July 15, 1958 A. G. NICKLE 2,843,327

OVERLOAD-UNDERLOAD CONTROL SYSTEM AND METHOD

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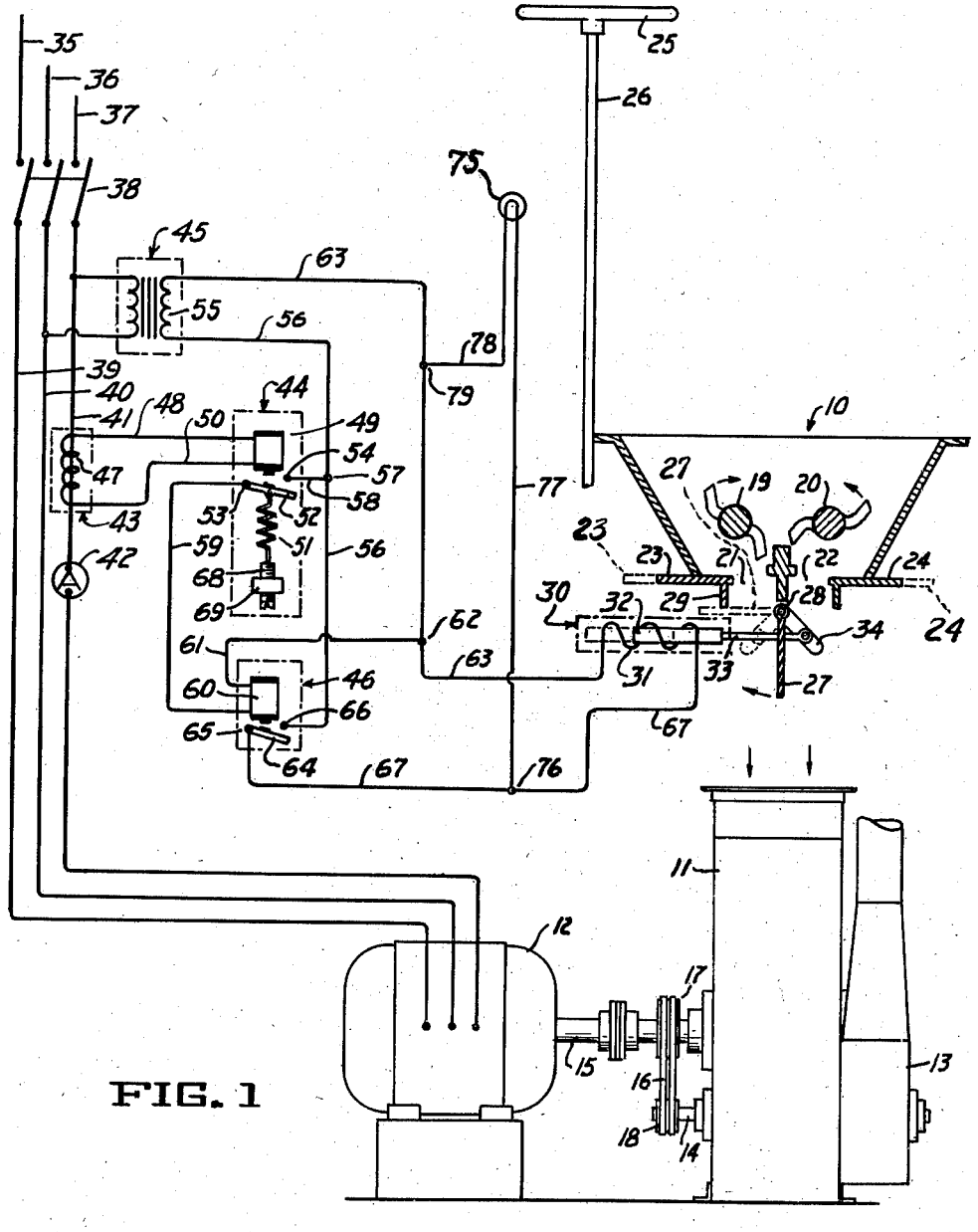



