Aug. 4, 1942. M. FRISCH 2,291,618

PULVERIZING APPARATUS

Original Filed April 25, 1932 2 Sheets-Sheet 1

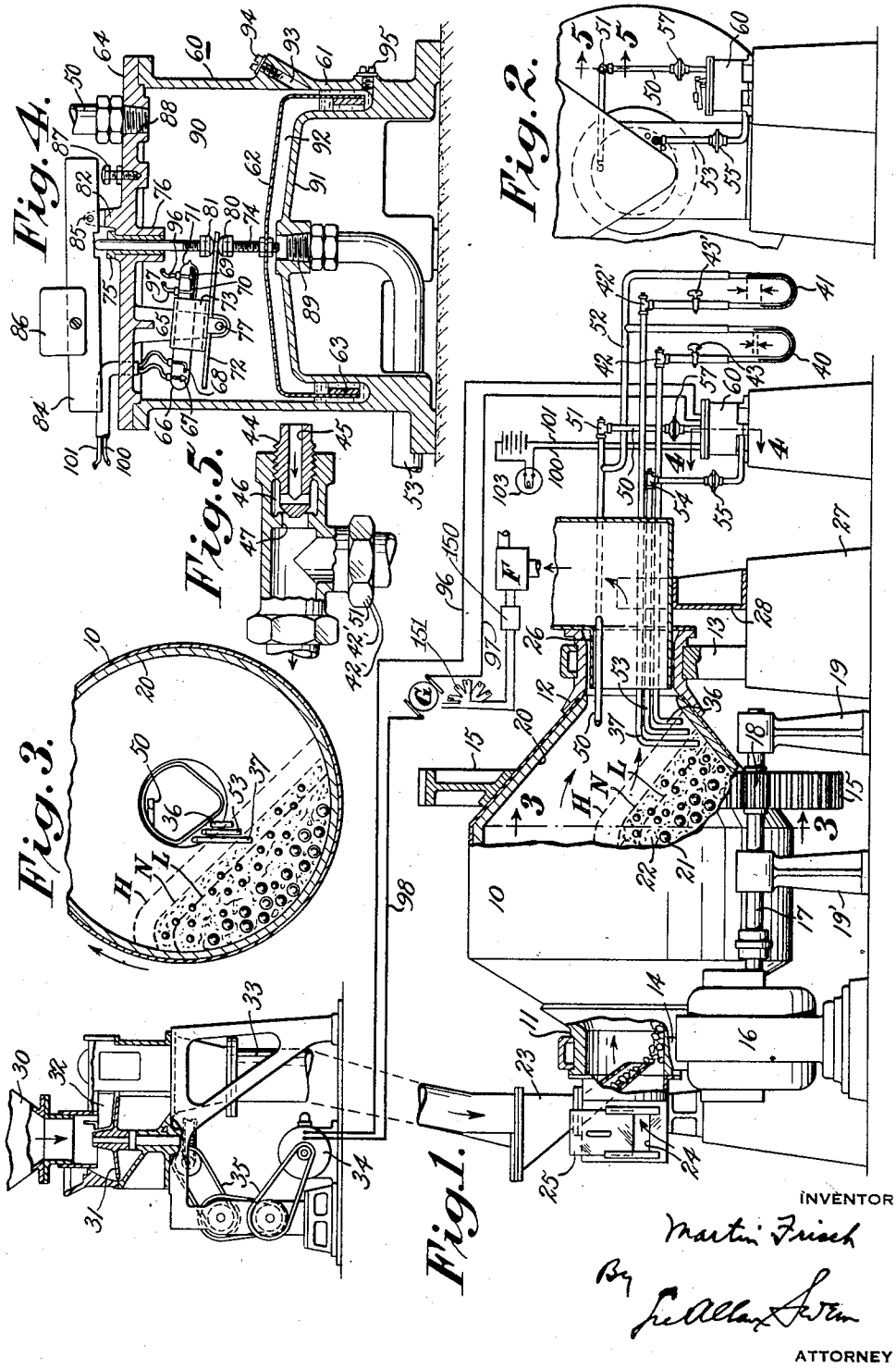


Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

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Fig. 6.

