obtaining positive agitation without external moving parts and eliminating the need for stuffing boxes. This invention is intended to insure proper travel of the agitator despite the varying degrees of resistance encountered as the viscosity of the agitated material changes, to adjust the speed with the viscosity so as to obtain the most efficient agitation, and to indicate when the agitator is operating as intended.

In the drawing, the single figure is a control diagram.

Referring to the drawing, 1 diagrammatically indicates the body of an autoclave and 2 indicates the cover carrying a tube 3 of non-magnetic material leading to a pressure gage 4. Mounted on the cover and surrounding the tube are magnetic coils 5 and 6 which are alternately energized to raise and lower a magnetic armature 7 freely slidable in the tube 3 and fixed to a depending rod 8 carrying cup agitators 9 arranged back-to-back. The armature is shown at its uppermost position when the coil 5 would normally be de-energized and the coil 6 energized so as to pull the armature downward. The parts so far described are or may be of common construction. It will be appreciated that the illustration is diagrammatic and that no attempt has been made to illustrate the construction and fittings to withstand typical operating pressures varying from a vacuum up to 50,000 lbs./sq. in. or more. The body and cover are shown in a vertical position with the armature at the top. The parts may be inverted or arranged at any intermediate inclination.

The reciprocation of the armature is controlled by two relays 10 and 24. The relay 10 has upper, middle, and lower contact arms 11, 12, 13 normally closed on contacts 11a, 12a, 13a when the relay is de-energized and closed on contacts 11b, 12b, 13b when the relay is energized.

The upper contact arm 11 of the relay 10 controls the energization of the magnetic coils 5 and 6. The contact arm 11 is connected to a strong negative bias 14 and the contacts 11a and 11b are respectively connected to the grids of thyratrons 15a, 15b, and 16a, 16b, connected in the manner of full wave rectifiers across an alternating power supply 17. The thyratrons, which are typical of grid-controlled gaseous discharge devices, are adjusted to fire on the positive half cycle in the absence of an external bias applied

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to the control grids. Whenever the negative bias from the contact arm 11 is applied, the pair of thyratrons 15a, 15b or 16a, 16b, as the case may be, is biased off and the other pair fires. Since only one of the pairs of thyratrons can fire at a time, both pairs are connected through the same full wave rectifier 18a, 18b, likewise connected across the power supply 17. The center point of the full wave rectifier 18a, 18b, is connected to the common terminal 19 of the magnetic coils 5 and 6. The midpoint of the thyratrons 15a, 15b is connected to the end terminal 20 of the magnetic coil 5 and the midpoint of the thyratrons 16a, 16b is connected to the end terminal 21 of the magnetic coil 6. For the position illustrated where the control grids of the thyratrons 15a, 15b are negatively biased, the magnetic coil 6 is energized by a full wave rectified current alternately through thyatron 16a and rectifier 18b and through thyatron 16b and rectifier 18a. When the contact arm 11 closes on contact 11b, the thyratrons 16a, 16b, which feed the magnetic coil 6, are biased off and the magnetic coil 5 is fed with a full wave rectified current through the thyratrons 15a, 15b.

The middle contact arm 12 of the relay 10 is connected through a resistance 22 and normally open contacts 23 of a relay 24 to the grid 25 of a discharge device 26 in series with the magnetic coil of the relay 10. Whenever the contacts 23 of the relay 24 close, a biasing condenser 27 is charged through a resistance 28 either positively or negatively depending upon whether the contact arm 12 is closed on the contact 12a (positive) or 12b (negative). For the position illustrated where the relay 10 is de-energized the biasing condenser 27 retains a negative charge sufficient to hold the discharge device 26 off. As soon as the contacts 23 of the relay 24 close, the biasing condenser 27 is almost immediately charged positively from the biasing voltage connected to the contact 12a and the positive bias on the control grids 25 of the discharge device 26 causes the tube to fire and energize the relay 10. This immediately shifts the position of the contact arms 11, 12, and 13 from the upper or de-energized position to the lower or energized position. As will hereinafter be described, the contacts 23, when the relay 24 is properly adjusted, only close momentarily and are not controlled by the relay 10 so that the movement of the contact arm 12 from the upper to the lower position as described above does not re-charge the biasing condenser 27 negatively when the contact arm closes on the contacts 12b. The negative charging of

the biasing condenser 27 does not take place until sometime later when the contacts 23 are reclosed momentarily.