FIG. 1

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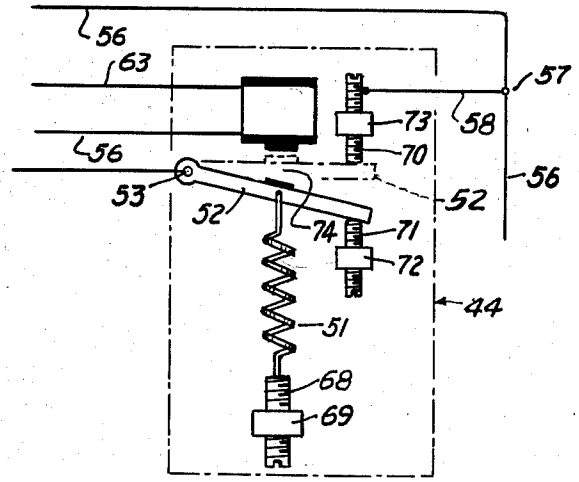



FIG. 2

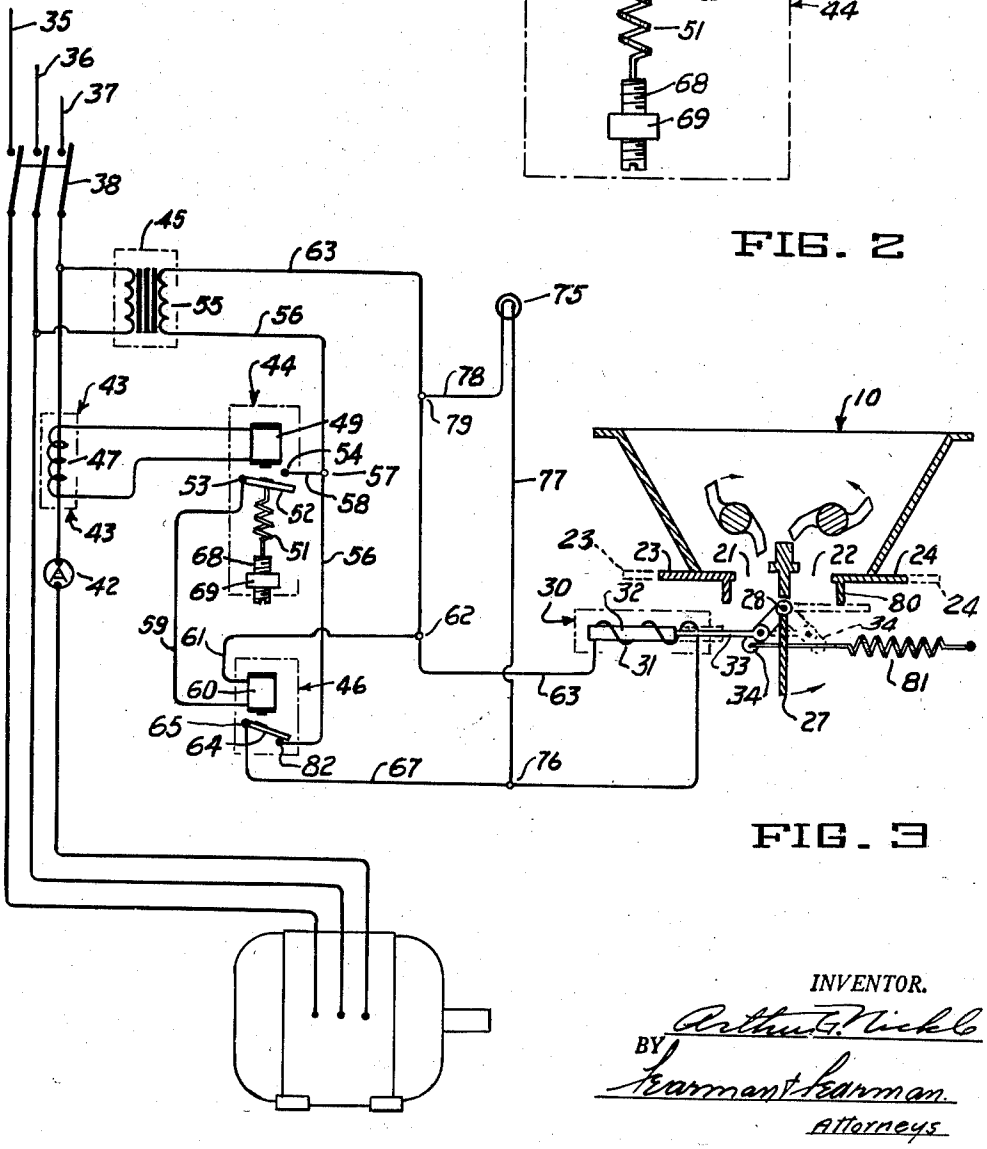



FIG. 3

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2,843,327

# OVERLOAD-UNDERLOAD CONTROL SYSTEM AND METHOD

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Application November 6, 1953, Serial No. 390,620

15 Claims. (Cl. 241—35)

My invention relates to means for automatically limiting overfeeding and underfeeding of pulverizing mills or the like, when such mills are fed material by means of a feeding machine equipped with an automatic flow-controlling mechanism.

When a motor-driven pulverizing mill, such as a hammer mill, is overfed to the extent that the speed of the hammer rotative element decelerates below normal, the mill tends to stop grinding, thereby wasting mill power. Also, such overfeeding, if not corrected, may overload the motor that drives the mill to the extent that motor will be burned out. Mill power is also wasted when the motor is underloaded as a result of under feeding. If the mill is fed materials of different grindabilities in sequence, such as shelled corn and oats, the motor will be underloaded or overloaded respectively most of the time, unless the operator makes frequent adjustments of the flow-controlling mechanism through which the material is being fed.

In conventional automatic load control systems, for feeding bulk material to grinding mills and the like, the material is fed at the most favorable rate of delivery to obtain an optimum or steady load on the mill motor. The motor loading may vary between allowable limits, but such loading does not necessarily reach the allowable limits in sequence, nor is the material fed continuously.

This invention discloses an automatic load control system wherein the load on the mill motor is always varying up and down between allowable maximum and minimum limits. The rate of the uninterrupted discharge from the feeding machine is great enough to overload the motor beyond the maximum limit. When the discharge rate is interrupted to reduce the motor load down to the minimum limit, such reduction is sufficient to cause underloading of the motor beyond the allowable minimum limit. In both cases the discharge rate from the feeding machine is constant but relatively less when the motor load is decreasing.

Also, means will be disclosed for raising and lowering the mean motor load, and for modifying the differential between maximum and minimum allowable load limits. Other means will be shown for modifying the frequency of the overload-underload cycle, and for signaling the operator so that he will be aware of the frequency of the cycle.

In the accompanying drawings:

Fig. 1 is a partly schematic view in elevation showing an overload-underload control system for a motor-driven hammer-grinding mill that is fed material from an automatic feeding machine.

Fig. 2 is a fragmentary enlargement of the wiring diagram shown in Fig. 1, with means added for modifying the differential between maximum and minimum motor load limits.

Fig. 3 is a modification of the wiring diagram and flow-controlling mechanism in Fig. 1.



This is continuation-in-part of my co-pending application Serial No. 234,792, filed July 2, 1951, which has been abandoned.

