Oct. 8, 1957 R. B. BECKER 2,808,735

AUTOMATIC COUNTERBALANCE FOR WELL PUMPING APPARATUS

Filed Nov. 19, 1953 2 Sheets-Sheet 1

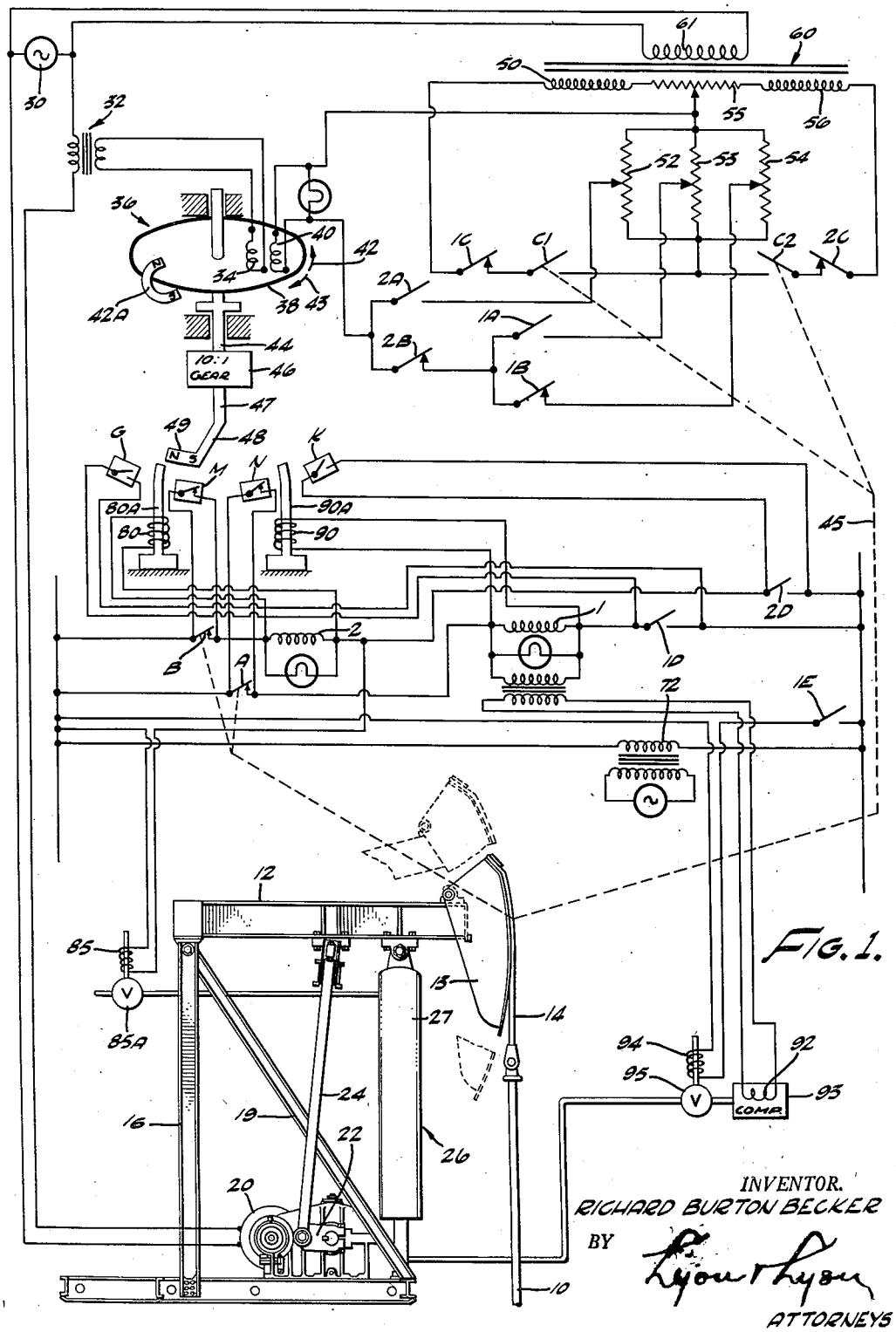


FIG. 1.