The lower contact arm 13 of the relay 10 is always connected to the magnetic coil 5 or 6 which is de-energized. In the position illustrated, where the magnetic coil 6 is energized and the magnetic coil 5 is de-energized, the contact arm 13 is connected to the contact 13a which is connected to the terminal 20 of the magnetic coil 5. When the contact arms 11, 12, and 13 of the relay 10 are moved to the lowered or energized position, then the contact arm 13 is connected through the contact 13b to the terminal 21 of the magnetic coil 6, the de-energized coil. Although only one of the magnetic coils 5, 6 is energized, there is a double frequency (ripple frequency) voltage in the de-energized coil due to the magnetic coupling between the coils provided by the magnetic armature 7. This magnetic coupling is a maximum when one of the coils is first energized and gradually decreases as the armature 7 moves out of the de-energized coil and into the energized coil. This double frequency voltage becomes a minimum at the extreme end of the stroke of the armature 7 when the armature is almost wholly within the energized coil and the magnetic coupling to the de-energized coil is a minimum. The double frequency voltage coupled into the de-energized magnetic coil is used to control the firing of a gaseous discharge device 29 in series with the coil of relay 24. The device 29 has a grid 30 adjustably biased through a potentiometer 31 connected to the negative bias supply 14. The adjustment of the potentiometer 31 is such that in the absence of any additional negative bias on the grid 30 the device 29 fires on each positive half cycle. In order to prevent the firing of the device 29 until the armature 7 reaches the end of the desired stroke, the double frequency voltage coupled into the de-energized coil 5 or 6, as the case may be, is rectified to produce an added negative bias on the grid 30. As the voltage coupled into the de-energized coil decreases, the magnitude of the added negative bias on the grid 30 decreases and finally at the extreme end of the stroke of the armature 7 the combined bias on the grid 30 from the potentiometer 31 and from the rectified double frequency voltage in the de-energized coil becomes low enough so that the device 29 fires and energizes the relay 24 to close the contacts 23. The closure of the contacts 23 changes the bias on the device 26 in series with the relay 10 so as to cause the relay 10 to change its position. Changing the position of the relay 10 switches the contact arm 13 to the opposite position so that the double frequency voltage appearing in the contact arm 13 comes from the other of the magnetic coils 5 and 6. In other words, the firing of the device 29 occurs when the armature 7 is almost out of the de-energized magnetic coil 5 or 6 and accordingly almost wholly within the coil next to be de-energized. When the firing of the device 29 causes the momentary closure of the contacts 23 and the switching of the contact arm 11 to energize the previously de-energized coil, the simultaneous switching of the contact arm 13 is to the previously energized coil in which the armature is in the position of maximum coupling so as to produce the maximum of negative bias on the grid 30 and insure against any more than momentary firing of the device 29 with the resultant momentary closure of the contacts 23. The transient appearing at the contact arm 13 is also in the di-

rection to produce an additional negative bias on the grid 30.