Referring to Fig. 1 of the drawings, **10** generally designates a two-roll crushing and feeding machine that is adapted to crush and feed bulk material to a conventional hammer-grinding mill **11** direct connected to motor **12**. The mill is equipped with exhaust fan **13** which withdraws reduced material from the mill grinding chamber and elevates it to a cyclone collector (not shown) where the product is separated from the air stream in usual manner. Fan shaft **14** may be driven from a separate motor, or as shown, from mill shaft **15** by means of V-belts **16** engaging driving sheave **17** on mill shaft **15** and driven sheave **18** on fan shaft **14**.

Feeding machine **10** is equipped with toothed rolls **19—20** which are driven in any manner (not shown) which will crush and agitate the material through outlets **21—22** underlying the rolls. The discharge from outlets **21—22** is interrupted by valve plates **23—24**, these plates being slidably mounted for horizontal movement simultaneously in inverse relation when manually adjusted by turning handle **25** mounted on the upper end of stem **26**, which stem projects above an operating floor (not shown) above the feeding machine. The mechanism employed to connect stem **26** with valve plates **23—24** is not shown as it forms no part of this invention.

Employed in combination with manually operated valves **23—24** in feeding machine **10**, is a normally open hinged valve plate **27** which is fixed to oscillatable shaft **28** supported by the feeding machine structure. In open position, valve plate **27** hangs vertically downward by gravity, or may be held open by other means. When swung upward in a clockwise direction, valve plate **27** assumes the horizontal position shown in broken lines, the upper face closing against bottom of vertical rib **29** carried by valve plate **23**, thereby interrupting the flow of material through discharge outlet **21** while outlet **22** remains open and continues to discharge material to the mill.

The means employed for closing hinged valve **27** is a solenoid, generally designated as **30** and including coil **31** which may be energized to move plunger core **32** and plunger stem **33** to the left, the closure being effected as a result stem **33** being pivotally connected to rocker arm **34** secured to oscillatable shaft **88** for movement therewith. The means employed for sensing over and under feeding of the mill, and likewise the corresponding loading on the mill motor, together with the electrical controls for solenoid **30**, will be presently disclosed.

With feeding machine **10** supplied with material, and manually operated valves **23—24** adjusted to afford a rate of discharge that will positively overload the motor beyond a maximum allowable limit when hinged valve **27** is open, the motor load will gradually increase. When the maximum load limit is reached, solenoid **30** is energized to closed valve **27** and interrupt the discharge through outlet **21**, this interruption being sufficient to reduce the motor load below an allowable minimum limit. However, when the minimum load is reached, then solenoid **30** is de-energized to allow valve **27** to reopen, thereby re-establishing the previous discharge rate to mill and completing the overload-underload cycle, the cycle being repetitious as long as manually operated valves **23—24** remain set to overfeed the mill and cause motor overloading beyond the allowable limit.

Mill motor **12** is energized by 3-phase current flowing from power lines **35—36—37** through 3-pole switch **38** and lead wires **39—40—41**. The load on the mill motor is shown by ammeter **42** applied to motor lead wire **41**. The means employed for sensing motor loading, and the

controls responsive thereto for enregizing and de-energizing solenoid 30, include current transformer 43, primary relay 44, potential transformer 45, and secondary relay 46, all of which are generally designated.

With current transformer 43 applied to motor lead wire 41, the current from transformer coil 47 flows through wire 48 to coil 49 of primary relay 44, the return being through wire 50 to complete the sensing circuit. As the value of the current flowing in this sensing circuit is substantially in proportion to the load on the motor, when the mill is overfed to the extent that ammeter 42 registers the maximum allowable motor load, then the induced current flow through coil 49 of relay 44 overcomes the tension of spring 51 attached to normally open magnetically operated switch blade 52, thereby causing blade 52, which is hinged on terminal 53, to swing in closed contact with terminal 54. This allows current from secondary winding 55 of potential transformer 45 to flow through lead wire 56, junction 57, wire 58, terminal 54, blade 52, terminal 53, wire 59 to coil 60 of secondary relay 46; thence through wire 61, junction 62, wire 63 to coil 55 of transformer 45, thereby completing the relay circuit. The closing of this relay circuit energizes solenoid coil 60 of secondary relay 46, thereby causing magnetically operated normally open switch arm 64, which is hinged on terminal 65, to close against terminal 66. This allows current to flow from secondary winding 55 of transformer 45 through wire 56, terminal 66, switch arm 64, terminal 65, and wire 67 to energize coil 31 of solenoid 30; thence through wire 63 back to coil 55 of transformer 45.