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AUTOMATIC COUNTERBALANCE FOR WELL PUMPING APPARATUS

Filed Nov. 19, 1953 2 Sheets-Sheet 2

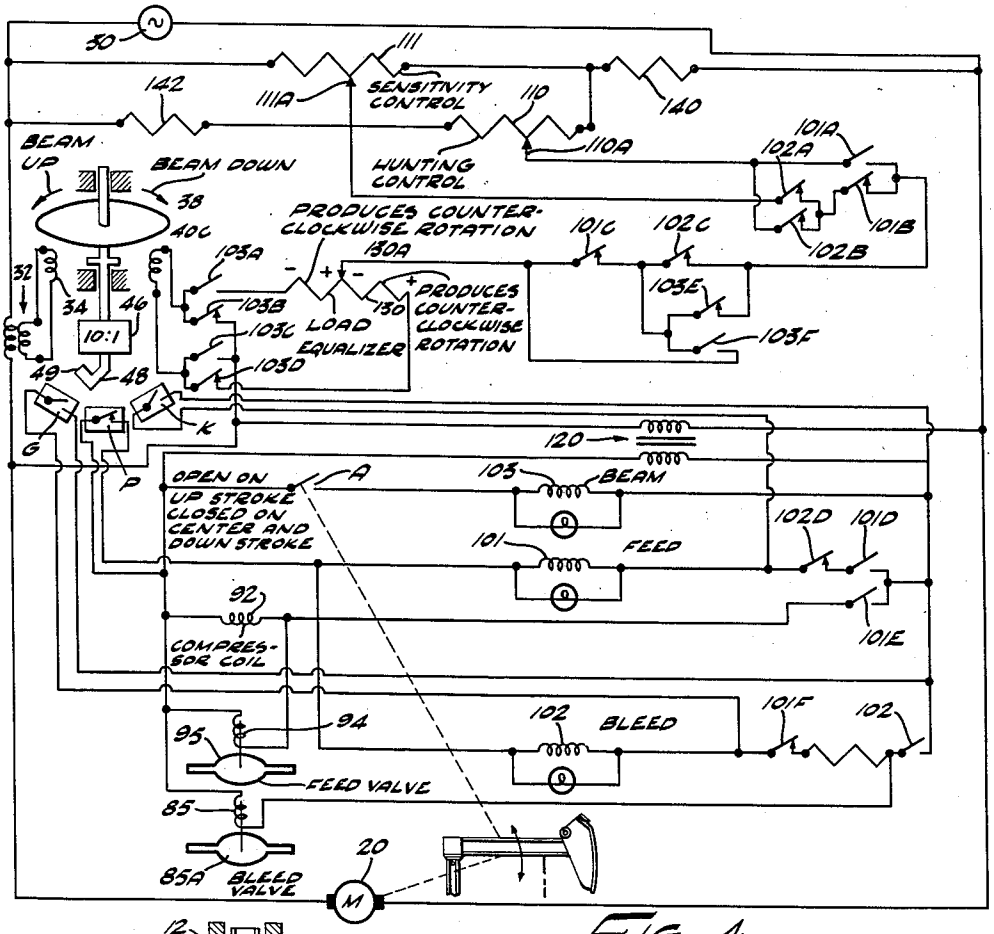


FIG. 4.

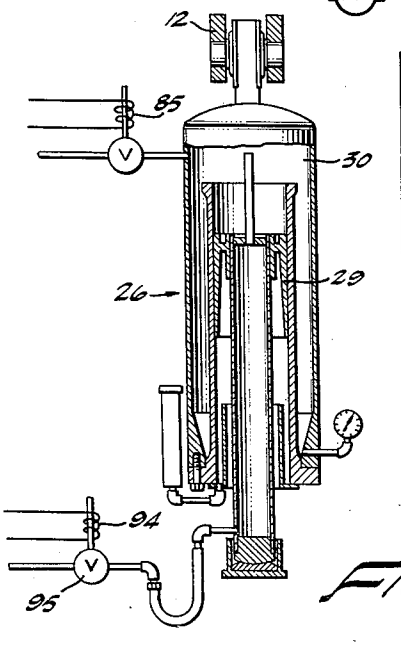


FIG. 3.

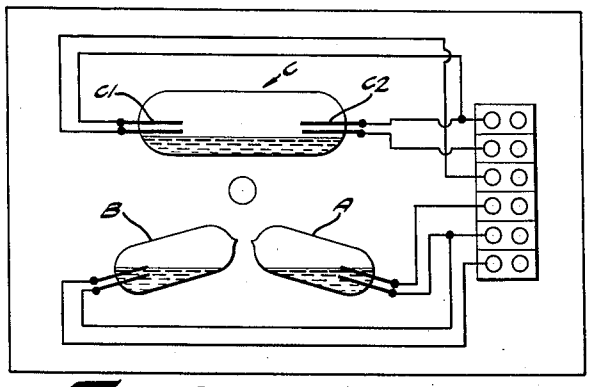


FIG. 2.

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2,808,735

AUTOMATIC COUNTERBALANCE FOR WELL PUMPING APPARATUS

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Application November 19, 1953, Serial No. 393,206

10 Claims. (Cl. 74—589)

The present invention relates to improved means and techniques for obtaining automatic counterbalancing for well pumping apparatus, although, it is understood that the present invention may find utility in other environment wherein it is desired to provide the correct counterbalance automatically for a reciprocating member driven by a rotating shaft and which is not counterbalanced, subjects the rotating shaft to unequal loads during the two oppositely directed strokes of the reciprocating member.

For these general purposes counterbalance units involving a piston operating in a cooperating air cylinder have heretofore been proposed. The general purpose of the present invention is to provide improved means and techniques whereby the proper amount of air pressure in a counterbalancing unit of that character is automatically regulated so that the engine or motor driving a string of sucker rods does not have any appreciable variation in load throughout a pumping cycle which comprises a complete up and down movement of the sucker rods. It is desirable to maintain the average air pressure within the air cylinder a certain amount since if, for example, the air pressure is too high, the counterbalance effect is too great and the driving engine or motor is required to work too hard on one-half of the pumping cycle; on the other hand, if the air pressure is too low the engine or motor is required to work too hard on the other half of the pumping cycle.