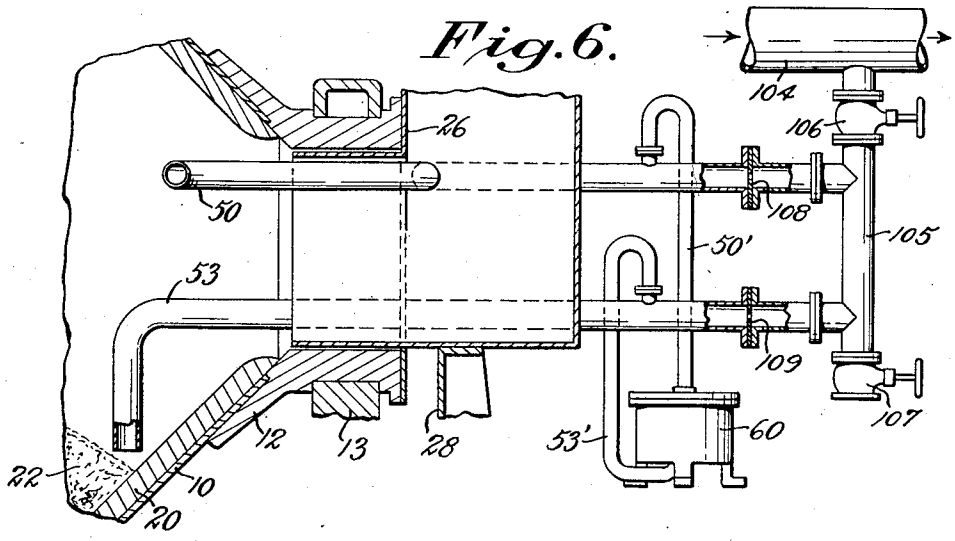


Fig. 8.

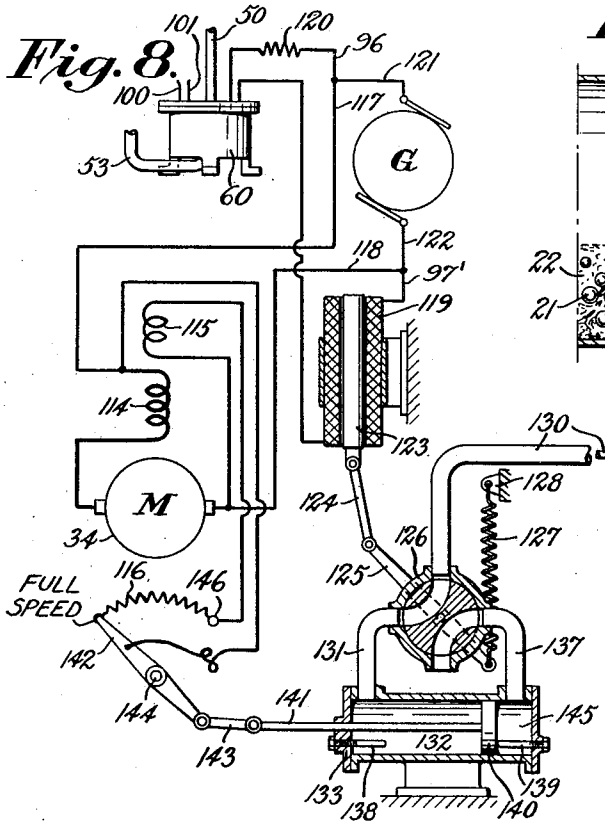
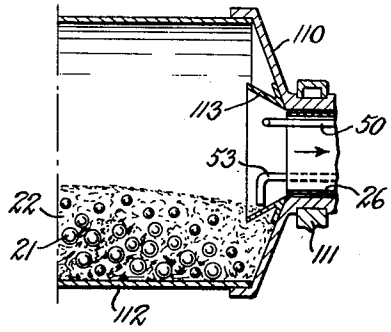


Fig. 7.



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UNITED STATES PATENT OFFICE

2,291,618

PULVERIZING APPARATUS

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Continuation of application Serial No. 607,282, April 25, 1932. This application February 8, 1939, Serial No. 255,226

33 Claims. (Cl. 83—9)

This invention relates to fuel pulverizers such as ball mill pulverizers, and more particularly relates to air-swept ball mills for pulverizing coal and to apparatus for, and methods of, indicating and controlling the charge therein, and controlling the output thereof.

This application is a continuation of application Serial No. 607,282, filed April 25, 1932.