The energizing of solenoid 30 closes hinged valve 27 and partially interrupts the discharge of material from the feeding machine to the mill as previously explained, thereby causing the motor load to gradually decrease until the minimum allowable underload limit is reached. This reduction in motor load is reflected in the amount of induced current flowing in transformer coil 47 to primary relay coil 49. When this current becomes weakened, as a result of the reduced discharge rate to the mill, to the point where it can no longer magnetically hold switch blade 52 against terminal 54, because of the pull of spring 51, then coil 60 of secondary relay 46 is de-energized and the relay circuit is automatically opened. This, in turn, allows switch blade 64 to break contact with terminal 66 and de-energize solenoid 30, thereby permitting hinged valve 27 to reopen so as to re-establish the original rate of discharge to the mill and again cause the motor load to increase to the maximum allowable limit. This completes the motor overload-underload cycle which is repetitious as long as manually operated valves 23—24 remain open and adjusted to insure overfeeding at a constant rate while the motor load is increasing. After valve 27 is closed to partially interrupt the flow of material to the mill, the discharge rate again becomes constant during the interval while the motor load is decreasing. Consequently, there is no optimum rate of discharge to the mill, nor is there any hunting for an optimum. There is, however, a mean motor load between established limits which can be raised and lowered as will be presently explained.

The mean motor load is raised by increasing the tension of spring 51, and vice versa, thereby varying the motor load limit at which primary relay 44 will function to magnetically close switch blade 52 to which spring 51 is attached. The tension of spring 51 is modified by adjusting screw 68 relative to supporting element 69 into which the screw is threaded.

The means employed for modifying the differential between allowable maximum and minimum motor load limits, for any given mean motor load, are shown in Fig. 2, wherein the amplitude through which hinged switch blade 52 swings is limited by adjustable stops 70—71. Stop 71 is threaded into supporting element 72 so that it can be adjusted upward to limit the downward swing of normally open switch blade 52. The upward swing of blade 52, when in closed position as shown in broken lines, is limited by stop 70 which is threaded into supporting element 73 for vertical adjustment. Adjustable stop 70 replaces stationary terminal 54 in Fig. 1, and is connected in same manner to wire 58 leading to junction 57 in wire 56 from transformer 45.

With magnetically operated switch blade 52 open, the maximum allowable motor load limit can be raised by adjusting stop 71 downward to increase air gap 74 between blade 52 and the pole face of coil 49 of primary relay 44, so that a higher motor load is necessary to lift blade 52 to close against stop 70. As a result of this adjustment, the energizing of solenoid 30 and the closing of valve 27 delays the load-decreasing step of the cycle. Contrawise, the maximum allowable motor load limit can be reduced by adjusting stop 71 upward to decrease air gap 74, thereby permitting an earlier closing of valve 27. With switch blade 52 closed against movable terminal stop 70, the minimum allowable motor load limit can be raised by adjusting stop 70 downward to increase air gap 74, thereby de-energizing solenoid 30 earlier and obtaining an earlier opening of valve 27 at the beginning of the load-increasing step of the cycle. The minimum motor load limit can be lowered by adjusting terminal stop 70 upward to decrease air gap 74, so that blade 52 is held in contact with stop 70 by a weakened current, thereby causing a delay in de-energizing solenoid 30 and closing valve 27.