If well pumping conditions would remain constant it would be a simple matter to determine the proper pressure required in a counterbalance unit by trial and error and then automatically maintain this desired pressure. However, well pumping conditions change from day to day and week to week so that the counterbalance effect should also change to provide the proper compensation.

The present invention concerns itself thus with means and techniques which involve effectively measuring the energy required to move the sucker rods upwardly during one-half of the pumping cycle with the energy required in lowering the sucker rods during the other half of the pumping cycle. These two measurements are effectively compared and the pressure in the compensating unit is regulated in accordance with such comparison so as to maintain the energy required during the two halves of the pumping cycle substantially equal.

Briefly, the arrangement described herein involves a modified conventional watt-hour meter having a conventional disk which turns in one direction while the sucker rods are being lifted and which turns in the opposite direction when the sucker rods are being lowered. The direction of movement of the disk is controlled by position-responsive switches mounted on the walking beam of the pumping apparatus. When such walking beam tilts one way the disk of the watt-hour meter is turned in one direction; and when the beam tilts in the other direction the disk of the watt-hour meter is caused to turn in the other direction. If the apparatus is in balance the watt-hour meter disk simply oscillates back and forth within relatively small limits. However, if such disk turns too far in one direction, beyond such limits, thereby indicating an unbalanced condition, a small arm carrying a permanent magnet and connected by reduction gearing to the disk shaft causes a control switch to be closed to thereby energize an electrical circuit for feeding compressed air to the counterbalance unit; or, on the other hand, to "bleed" air from such counter-balance unit depending upon the correction required. One such limit switch causes feeding, and a second limit switch causes "bleeding" to effect the proper balance in which case the watt-hour meter disk, as mentioned before, simply oscillates back and forth within limits without actuating the "bleed" or feed switch.

It is, therefore, a general object of the present invention to provide improved means and techniques of the character outlined above.

A specific object of the present invention is to provide improved means and techniques whereby well pumping apparatus is automatically balanced regardless of the fact that well pumping conditions change.

Another specific object of the present invention is to provide improved means and techniques of this character involving effectively measuring the energy required to lift the sucker rods in a pumping operation with the energy required to lower the same and to render both of such energies substantially equal.

Another specific object of the present invention is to provide improved means and techniques of this character whereby the air pressure in a compensating unit is automatically and continuously regulated during changing well conditions to assure at all times a condition wherein the energy required to lift the sucker rods is substantially equal to the energy required to lower the same during a pumping cycle.

Another specific object of the present invention is to provide improved means and techniques of this character which involve relatively simple and compact apparatus for these general purposes, such apparatus being easily and quickly adapted to the well pumping apparatus without alteration.

The features of the present invention which are believed to be novel are set forth with particularity in the appended claims. This invention itself, both as to its organization and manner of operation, together with further objects and advantages thereof, may be best understood by reference to the following description taken in connection with the accompanying drawings in which:

Figure 1 illustrates a system embodying features of the present invention with the apparatus illustrated in structural and schematic form;

Figure 2 illustrates the character and placement of certain switches illustrated in Figure 1, such switches being operated in accordance with the position of the walking beam upon which they are mounted as a unit;

Figure 3 illustrates certain constructional features of the cylinder-piston compensating unit, also shown in Figure 1;

Figure 4 illustrates a modified form of the present invention.

The well pumping apparatus illustrated in Figure 1 includes the conventional sucker rods **10** which are moved up and down during a pumping cycle upon oscillatory movement of the walking beam **12** carrying the horsehead **13** over which a flexible cable **14** passes, one end of the cable **14** being affixed to the horsehead and the other end of the cable **14** being attached to the sucker rods **10**. The beam **12** is pivoted on the Samson post **16** which is secured to the base **18** and braced by the bracing **19**.

The alternating current motor 20 mounted on the base 18 drives the crankarm 22 through suitable reduction gearing. The crankarm 22 is connected through a suitable pitman 24 to the beam 12 to produce the desired up and down movement of the same.

A counterbalancing unit comprising a piston-cylinder assembly 26 is disposed as shown in Figures 1 and 3. It is noted that the cylinder portion 27 is pivotally mounted on the beam 12 and that movement of the piston portion 29 is restricted in such a manner that during the down stroke of the sucker rod string the air in the unit 26 is compressed in increasing amount while on the up stroke of the sucker rod string the compressed air in the unit 26 aids in lifting the weight of such string and in pumping. The chamber 30 in the unit 26 is filled with compressed air, for these purposes, and the pressure of such air is automatically and continuously regulated in the manner now described in detail to produce a balanced arrangement, i. e., one in which the energy required by the driving motor 20 to lift the sucker rod string is substantially equal to the energy required by the same motor 20 during the time that such string is being lowered.