In order to control the output and fineness of the product of ball mill pulverizers, it is necessary to maintain the quantity or volume of the charge in the mill, that is to say, the amount of mixture of the product and the grinding balls, not including the powdered material suspended in the air current, substantially constant irrespective of the rate of grinding of the product. If the volume of the charge is permitted to increase materially above normal, the charge may spill over into one or more of the trunnions, particularly the discharge trunnion, and may restrict the opening through which the air enters the pulverizer and the connection through which the product leaves the mill, thereby reducing the output of the pulverizer. If the quantity of charge is permitted to fall materially below normal, there will be a deficiency of product and an excessive rate of wear of the grinding balls and the liners of the mill. It has heretofore been the practice to judge the correctness of the quantity of charge in ball mill pulverizers by the sound produced by the mill and to control the rate at which the product was fed to the mill by hand in accordance with the sound. This has required the constant attention of experienced operators.

In accordance with the present invention, provision is made for positively indicating the quantity of the charge in ball mill pulverizers and for automatically controlling the same irrespective of pressure variations within the mill.

To control the output of pulverizers, it has been the practice heretofore to vary the feeding to the mill of the material to be pulverized proportionally to the output desired without changing the air flow through the mill excepting to provide more or less air at the burners or at other points of use. When the capacity of the mill is varied by varying the feed, the quantity of material in the mill undergoing pulverization may change by several hundred percent if the rate of feed and the output are not synchronized exactly. If the output is substantially greater than the rate of feed for any length of time, the quantity of material in the mill may be completely depleted, whereas if the output is less than the rate of feed at any given time, the amount of material in the mill may be increased until the mill plugs up. Exact synchronization of the feed and the output has seldom been anything but accidental because the mill operator had other duties and could not spend all his time listening to the mill.

In accordance with the present invention, the capacity or output of pulverizing mills is controlled by automatically maintaining a constant or substantially constant supply of material in the mill and varying the flow of air through the mill to vary the output thereof. By maintaining a constant quantity of material in the mill, a constant state of agitation is maintained, in consequence of which a substantially constant concentration of pulverized material in suspension per unit quantity of air is maintained. Hence by varying the air flow through the mill in accordance with the present invention, the quantity of pulverized material taken out of the mill may be readily varied without lag. Actual measurements have shown that, irrespective of the output of the mill, the quantity of pulverized material taken out per pound of air is substantially the same over the operating range in ball mill pulverizers of the character disclosed, or otherwise expressed, the quantity of material removed from the mill is substantially proportional to the flow of air through the mill over the operating range. This result cannot be obtained with prior practice wherein the mill output is controlled by varying the feed and the air flow through the mill is maintained substantially constant or is varied only to suit the requirements of the burner, because the amount of pulverized material in suspension at any given time per unit quantity of air varies with the amount of material in the mill, and even though the air flow through the mill is maintained substantially the same, different quantities of material will be taken out of the mill in a given time, depending upon the amount of material in the mill at that time.

The nature and advantages of the invention will be apparent from the following description taken in conjunction with the accompanying drawings forming a part of this specification, and in which:

Fig. 1 is a view in elevation, with parts in section, of a ball mill pulverizer together with indicating and charge controlling apparatus embodying the invention;

Fig. 2 is an end elevation of part of the structure shown in Fig. 1;

Fig. 3 is a transverse sectional view taken on line 3—3 of Fig. 1;

Fig. 4 is an enlarged transverse sectional view taken on line 4—4 of the controller shown in Fig. 1;

Fig. 5 is a cross-sectional view taken on line 5—5 of Fig. 2 showing in detail the fitting and atmospheric air inlet plug located in the pipe connections to the controller;

Fig. 6 is a fragmentary sectional view of another form of the apparatus shown in Fig. 1;

Fig. 7 is a transverse sectional view showing the charge controlling apparatus applied to a ball mill having a cylindrical drum, and

Fig. 8 is a view showing the application of the feed controller to an air pressure control system.

Referring to Figs. 1, 2 and 3, reference character 10 designates the steel shell of the drum of a conical type ball mill for pulverizing coal or other material, but as will appear hereinafter, the novel charge controlling apparatus may be used with various types of ball or tube mills. The drum or shell is provided with trunnions 11 and 12 which are rotatably mounted in bearing supports 13 and 14. A ring gear 15 is suitably fastened to the conical portion of the drum and is driven by motor 16 through a shaft 17 and a pinion 18. Shaft 17 is journalled in bearing brackets 19 and 19'. The interior of the steel shell is lined with a plurality of liners 20 made of steel or other suitable wear resisting material. The drum contains grinding balls 21 and coal 22. Coal to be pulverized is fed to the mill through trunnion 11 from a chute 23. Air for sweeping the mill is introduced through an opening 24 located in the side of the chute. The size of the opening is varied by adjusting the slide 25. A discharge conduit 26 extends into the trunnion 12 and is supported on the foundation 27 by a support 28. An exhauster fan F is connected to the discharge conduit and maintains a suction within the mill, the degree of suction depending upon the position of damper 25 and the size of opening 24, and the speed of fan F. Fan F is driven by a variable speed electric motor 150, the operating speed of which may be varied by a rheostat 151 in the motor circuit.