With other conditions remaining the same, it should be noted that increasing the differential between the maximum and minimum motor loading limits decreases the frequency of the cycle, and vice versa. Also, the frequency of the cycle can be increased by opening manually operated valves 23—24, so as to overfeed and overload the motor more quickly while valve 27 is open; or in other words, the time interval during the load-increasing step is shortened. Conversely, the cycle frequency is decreased when manually operated valves 23—24 are adjusted to reduce the rate of discharge to the mill, such reduction not being, of course, enough to eliminate motor overloading and the closing of valve 27.

To provide an electrically operated indicator, such as signal lamp 75, Fig. 1, stationed remotely from the mill, which will inform the operator as to the frequency of the overload-underload cycle, lamp 75 is energized by current flowing from junction 76 in wire 67 through lead wire 77 to the lamp; thence through wire 78 to junction 79 in wire 63, thereby completing the circuit which is energized simultaneously with coil 31 in solenoid 30 which operates valve 27. When lamp 75 fails to be lighted from time to time, this indicates that the mill is being underfed, which condition the operator should correct by opening valves 23—24 to insure a rate of discharge that will cause motor overloading when valve 27 is open. On the other hand, if lamp 75 is lighted continuously, this tells the operator that the mill is being overfed to the extent that solenoidally operated valve 27 cannot cope with the situation. To correct this difficulty, the operator partially closes valves 23—24 to obtain a discharge rate that will intermitently energize the lamp.

Fig. 3 shows a modification of the apparatus employed in Fig. 1 to obtain the repetitious cycle. In this case, hinged valve 27 is swung in a counter-clockwise direction, so that in closed position, as shown by broken lines, the upper face bears against the bottom edge of vertical rib 80 carried by valve plate 24, thereby interrupting the discharge of material through outlet 22 during the load-reducing step of the cycle. Valve plates 23—24 are mounted for simultaneous movement in inverse relation, same as in Fig. 1, handle 25 and stem 26 not being shown. Also, as previously mentioned, valves 23—24 are manually adjusted to insure mill overfeeding when valve 27 is open. When the motor load increases to the predeter-

mined allowable limit, valve **27** is closed by the pull of spring **81** attached to the lower end of rocker arm **34** mounted on pivot shaft **28**, the closing being effected while solenoid **30** is de-energized.

The electrical apparatus employed for sensing the motor load is same as in Fig. 1 with one exception, this being terminal **66** replaced by terminal **82** in secondary relay **46**, terminal **82** being positioned below switch arm **64** which is normally closed instead of being open as in Fig. 1. With wire **56** attached to terminal **82**, the closing of switch arm **64** against terminal **82** allows current from secondary winding **55** of transformer **45** to flow through wire **56**, terminal **65**, wire **67** to coil **31** of solenoid **30**; thence through wire **63** back to winding **55**, thereby energizing solenoid **30** to hold valve **27** open against the pull of spring **81** until load on motor exceeds the predetermined allowable maximum limit. Then solenoid **30** is de-energized and valve **27** is closed by spring **81** and remains closed until the motor load is reduced to the minimum allowable limit, valve **27** then reopening to complete the cycle which will be repeated over and over as long as manually operated valves **23—24** remain adjusted to overfeed the mill.

With further reference to Fig. 3, signal lamp **75** serves the same purpose as lamp **75** in Fig. 1, and is likewise simultaneously energized with solenoid **30**. However, in Fig. 3, the lamp is energized when valve **27** is open, instead of when closed as in Fig. 1.

A modification (not shown) which will simplify the valve mechanism used in Figs. 1 and 3, can be made by eliminating hinged valve **27** and using valve **24** as automatically operated oscillatable means for limiting over and under loading of the motor. To do this, stem **26** (Fig. 1) is disconnected from valve **24** and spring **81** (Fig. 3) is connected thereto, and likewise solenoid **30** is connected to valve **24**. In operation, manual valve **23** is set to overload the mill beyond the allowable maximum limit when valve **24** is fully open, valve **24** then being automatically closed to interrupt the discharge from outlet **22** to afford motor underloading below the minimum allowable limit. When motor load is reduced to the minimum limit, valve **24** reopens to complete the cycle, as previously explained.