It is observed that when the crankarm 22, in its rotation, is nearly vertical, the component of its movement parallel to the direction of travel of the walking beam and the pump plunger is relatively small, and therefore the load on the motor 20 when the crankarm is in this position is also relatively small. On the other hand, when the crank arm 22 is near either of its horizontal positions, it has a relatively large component of its movement parallel to the direction of travel of the walking beam and the pump plunger attached to the sucker rods, and the load on the prime mover is then most influenced by the load on the walking beam. If no counterbalance is employed, it is evident that on the up stroke of the string of sucker rods, when the crankarm is horizontal, the motor 20 is subjected to its greatest load, being required at that time to lift with greatest velocity the walking beam, the string of sucker rods, and all of the liquid being elevated in the well tubing; while on the down stroke, the walking beam 12 and the string of sucker rods fall by gravity, subjecting the motor 20 to little or no load. By proper adjustment of the pressure of the air in the chamber 30, the work done by the motor 20 during the downward stroke is substantially equal to the work done by the motor during the upward stroke.

In order that the amount or degree of counterbalancing may change in accordance with changing well conditions air is automatically fed into the chamber 30 or "bled" therefrom, as the occasion may require.

The motor 20 is supplied with currents from the alternating current source 30, such current flowing through the primary winding of the current transformer 32. The secondary winding of the transformer 32 is connected to the current coil of a watt-hour meter 36 which includes the disk 38 magnetically associated in conventional manner with the current coil 34 and the voltage coil 40. If desired a conventional braking magnet 42A may be associated with disk 38 to retard its movement.

Disk 38 has its rotatable shaft 44 connected to a ten-to-one gear reduction box 46, the output shaft 47 of the box 46 carrying an arm 48 upon which a permanent magnet 49 is disposed for operating any one of the magnetically operated switches G, M, N, and K depending upon the angular position of the shaft 47.

The voltage coil 40 of the watt-hour meter has a voltage applied thereto, in normal balanced operation, with such phase as to produce clockwise rotation of the disk 38 in the direction indicated by the arrow 43 on the down stroke of the beam 12; and to produce counterclockwise rotation of the disk as indicated by the arrow 42 on the up stroke of the beam 12. In order to thus change the phase of the voltage applied to the coil 40 the switches *c*–1 and *c*–2 are provided, such switches being

mounted on the beam 12 as shown in Figure 2 and indicated by the dotted line 45 in Figure 1.

In general the speed of rotation of the disk 38 is determined by the current flowing in the current coil 34, i. e., the current flowing to the motor 20 while the direction of the rotation of the disk 38 is determined by the phase of the voltage applied to the voltage coil 40. Also, as described hereinafter, the speed of rotation of the disk 38 is adjustably controlled by adjusting the amplitude of the voltage applied to the coil 40.

The switch *c*–1 is connected in a serial circuit with the switch 1-c, the secondary winding 50, and a voltage dividing network 51 comprising the three parallel connected potentiometer type resistances 52, 53 and 54, as well as a portion of the potentiometer type resistance 55. Likewise, the switch *c*–2 is serially connected with the relay switch 2–*c*, the transformer secondary winding 56, a portion of the resistance 55 and the voltage dividing network 51. For purposes of simplification the two relays used in Figure 1, each have their coils designated by a characteristic reference numeral and the associated switches have the same reference numeral but with a letter appended thereto. Thus, one of such relays has a coil designated by the reference numeral 1 and the associated relay switches are designated as 1–*a*, 1–*b*, 1–*c*, 1–*d* and 1–*e*; likewise, the other relay has a coil designated by the reference numeral 2 and has associated switches 2–*a*, 2–*b*, 2–*c* and 2–*d* which are operated when the winding 2 is energized or deenergized as the case may be.

It is observed that the secondary windings 50 and 56 are serially connected through the resistance 55 with aiding polarity so that when the left-hand terminal of winding 50 is considered to have a positive polarity the right-hand terminal of the winding 56 has a negative polarity. The windings 50 and 56 comprise elements of the transformer 60 having the primary winding 61 connected to opposite terminals of the source 30. One terminal of the voltage coil 40 is connected to the adjustable tap on resistance 55, termed the "load equalizer control." The other terminal of the coil 40 is connected through various switches to the adjustable taps on resistances 52, 53 and 54, the resistance 52 being termed a "bleed time control," the resistance 53 being termed a "feed time control" and the resistance 54 being termed a "sensitivity control." More specifically, the adjustable tap on resistance 52 is connected through switch 2–*a* to one terminal of coil 40; the adjustable tap on resistance 53 is connected through relay switches 1–*a* and 2–*b* to such one terminal of coil 40; and likewise the adjustable tap on resistance 54 is connected through switches 1–*b* and 2–*b* to such one terminal of coil 40. By these means, it is clear that the phase of the voltage appearing at any one particular time across the voltage dividing network 51 is determined by the position of the beam switches *c*-1 and *c*–2 and that the tntensity of the voltage applied to the coil 40 under different circumstances is determined by the position of the taps on resistances 52, 53 and 54. In normal balanced operation the switches *c*–2 and *c*–1 are alternately and sequentially closed to, in turn, produce oscillatory movement of the watt-hour meter disk 38, with an amplitude of oscillation as determined by the position of the tap on the sensitivity control resistance 54. The central axis about which oscillations of the disk 38 occur is determined by the position of the tap on the load equalizer control resistance 55. The resistance 55 thus provides a means for compensating for electrical dissimilarity in the circuitry as well as to compensate for inaccurate positioning of the switches *c*–1 and *c*–2 on the beam 12. Preferably the secondary windings 50 and 56 have equal voltages induced therein so that ideally the tap on resistance 55 is exactly at the midpoint of the resistance strip which comprises resistance 55.