The specific arrangement for rectifying the double frequency voltage appearing in the de-energized magnetic coil 5 or 6, as the case may be, comprises a condenser 32 connected to the contact arm 13 in a voltage doubler circuit comprising rectifiers 33 and 34. The double frequency voltage rectified and doubled appears across a condenser 35 shunted by a resistor 36 and connected to the grid 30 through a resistance 37. When the parts are in the position illustrated where the magnetic coil 6 is energized and the magnetic coil 5 is de-energized, the double frequency voltage appearing in the magnetic coil 5 is at a maximum and accordingly the negative bias appearing on the grid 30 of the discharge device 29 is at a maximum. As the armature 7 is drawn downward into the coil 6 and accordingly out of the coil 5, the double frequency in the coil 5 decreases and the combined negative bias on the grid 30 due to the potentiometer 31 and to the rectified double frequency voltage decreases until it reaches the firing value for the device 29. This can be adjusted so that the device 29 fires when the armature 7 is at the opposite end of its travel, or in other words almost wholly within the magnetic coil 6 and only partially within the magnetic coil 5. Since the double frequency voltage in the magnetic coil 5 is now at a minimum, this double frequency voltage when fed through the contact 13a and the contact arm 13 of the relay 10 results in a bias on the device 29 which causes the device to fire and energize the relay 24 to momentarily close the contacts 23. The momentary closure of the contacts 23 places a positive bias on the grid 25 of the device 26 through the contact arm 12 and contact 12a. This causes the device 26 to fire energizing the relay 10 and shifting the contact arms 11, 12, and 13 from the position illustrated to the lowered position in which the arms close respectively on contacts 11a, 12b, and 13b. The closing of the contact arm 11 on the contact 11b places a negative bias on the grids of the devices 16a and 16b feeding the magnetic coil 6 and removes the negative bias from the grids of the devices 15a, 15b feeding the magnetic coil 5 so that the magnetic coil 6 is de-energized and the magnetic coil 5 is energized so as to raise the armature 7 from its lowered toward its uppermost position. The closing of the contact arm 13 on the contact 13b connects the voltage in the magnetic coil 6 through the voltage doubler 32, 33, 34 to the biasing condenser 35. Since at this time, the armature 7 is at its lowermost position and the coil 5 is energized while the coil 6 is de-energized, the double frequency voltage appearing in the magnetic coil 6 is at a maximum and accordingly the negative bias on the device 29 is at its maximum. This bias is always sufficient to hold the device off so that the relay 24 is de-energized. The closing of the contact arm 12 on the contact 12b connects the contact arm 12 to the source of negative bias 14 so that the next time the contacts 23 momentarily close the bias on the condenser will become negative. In other words, the next time the contacts 23 close, the device 26 will be biased off and the relay 10 de-energized so as to return the contact arms 11, 12, and 13 to the uppermost position where the arms close on contacts 11a, 12a, and 13a.

The control circuit insures complete travel of the armature 7 with the resultant complete agitation of the charge in the body 1 of the autoclave by the agitator 9. The full stroke or com-

plete travel of the agitator results from the fact that the travel is controlled by the double frequency voltage coupled into the de-energized coil. This double frequency voltage is a maximum at the start of a stroke and becomes a minimum at the end of the stroke. When the double frequency voltage becomes a minimum, the energization of the magnetic coils is reversed starting the reverse stroke. With this control, it is the length of the stroke which is controlled and not the timing of the stroke. This insures full stroke agitation independent of the changes in the viscosity of the charge.

Since these autoclaves are frequently used behind barriers due to the high operating pressures, it is desirable that remote indication of the agitation be provided. This is accomplished by signal lights 38 and 39 respectively connected across the coils 5 and 6 so as to be energized with the coils. When the agitator is operating, the lights 38 and 39 alternately light at a frequency determined by the speed of reciprocation. If the agitator should stop, one of the lights will remain lighted continuously.

From one aspect, the control operates from the mutual inductance effect between the coils 5 and 6 and switches the power supply from one to the other when the mutual inductance of the de-energized coil is at or below a minimum which occurs only at the ends of the stroke. This makes the control truly dependent upon the stroke of the agitator.

It has been found from tests run with variable speed variable stroke agitators that for any viscosity there is one speed and stroke at which the agitation is most efficient. The body is ordinarily charged to 60% capacity or less and the most efficient agitation is obtained when the agitator moves at a speed slow enough so there is no cavitation on the downstream side of the agitator and the agitator on its upstroke reverses immediately after breaking the surface of the liquid and on the downstroke immediately upon reaching the bottom. These conditions are realized with the control of the present application. The agitator is set to travel through a fixed stroke which insures reversal when the agitator surfaces on the upstroke and bottoms on the downstroke. The power input or thrust insures against cavitation on the downstream side of the agitator. The result is an accommodation of the speed of reciprocation to the material so that as the viscosity changes, the agitator speed varies and the agitation is at all times at the most efficient point. This is an unexpected advantage which would not be obtained by a fixed speed commutator control switching back and forth from one to the other magnetic coils 5, 6. Nor, would the advantages be obtained by a fixed speed mechanical drive. Either of these fixed speed arrangements would produce most efficient agitation at only one viscosity and would not automatically adjust to variations in the viscosity as does the present control.

What is claimed as new is:

1. In a magnetic actuator having a pair of magnetic coils and a cooperating armature alternately drawn into one and then the other of the coils, a rectifier power supply, means for sequentially switching the power supply to one and then the other of the coils, and a control for the switching means comprising means controlled by the amount of ripple frequency magnetic flux coupled into the de-energized coil as the position of the armature varies for switching

the power supply from the previously energized coil to the previously de-energized coil.