What I claim is:

1. In an overload-underload control system that operates on a repetitious cycle for limiting overfeeding and underfeeding of material to a motor driven mill or the like and the motor load being varied to and from between allowable limits, a housing containing a supply of material to be fed to the mill, a discharge outlet in the housing, flow-interrupting means for the outlet, said means comprising in combination a manually operated valve and an automatically operated oscillatable valve, means for adjusting the manual valve to afford a rate of discharge that will overload the motor beyond a maximum allowable limit when the oscillatable valve is open, means for closing the oscillatable valve when motor load increases to the maximum limit, said closing means being a spring adapted to hold the oscillatable valve closed until motor load decreases to the minimum limit, solenoidally operated means for reopening the closed valve when motor load decreases to the minimum limit, said solenoidally operated means being adapted to hold said valve open to re-establish the overloading discharge rate and complete the cycle, a source of electrical energy, a circuit for the solenoid, electrical controls for opening and closing the circuit, electrical means for sensing the motor load, and means responsive to and load-sensing means for operating the controls.

2. In an overload-underload control system that operates on a repetitious cycle for limiting overfeeding and underfeeding of material to a motor driven mill or the like and varying the motor load to and from between allowable limits, a housing containing a supply of material to be fed to the mill, a discharge outlet in the housing, flow-interrupting means for the outlet, said means comprising in combination a manually operated valve and an oscillatable valve, means for adjusting the manual valve to afford a rate of discharge that will overload the motor beyond an allowable limit while the oscillatable valve is open, means including a solenoid for operating the oscillatable valve, said operating means being adapted to close the oscillatable valve when the motor load increases to the allowable limit and to reopen said oscillatable valve when load is reduced to allowable limit, a source of electrical energy, a circuit for the solenoid, electrical controls for the circuit, electrical means for sensing the load on the motor, and means responsive to the load-sensing means for operating the controls.

3. In a cyclic overload-underload control system for feeding a continuous stream of material to a motor driven mill or the like, and repetitiously increasing and decreasing the load on the motor between allowable limits, a housing containing material to be fed, a discharge outlet in the housing, a flow-controlling mechanism for the outlet comprising in combination, a manually operated valve and an automatically operated valve, said manual valve being adjusted for a constant delivery rate that will overload the motor in excess of allowable limit when the automatic valve is open, said automatic valve being adapted to close when motor load increases to the allowable limit, and subsequently reopening when the load decreases to allowable limit, means including a solenoid for operating the automatic valve, a source of electrical energy, a circuit for the solenoid, electrical controls for the circuit, electrical means for sensing motor loading, and means responsive to the load-sensing means for repetitiously operating the controls to effect a mean load on the motor that is constant.

4. In the control system defined in claim 3, in which the electrical load-sensing means includes means for varying frequency of cycle, said varying means being a relay that is adjustable for modifying differential between allowable load limits.

5. A control system as defined in claim 3, in which the cycle frequency is in proportion to the overloading discharge rate from the manual valve.

6. A control system as defined in claim 3, in which is included electrically operated means for indicating frequency of the cycle, a circuit for the indicative means, and means for opening and closing the indicant circuit simultaneously with the solenoid circuit.

7. The control system defined in claim 3, further including indicant means for indicating when the automatic valve is functioning, said means being electrically operated, a circuit for the indicant means, and means for opening and closing said circuit simultaneously with the solenoid circuit.

8. The control system as defined in claim 3, further including means for raising and lowering the mean load on the motor, said means being an adjustable relay in the load-sensing means.