For purposes of definition, the system is said to be balanced or compensated when the average air pressure in the equalizing unit **26** is such that substantially equal amounts of energy are required in the prime mover or motor **20** in the up and down movement of the beam **12**; an overbalanced or overcompensated condition is one in which the air pressure is higher than that required for a balanced condition; and, likewise, an underbalanced or underequalized condition is one in which the air pressure in the equalizing unit **26** is below that required for attainment of a balanced condition.

In a balanced condition the permanent magnet **49** is caused to oscillate back and forth between relatively small limits comparable to the angular distance between switches M and N, without actuating either switch K or G. When the system is overcompensated, i. e., the pressure in unit **26** is excessive and some air is required to be bled therefrom, the current flowing to the motor **20** in the up stroke of the beam **12** is less than the current flowing to the same motor in the down stroke of beam **12**, in which case the disk **38** is rotated in a clockwise direction a greater angular distance when switch *c*–**2** is closed than the counter-clockwise angular distance traversed when the switch *c*–**1** is closed, with the result that the permanent magnet **49** is rotated adjacent the switch K, a normally open switch, to cause such switch K to close.

Switch K is serially connected with the bleed relay coil **2** and causes the same to be energized through a circuit which includes the secondary winding **72**, the normally closed switch M, winding **2** and switch K.

Similarly, when there is an underbalanced or underequalized condition the permanent magnet **49** moves to a position adjacent the normally open switch G to cause the same to operate to, in turn, energize the feed relay winding **1** through a circuit which includes the following: Secondary winding **72**, the normally closed switch N, relay winding **1** and switch G.

When relay winding **2** is energized, as described above, its associated switch contacts **2**–*a*, **2**–*b*, **2**–*c* and **2**–*d* are actuated; and simultaneously the solenoid winding **80** is energized for a purpose described later. Closure of switch **2**–*a* results in the application of voltage from the bleed time control resistance **52** to the coil **40**. Opening of the normally closed switch **2**–*b* disconnects the tap of resistance **54** from coil **40**. Opening of switch **2**–*c* prevents further counterclockwie rotation of the magnet **49**. Closure of switch **2**–*d*, which is in parallel with switch K, assures continued energization of the winding **2** after the permanent magnet **49** moves away from the magnetically operated switch K.

During the time that relay **2** is energized, switch **2**–*d* is, of course, closed and the bleed valve solenoid winding **85** is energized during that time to allow the excess pressure in the unit **26** to be relieved. While such air bleeding occurs the arm **48** is rotated in a clockwise direction during the up stroke of the beam **12** to cause the magnet **49** to approach the normally closed magnetically operated switch M. In order to limit the movement of the permanent magnet **49** to a position adjacent the switch M the magnetically operated stop or motion-limiting member **80**–*a* is provided. This member may be in the form of a core of a solenoid or an extension thereof and which is automatically positioned in motion-limiting position upon energization of the solenoid winding **80**, as described above. Subsequently when the switches M and B, which is parallel with switch M, are both simultaneously open, the winding **2** is deenergized and the air bleeding operation ceases; and the winding **80** is likewise deenergized to allow the stop member **80**–*a* to move out of motion limiting position.

The switches B and A are both beam position responsive switches and are mounted for that purpose on the beam **12** as indicated by the dotted lines in Figure 1 and as shown in Figure 2. The switch B is open on the down stroke of the beam and closed at the center position of the beam as well as on the up stroke of the beam. On the other hand, the switch A is open on the upstroke of the beam and is closed at the center position of the beam as well as on the down stroke of the beam. The other beam position responsive switches *c*–**1** and *c*–**2** operate as follows: The switch *c*–**1** is closed on the upstroke of the beam and is open on the down stroke of the beam as well as in the center position of the beam. The switch *c*–**2** is closed on the down stroke of the beam, is open on the upstroke and is open at the center position of the beam.

When there is an underbalanced or unequalized condition the disk **38** and the arm **48** connected thereto eventually move to a position wherein the permanent magnet **49** is effective to operate the normally open switch G. This is so since during the up stroke of the beam, the motor **20** requires a greater amount of energy than is required on the down stroke.

When switch G is operated the relay winding **1** is energized through a circuit which includes: the secondary winding **72**, the normally closed switch N, the winding **1** and switch G. Simultaneously with energization of relay winding **1**, the solenoid winding **90** in parallel with winding **1** is energized. Also the compressor motor starter coil **92** is energized to cause operation of the air compressor **93**.

Operation or energization of the solenoid winding **1** results in actuation of the associated relay switches **1**–*a*, **1**–*b*, **1**–*c*, **1**–*d* and **1**–*e*. Closure of the normally open relay switch **1**–*a* results in application of the voltage at the tap of the feed time control resistance **53** to the voltage coil **40** to thereby cause the disk **38** to rotate, under particular conditions, at a speed determined by the setting of the tap on resistance **53**. Opening of the normally closed relay switch **1**–*b* interrupts the normal energizing circuit for the voltage coil **40**. Opening of the relay switch **1**–*c* prevents further counterclockwise rotation of the disk **38** and clockwise rotation of permanent magnet **49**.