2. In a magnetic actuator having a pair of magnetic coils coupled through an armature alternately drawn into the energized coil and out of the de-energized coil, a full wave rectifier power supply, means for sequentially switching the power supply to one and then to the other of the coils, and means responsive to the magnitude of the double frequency magnetic field coupled into the de-energized coil for indicating the withdrawal of the armature from the de-energized coil.

3. In a magnetic actuator having a pair of magnetic coils coupled through an armature alternately drawn into the energized coil and out of the de-energized coil, a full wave rectifier power supply, a relay for sequentially switching the power supply to one and then to the other of the coils, contacts actuated with the relay to connect with the de-energized coil, a rectifier connected to the contacts for rectifying the double frequency voltage coupled into the de-energized coil, a grid-controlled discharge device biased off by the rectified double frequency voltage and firing when the double frequency voltage drops below a pre-selected minimum, and a control circuit utilizing the firing of the discharge device to actuate the relay to de-energize the previously energized coil and to energize the previously de-energized coil.

4. In a pressure or vacuum vessel of the type having a body, a non-magnetic tube leading from the body and forming part of the envelope of the vessel, a reciprocable armature in the tube and exposed to the atmosphere within the vessel carrying an agitator reciprocable in the body, and a pair of alternately energized magnetic coils outside and surrounding the tube and cooperating with the armature through the walls of the tube to reciprocate the agitator, the combination of rectifier power supply, a relay for sequentially switching the power supply to one and then the other of the coils, and means controlled by the amount of ripple frequency magnetic flux coupled into the de-energized coil for actuating the relay to switch the power supply from the previously energized coil to the previously de-energized coil.

5. In a pressure or vacuum vessel of the type having a body, a non-magnetic tube leading from the body and forming part of the envelope of the vessel, a reciprocable armature in the tube and exposed to the atmosphere within the vessel carrying an agitator reciprocable in the body, and a pair of alternately energized magnetic coils outside and surrounding the tube and cooperating with the armature through the walls of the tube to reciprocate the agitator, the combination of a full wave rectifier power supply, means for sequentially switching the power supply to one and then to the other of the coils, and means responsive to the magnitude of the double frequency magnetic field coupled into the de-energized coil for indicating the position of the armature relative to the de-energized coil.

6. In a pressure or vacuum vessel of the type having a body, a non-magnetic tube leading from the body and forming part of the envelope of the vessel, a reciprocable armature in the tube and exposed to the atmosphere within the vessel carrying an agitator reciprocable in the body, and a pair of alternately energized magnetic coils outside and surrounding the tube and cooperating with the armature through the walls of the tube to reciprocate the agitator, the combination of a

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full wave rectifier power supply, a relay for sequentially switching the power supply to one and then to the other of the coils, contacts actuated with the relay to connect with the de-energized coil, a rectifier connected to the contacts for rectifying the double frequency voltage coupled into the de-energized coil, a grid-controlled discharge device biased off by the rectified double frequency voltage and firing when the double frequency voltage drops below a pre-selected minimum, and a control circuit utilizing the firing of the discharge device to actuate the relay to de-energize the previously energized coil and to energize the previously de-energized coil.

7. In a pressure or vacuum vessel of the type having a body, a non-magnetic tube leading from the body and forming part of the envelope of the vessel, a reciprocable armature in the tube and exposed to the atmosphere within the vessel carrying an agitator reciprocable in the body, and a pair of alternately energized magnetic coils outside and surrounding the tube and cooperating with the armature through the walls of the tube to reciprocate the agitator, the combination of a full wave rectifier power supply, a relay having contacts for sequentially switching the power supply to one and then to the other of the coils,

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other contacts connecting to the de-energized coil, and third contacts sequentially connecting to a source of positive and negative bias in the sense required for the next actuation of the relay, a grid-controlled discharge device controlling the relay, another grid-controlled discharge device controlling normally open contacts in circuit with the control grid of the first device and the third contacts of the relay, and means biasing the grid of the second device from the double frequency voltage in the de-energized coil whereby the second device causes closing of the normally open contacts when the double frequency voltage in the de-energized coil drops to a minimum value.

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