A disc-type coal feeder has been shown, but it will be understood that any suitable feeder, such as one of the screw or plunger types, may be used if desired. The hopper 30 is supplied with coal from a bunker in the usual manner. This coal falls onto a rotating feed table or disc 31 and is swept therefrom by a shear plate 32 into the conduit 33. The feed table is driven by an electric motor 34 through suitable reduction gearing 35. From conduit 33 the coal enters charging trunnion 11 by means of the chute 23.

Two relatively small metal indicator tubes 36 and 37 are situated adjacent the discharge conduit and enter the mill through the discharge trunnion. These tubes are rigidly fastened in place and have their inner ends bent downwardly. The extreme inner ends of the indicator tubes are each given a different position with respect to the quantity of charge in the mill. The outer ends of the indicator tubes are suitably connected to U tubes 40 and 41. Positioned in indicator tube 36 is a fitting 42 and a pet-cock 43. Similarly in indicator tube 37 is a fitting 42' and a pet-cock 43'. As shown in Fig. 5, the fitting is provided with a threaded plug 44 which has a passage 45 through which air from the atmosphere is drawn. The passage terminates in a chamber 46 from which the air is admitted to the indicator tubes through port 47, the rate of flow through the port 47 being determined by the position of the threaded plug.

Another small metal tube 50, which may be termed a reference tube, is arranged parallel to the indicator tubes and has an open inner end within the mill permanently out of contact with the charge in the mill. The reference tube is provided with a fitting 51 similar in all respects to fitting 42. The U tubes are connected in parallel to the reference tube by a suitable tube connection 52.

The operation of the means for indicating the quantity of charge in the mill is as follows: As shown in Fig. 3, variations in quantity of charge in the mill have been indicated by the surface lines H, N and L. The arrow indicates the direction of rotation of the drum. Assume that the quantity of charge in the mill is that represented by line N, which may be considered as a normal charge. Under this condition the inner ends of tubes 36 and 50 are uncovered while the charge has covered the inner end of tube 37. Due to the suction or low pressure in the mill resulting from operation of the fan F, air is drawn into the mill through the conduits 36, 37 and 50. The closing of conduit 37 by the charge makes the drawing of air through the same difficult and the pull of air through this conduit may be even substantially prevented. With substantially the same opening in fittings 42 and 51 or by suitable adjustment thereof, the suction applied to the pipes 36 and 50 will be substantially the same, wherefore there will be no substantial difference of level of liquid in the U tube 40. On the other hand, there is an appreciable suction on the right-hand leg of U tube 41 compared with the left-hand leg which is in communication with pipe 37. Consequently, the liquid will rise in the right-hand leg of U tube 41 to a substantial height with reference to liquid in the left-hand leg. Thus, a comparison of the difference of height in the U tubes 40 and 41 will indicate the quantity of charge in the mill.

Referring now to the charge regulating apparatus, a control tube 53 is provided adjacent tubes 36 and 37 and is open inside the mill at surface N and has positioned therein a fitting 54 like fitting 42 and a filter 55. Likewise, a fitting 51 and a filter 57 are located in the reference tube 50. The control and reference tubes are connected to a feed controller 60.

Referring now to Fig. 4 where the pulverizer feed controller is shown in detail, 61 designates the casing of the controller in which is located a bell float 62, the lower edge of which is submerged in a liquid such as water or mercury. The edge of the bell float may be provided inside with a band 63 of cork or other material for floating the bell. The casing 61 is provided with a cover-plate 64. A bracket 65, preferably formed integral with the cover-plate, supports a mercury switch 66. This switch comprises switch points 67, 68, 69 and 70 which are sealed in a glass tube 71 containing inert gases and a quantity of mercury. The glass tube is secured to a lever 72 by a strap 73. The lever is pivotally fastened at 77 to the bracket. The end of the lever is provided with a slot. A rod 74 is attached at its lower end to the bell float and slides through guide 75 arranged in the boss 76 located centrally of the cover-plate. The rod is threaded and carries two adjusting nuts 80 and 81. These nuts are provided with spherical faces. The upper end of the rod is pressed downwardly by the weighted lever 84 which is pivotally fastened by pin 85 to a