Closure of the relay switch **1**–*b* which is in parallel with the switch G assures continued energization of the relay winding **1** as well as the solenoid winding **90** and starter coil **92** when the permanent magnet **49** moves away from the switch G. Closure of switch **1**–*c* results in energization of the solenoid coil **94** of the feed valve **95** to thereby allow air from the compressor **93** to enter the cylinder **27** to relieve the under-compensated or underequalized condition.

Under these conditions the arm **48** is moved in the counterclockwise direction and its motion is limited by the stop member **90**–*a*, which at this time maintains the permanent magnet **49** in a position adjacent the normally closed magnetically operated switch N. When switches N and A are simultaneously opened the relay winding **1** is deenergized.

As shown in Figure 2 the switches *c*–**1**, *c*–**2**, A and B are each mercury type switches having a pair of electrodes which are arranged to be bridged by mercury sealed in glass envelopes depending upon the position of the beam **12** upon which such switches are mounted as a unit. In the center position of the beam **12** the switches A and B are each closed, while the switches *c*–**1** and *c*–**2** are each open; in the down stroke of the beam the switches *c*–**2** and A are each closed; and in the up stroke of the beam **12** the switches *c*–**1** and B are each closed.

Figure 4 illustrates a modified form of the present invention with corresponding elements in Figures 1 and 4 having identical reference numerals. The following changes are noted. Instead of having four magnetically operated switches, as illustrated in Figure 1, only three magnetically operated switches are used in Figure 4. The switches G and K in Figures 1 and 4 are identical and are operated in the same way, namely, switch K is operated when there is an under-equalized or under-balanced condition requiring the addition of air to the equalizing cylin-

der, while on the other hand, the switch G is operated when the system is overbalanced or over-compensated to cause air to be bled from the cylinder. The normally closed magnetically operated switch P in Figure 4 replaces the two switches M and N, the switch P being disposed midway between the extreme switches P and K. One additional relay is used in Figure 4, namely, the relay **103** serving to change the phase of the voltage applied to the voltage coil **40** of the watt-hour meter as well as other purposes. The feed relay instead of being characterized by the reference numeral **1** is now characterized by the reference numeral **101** and the bleed relay winding instead of being characterized by the reference numeral **2** is now characterized by the reference numeral **102**. The associated relay switches are designated as described above. Energization of the relay winding **101** causes actuation of the associated switches **101**–*a*, **101**–*b*, **101**–*c*, **101**–*d*, **101**–*e*, and **101**–*f*. Energization of the relay winding **102** results in operation of the associated relay switches **102**–*a*, **102**–*b*, **102**–*c*, **102**–*d*, and **102**–*e*. Similarly, energization of the relay winding **103** results in operation of the associated relay switches **103**–*a*, **103**–*b*, **103**–*c*, **103**–*d*, **103**–*e*, and **103**–*f*.

Further, whereas, four beam responsive positions A, B and *c*–**1** and *c*–**2** are used in the arrangement illustrated in Figure 1, only one beam position responsive switch is required in Figure 4, namely, the switch A which is positioned and mounted in the same manner as the corresponding switch A in Figure 1. Switch A is open on the up stroke of the beam but is closed at the center position of the beam and during the down stroke of the beam.

During the down stroke of the beam, closure of switch A results in energization of the relay winding **103** through a circuit which includes the secondary winding of transformer 120, switch A and the coil **103**. It is noted that the watt-hour meter disk **38** is rotated in the clockwise position during downward movement of the beam **12** and conversely the disk **38** is rotated in the counterclockwise direction when the beam is moving upwardly. To achieve this result, the phase of the voltage applied to the voltage coil **40** is alternately changed in timed relationship with the movement of the beam, i. e., in timed relationship with energization of the coil **103**. Thus, during the downward movement of the beam **12** (assuming a balanced condition), the coil **40** is energized through a circuit which includes the coil **40**, the normally open relay switch **103**–*a*, the lefthand portion of the load equalizer resistance **130**, the tap **130**–*a*, the normally closed relay switch **101**–*b*, the normally closed relay switch **102**–*a*, the adjustable tap **111**–*a* on the sensitivity control resistance **111** which is serially connected with the alternating current voltage source **30** and the voltage dropping resistance **140**, and the normally open relay switch **103**–*c* completes a path for the current flow to the coil **40**. Under the same balanced condition, and during the up stroke of the beam, the switch A is open, and the relay winding **103** is deenergized, in which case the voltage appearing across the righthand portion of the load equalizer resistance, instead of the lefthand portion as previously, is applied to the coil **40** through the normally closed relay switches **103**–*b* and **103**–*d*.

Thus, under balanced conditions the watt-hour meter disk **38** simply oscillates back and forth through relatively small limits and excursions thereof are insufficient to cause operation of either switch G or switch K.