9. In a cyclic overload-underload control system for feeding a continuous stream of material to a motor driven mill or the like and repetitiously increasing and decreasing the load on the motor between allowable limits, a housing containing material to be fed, an outlet in the housing, said outlet being large enough to discharge material at a rate that will overload the motor in excess of allowable limit, an automatically operated valve for the outlet operable to reduce the discharge of material from said housing when motor load increases to the allowable limit and to reestablish the overloading rate of feed when motor load decreases, means including a solenoid for operating said valve, a source of electrical energy, a circuit for the solenoid, electrical controls for the circuit, electrical means for sensing motor loading, and means responsive to the load-sensing means for repetitiously operating the controls to effect a mean load on the motor that is constant.

10. The control system defined in claim 9, further including indicant means for indicating when the automatic valve is functioning, said means being electrically operated, a circuit for the indicant means, and means for opening and closing said circuit simultaneously with the solenoid circuit.

11. The control system as defined in calim 9, further including means for raising and lowering the mean load on the motor, said means being an adjustable relay in the load-sensing means.

12. A method of feeding a stream of material continuously to a motor driven mill or the like wherein the delivery rate is in response to loading of the motor, comprising the steps of feeding the material at a constant rate of delivery that will cause overloading of the motor in excess of an allowable limit, partially interrupting the delivery rate when motor load increases to the allowable limit, said interruption being sufficient to cause motor loading to decrease to an allowable limit, holding the interrupted feeding rate constant until motor load is reduced to the allowable limit, and then re-establishing the excess delivery rate to complete a cycle that is automatically repetitious, thereby effecting a mean load on the motor that is constant.

13. In an overload-underload control system that operates on a repetitious cycle for limiting overfeeding and underfeeding of material to a motor driven mill or the like, a housing containing material to be fed, a discharge outlet in the housing, a flow interrupting mechanism for the outlet, said mechanism comprising in combination a manually operated valve and an oscillatable valve, means for adjusting the manual vaive to afford a constant discharge rate that will overload the motor beyond an allowable limit when the oscillatable valve is open, means for closing said oscillatable valve when the discharge rate increases motor load to the allowable limit, means for reopening said oscillatable valve when the reduced discharge rate has decreased motor load to allowable limit, said oscillatable valve operating means including a solenoid, a circuit for the solenoid, a source of electrical energy, electrical controls for the circuit, electrical means for sensing load on the motor, and means responsibe to the load sensing means for operating the controls.

14. In a cyclic overload-underload system for feeding a continuous stream of material to a motor driven mill or the like and repetitiously increasing and decreasing motor loading between allowable limits to effect a mean load on the motor that is constant, a housing containing material to be fed, a discharge outlet in the housing, a flow-controlling mechanism for the outlet comprising in combination a manually operated valve and an automatically operated valve, said manual valve being adjusted for a constant delivery rate that will overload the motor in excess of allowable limit when the automatic valve is open, said automatic valve being operable to partially interrupt the discharge from the manual valve when the motor load increases to the allowable limit, and subsequently reopen when the motor load decreases to allowable limit, means including a solenoid for operating the automatic valve, a source of electrical energy, a circuit for the solenoid, electrical controls for the circuit, electrical means for sensing motor loading, means responsive to the load-sensing means for repetitiously operating the controls, and means for varying frequency of the cycle.

15. In a cyclic overload-underload control system for feeding material to a motor driven mill or the like and repetitiously increasing and decreasing motor loading to and from allowable limits to effect a mean load on the motor that is constant, a housing containing material to be fed, a discharge outlet in the housing, a flow controlling mechanism for the outlet comprising in combination a manually operated valve and an electrically operated valve, said manual valve being adjusted for a constant delivery rate that will overload the motor in excess of allowable limit when the electrically operated valve is open, said electrically operated valve closing when motor load increases to allowable limit and reopening when the motor load decreases to allowable limit, a source of electrical energy, a circuit for the electrically operated valve, electrical controls for the circuit, electrical means for sensing motor loading, means responsive to the load-sensing means for repetitiously operating the controls, and means for varying frequency of the cycle.

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