cored lug 82 on the cover-plate. The weight 86 may be moved along the lever to any position for adjustment purposes. The upward movement of the bell float is limited by the adjustable stop 87. The slotted portion of lever 72 fits between the nuts having spherical faces. In the cover-plate is a threaded bore 88 for connecting the reference tube with chamber 90. Similarly, in the depressed bottom portion 91 of casing 61 is another threaded bore 89 for connecting the control tube 53 to chamber 92. Liquid is supplied for sealing chamber 90 from chamber 92 by means of an opening 93 covered by a cap-screw 94. The liquid may be drained from the casing by removing cap-screw 95.

Switch points 69 and 70 of the mercury switch 66 are adapted to be electrically connected by a movable mass of mercury therein in a known manner. Switch point 69 is connected by a wire 96 to one terminal of the electric motor 34 and switch point 70 is connected by wire 97 to a source of electric current such as a generator G. A wire 98 connects the generator G with the other terminal of motor 34. Switch points 67 and 68 are connected to wires 100 and 101, respectively. When the movable mass of mercury in switch 66 electrically connects points 67 and 68, current flows through a signal lamp 103.

The operation of the mill and pulverizer feed controller is as follows:

The electric motor 34, when in operation, drives the feeding mechanism at such a rate that more coal is supplied to the mill than needed. The supply will usually be in excess of load requirements and will at least correspond to the maximum capacity of the mill. As the quantity of charge increases, the inner end of control tube 53 becomes more and more obstructed. The reference tube 50 is permanently beyond contact with the charge. The control tube is thus rendered less effective to conduct air from the atmosphere through the port 47 to the mill. A pressure approaching atmospheric pressure is thereby built up in the control tube and transmitted to the chamber 92 of the controller. Since the chamber 90, by means of the reference tube, is put under a pressure directly related to the suction pressure in the mill, a differential pressure will result which causes the bell float to rise.

The glass tube 71 of the mercury switch is tilted by movement transmitted thereto through lever 72 and rod 74 from the bell float. The mass of mercury is thereby caused to move away from switch points 69 and 70 thus breaking the motor circuit and stopping the feeding mechanism. When this occurs, the signal lamp circuit is closed by the mass of mercury which now connects switch points 67 and 68. Current then flows through the signal lamp and lights the same indicating that the motor circuit is broken and the feeding mechanism is out of operation.

When the quantity of charge in the mill is reduced and the inner end of the control tube 53 is uncovered, the procedure just described is reversed and the feeding mechanism put into operation again.

With the charge of material in the mill maintained substantially constant as heretofore described, the capacity or output of the mill is varied by varying the flow of air through the mill. This is accomplished as previously mentioned, by varying the size of opening 24 by adjustment of slide 25 or by changing the speed of fan F, or both. If both control means are utilized, the flow of air through the mill is varied by varying the speed of the fan F, and a constant suction is maintained in the mill irrespective of the air flow by varying the position of damper 25 to vary the size of opening 24.

In Fig. 6, air under pressure from any suitable source, such as a compressed air line or forced draft duct, is carried through conduit 104. A pipe 105 is connected to conduit 104. Valves 106 and 107 are located in pipe 105. The feed controller 60 is connected to reference tube 50 by a tube 50' and to control tube 53 by a tube 53'. Orifice plates 108 and 109 in tubes 50 and 53 respectively, are used for the same purpose as fitting 42 shown in Fig. 5. By closing valve 106 and opening valve 107, air under atmospheric pressure is admitted through the orifice plates and the operation of the mill and charge controlling equipment associated therewith is the same as that set out for the apparatus shown in Fig. 1. When valve 107 is closed and valve 106 open, air under a pressure higher than atmospheric is admitted through the orifice plates. A positive flow of air is thus introduced through the tubes 50 and 53. This prevents the tubes from being clogged with coal dust while at the same time permitting the quantity of charge within the mill to determine the operation of the feed controller 60 even if the suction in the mill should decrease to such a low value as to be insufficient to actuate the feed controller 60. In such an eventuality the motive force for operating the controller would be the excess in pressure in tube 53 over that existing in tube 50. Consequently, if the air pressure in pipe 105 is in excess of the pressure within the mill, the feed controller will operate as described, even if a positive pressure is maintained within the mill.