When the system is overcompensated or overbalanced the driving motor **20** draws more current during the down stroke than during the up stroke. In such case, the increased current flow during the down stroke causes the current winding **34** of the watt-hour meter, causes the disk **38** to be rotated a greater amount in the clockwise direction to such an extent as to cause operation of the switch G. Closure of switch G results in energization of the bleed relay coil **102** through a circuit which includes: the secondary winding of transformer **120**, the normally closed switch P, the winding **102** and the switch G. In such case the relay switch **102**–*a* is opened to interrupt the voltage normally applied to the coil **40** from the tap **111**–*a*. Operation of switch **102**–*b* closes a different energizing circuit for coil **40**, such that the voltage appearing on the tap **110**–*a* of the so-called hunting control resistance **110** is applied to the coil **40** through a circuit which includes the tap **110**–*a*, the switch **102**–*b*, the normally closed relay switch **101**–*b*, the normally closed relay switch **103**–*e*, the normally closed relay switch **101**–*c*, the tap **130**–*a*, the righthand portion of resistance **130**, and the normally closed relay switch **103**–*b*, the coil **40**, the normally closed relay switch **103**–*b* and the lefthand terminal of source **30**, it being observed that the source **30** is serially connected with the resistance **110** through voltage dropping resistances **140** and **142**. This voltage appearing on the tap **110**–*a*, under this particular overbalanced condition, is applied to the voltage coil **40** only during the up stroke of the beam **12**, i. e., only when the relay coil **103** is deenergized. On the down stroke, the coil **103** is energized, as described previously, causing the switch **103**–*e* to open thereby interrupting the voltage otherwise applied to the coil **40** from the tap **110**–*a*. By these means assurance is had that the disk **38** will be restored to a balanced condition, i. e., will rotate in a counterclockwise direction to effect a control operation involving the actuation of the control switch P. Operation of the normally closed relay switch **102**–*d* assures prevention of energization of the feed relay coil **101** thereby preventing simultaneous air feeding and air bleeding. Operation of the normally open relay switch **102**–*e*, a sealing switch, which is in parallel with the switch G assures continued energization of the relay coil **102** during the bleeding operation, i. e., during the time the permanent magnet **49** is being moved from a position adjacent the switch G to a position adjacent the control switch P. Closure of switch **102**–*e* completes a circuit through the bleed valve solenoid coil **85** to allow air to be bled. Subsequently, when the permanent magnet **49** is restored to a position adjacent the switch P, it is opened to thereby interrupt the current flow in relay coil **101** to thereby terminate the bleeding operation.

When there is an under-balanced or under-compensated condition, the motor **20** draws more current during the up stroke of the beam **12** than during the down stroke of the beam and the increased current flow through the current coil **34** causes increased rotation of the disk **38** in the counterclockwise direction to ultimately place the permanent magnet **49** adjacent the switch K to cause the switch K to close. Closure of switch K results in an air feeding operation as now described. Closure of switch K results in the energization of the feed relay coil **101** through a circuit which includes the secondary winding of transformer **120**, the normally closed switch P, the relay coil **101**, and the switch K. The resulting operation of the normally open relay switch **101**–*a* applies the voltage appearing on the tap **110**–*a* to the watt-hour meter voltage coil **40** through a circuit which includes: the tap **110**–*a*, the switch **101**–*a*, the switch **102**–*c*, the switch **103**–*f* (only during the down stroke of the beam **12**), and the tap **130**–*a*. Operation of the relay switch **101**–*b* interrupts the voltage normally applied to the coil **40** from the tap **111**–*a*. Operation of the normally closed relay switch **101**–*c* prevents application of voltage to the coil **40** during the up stroke of the beam to thereby assure movement of the disk **38** in a clockwise direction only. Operaton of the normally open relay switch **101**–*b*, a sealing switch, which is in parallel with the switch K, assures continued energization of the coil **101** during the air feeding operation, i. e., during that interval when the permanent magnet **49** is being moved from the position adjacent switch K to a position adjacent switch P. Operation of the switch **101**–*e*, shown herein as a normally open switch, results in energization of the compressor coil **92** as well as the solenoid winding **94** of the feed valve **95**. Alternatively, the switch **101**–*e* may comprise a normally closed switch connected in a related control circuit

for accomplishing the same results, namely, to supply air to the air cylinder of the compensating unit during the air feeding operation. Actuation of the normally open switch **101**–*f* assures prevention of energization of the bleeding relay coil **102** thereby assuring no simultaneous bleeding and feeding operation.

While the particular embodiments of the present invention have been shown and described, it will be obvious to those skilled in the art that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

I claim:

1. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including a driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the energy required by said motor during the power and return strokes of said member are substantially equalized, electrical energy measuring means coupled to said motor for effectively measuring the electrical energy during said power stroke and for effectively measuring the electrical energy during said return stroke, and means responsive to the difference in the mentioned electrical energies for controlling the effectiveness of said counterbalancing force applying means.

2. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke, and including an electrical driving motor, means for applying a counterbalancing force to a moving part of the said apparatus for counterbalancing the reciprocating parts thereof, whereby the energy required by said motor during the power and return strokes of said member are substantially equalized, electrical energy measuring means coupled to said motor for effectively measuring the electrical energy during said power stroke and for effectively measuring the electrical energy during said return stroke, means responsive to the difference in said electrical energy during the oppositely directed strokes of said member arranged upon relative increase in energy during the power stroke to increase said counterbalancing force, and arranged upon relative decrease in energy during the power stroke to decrease said counterbalancing force.

3. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including an electrical driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, means for increasing said counterbalancing force, means for decreasing said counterbalancing force, electrical energy measuring means coupled to said motor for measuring the energy required during said power stroke and for measuring the electrical energy required during said return stroke, means responsive to the difference in said energies during the pumping and return strokes of said member arranged upon relative increase in electrical energy during the pumping stroke to operate said means for increasing said counterbalancing force, and arranged upon relative decrease in electrical energy during the pumping stroke to operate said means for decreasing said counterbalancing force.

4. In a counter-balancing system of the character described, the combintaion comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including a driving motor, a watt-hour meter, electrical circuit means connected to said motor for supplying energy thereto, means coupling said watt-hour meter to said circuit for measuring the energy required by the motor during the power stroke and for measuring the energy required by the motor during the return stroke of said member, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, and means responsive to the difference in energy measured by said watt-hour meter during said power and return strokes for controlling the effectiveness of said counterbalancing force applying means.

5. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including an electrical driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the energy required by said motor during the power and return strokes of said member are substantially equalized, a watt-hour meter having a rotatable disk, an electrical circuit coupled to said motor for supplying energy thereto, means coupling said watt-hour meter to said circuit, said last mentioned means incorporating means for rotating said disk in one direction during said power stroke and for rotating said disk in the opposite direction during said return stroke, and means responsive to differences in excursions of said disk in said one and opposite directions for controlling the effectiveness of said counterbalancing force applying means.

6. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including a driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the electrical energy required by said motor during the power and return strokes of said member are substantially equalized, an electrical circuit coupled to said motor for supplying energy thereto, a watt-hour meter coupled to said circuit and including a rotatable disk, means coupling said watt-hour meter to said circuit whereby said disk is rotated in one direction during the power stroke and said disk is rotated in the opposite direction during said return stroke, whereby said disk oscillates within a relatively small range when said power and return strokes of said member are substantially equalized, and means rendered effective when said disk oscillates beyond said range for controlling the effectiveness of said counterbalancing force applying means.

7. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including an electrical driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the electrical energy required by said motor during the power and return strokes of said member are substantially equalized, an electrical circuit coupled to said motor for supplying energy to said motor, a watt-hour meter having a disk and coupled to said circuit for measuring the energy supplied to said motor during said power and return strokes of said member, said last mentioned means incorporating means whereby said disk is rotated in one direction during said power stroke and said disk is rotated in the opposite direction during said return stroke, means rendered effective when said disk is rotated in said one direction past a predetermined point for decreasing the effectiveness of said counterbalancing force applying means, and means rendered effective when said disk rotates beyond a second predetermined point in said opposite direction for increasing the effectiveness of said counterbalancing force applying means.

8. The arrangement set forth in the next preceding claim in which said coupling means incorporates means

for preventing said disk from rotating beyond either said first predetermined point or said second predetermined point.

9. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including a driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the energy required by said motor during the power and return strokes of said member are substantially equalized, electrical circuit coupled to said motor for supplying electrical current thereto, a watt-hour meter having a current coil, a voltage coil and a rotatable disk, means coupling said current coil to said circuit, a phase shifting network coupling said voltage coil to said circuit, means controlling said network in accordance with reciprocation of said member whereby said disk is rotated in a first direction during said power stroke and said disk is rotated in the opposite direction during said return stroke with said disk thus oscillating through a limited range when the power and return strokes of said member are substantially equalized, means effective when said disk rotates in said one direction to a predetermined point outside of said range for preventing further rotation of said disk in said one direction, for altering the intensity of the voltage applied to said voltage coil, and for changing the effectiveness of said counterbalancing force applying means, and means rendered effective upon rotation of said disk in said opposite direction to a predetermined point beyond said range for preventing further rotation of said disk in said opposite direction, for altering the intensity of the voltage applied to said voltage coil, and for altering the effectiveness of said counterbalancing force applying means.

10. In a counter-balancing system of the character described, the combination comprising: apparatus for reciprocating a member through a power stroke and a return stroke and including an electrical driving motor, means for applying a counterbalancing force to a moving part of said apparatus for counterbalancing the reciprocating parts thereof, whereby the energy required by said motor during the power and return strokes of said member are substantially equalized, an electrical circuit coupled to said motor for supplying energy thereto, a watt-hour meter having a disk, means coupling said watt-hour meter to said circuit, said coupling means incorporating means whereby said disk is rotated in one direction during said power stroke and said disk is rotated in the opposite direction during said return stroke, whereby said disk oscillates through a relatively small range when said energy required by said motor during said power and return strokes of said member are substantially equalized, and means rendered effective upon movement of said disk to a point outside of said range to control the effectiveness of said counterbalancing force applying means such that movement of said disk is restored to said limited range.

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