In Fig. 7, an air swept mill of the cylindrical type is shown. The trunnion 110 is supported by bearing member 111. The cylindrical drum portion 112 is fastened to the trunnion and is filled with a charge of grinding balls 21 and coal 22. A cone 113 is arranged axially of the trunnion and is fastened thereto by any suitable means and projects inwardly of the drum intermediate the discharge conduit 26 and the cylindrical wall of the drum. During operation, the material in the drum comes in contact with cone 113 which prevents the material from entering the discharge conduit 26. Coal particles obstruct the inner end of tube 53 when the quantity of charge is too great in the same manner as shown in connection with Fig. 1. The operation of the feed controller and cylindrical type ball mill is as described for the form shown in Fig. 1. It will be understood that the tubes 50 and 53 may be connected either to the regulating means or the indicating means, or both.

Fig. 8 diagrammatically indicates the application of the feed controller 60 to an air pressure control system for the motor 34 driving the feeding mechanism. The motor 34 is shown as of the compound-wound type having series field 114 and shunt field 115. A rheostat 116 is located in the shunt field circuit. A source of electricity generally indicated by generator G supplies current to the motor circuit 117—118. A solenoid 119 is connected in a solenoid circuit which is arranged in parallel with the motor circuit and is indicated by wires 96 and 97. As shown in Fig. 4, wires 96 and 97 are connected to switch points 69 and 70, respectively. A resistance 120 is located in the solenoid circuit. When switch points 69 and 70 are connected by the mass of

mercury in glass tube 71 of the mercury switch, current from generator G flows through lead 121 to wires 96 and 117. After flowing through the solenoid 119 and the motor 34, the current from wires 97' and 118 enters the lead 122 and thus the circuits are completed.

The core 123 of the solenoid 119 is connected by link 124 to a lever 125 for turning valve 126. A spring 127 is hooked in lever 125 and fastened at 128. When the solenoid is energized, as shown in Fig. 8, valve 126 is in a position for distributing air under pressure from tank 129 through conduit connections 130 and 131 to chamber 132 of servo-motor 133. Motor compressor 134 compresses air into tank 129 through a conduit 135. Air is exhausted from the servo-motor through a conduit connection 137 to valve 126. Stops 138 and 139 prevent over travel of piston 140. The piston rod 141 is connected to rheostat arm 142 by a link 143. The rheostat arm swings about a pivot 144. The motor 34 is operating at full speed with the parts in the position shown. If the quantity of charge in the mill becomes too great, the bell float rises, as described in connection with Fig. 1, and the connection between switch points 69 and 70 is broken. The solenoid is thus de-energized and spring 127 shifts the valve 126 counter-clockwise 90 degrees. In this position of the valve, air under pressure is admitted through conduit connections 130 and 137 to chamber 145 and exhausted from chamber 132 through conduit connection 131. The piston then travels to the left as viewed in the drawings. This causes the rheostat arm to be moved to contact point 146 with the result that the speed of the motor 34 is reduced to approximately half. With the motor 34 driving the feeding mechanism at reduced speed, a considerable reduction is realized in the quantity of coal fed to the mill.

It will be seen that with all of the arrangements disclosed, the charge level or the quantity of the charge in the mill is controlled and indicated in response to the differential of the pressure existing in a so-called control tube or fluid conducting member through which air, in the forms disclosed, flows into the mill and which has an opening disposed in the mill so that it will be covered and uncovered by the material being pulverized, and the pressure existing in a so-called reference tube or fluid conducting member through which air flows into the mill and which has an opening disposed in the mill above the maximum desired level of the charge so that it will not be covered by the material being pulverized. Variations in the charge level cause variations in the extent to which the material closes and opens the mill end of the control tube and hence causes changes in pressure in the control tube. Since the mill end of the reference tube is always fully open and the pressure responsive devices which control the feeding means and the indicating means respond to the difference in pressures in the control and reference tubes, the control and indication of the charge level in the mill is effected regardless of any pressure variations in the mill itself. The material being pulverized in effect operates as a valve which opens and closes the mill ends of the control tubes and thereby causes the operation of the pressure responsive devices which control the feeding means and indicate the quantity of charge in the mill.

By varying the air flow through the mill while maintaining the quantity of material in the mill substantially constant, a substantially constant state of agitation is maintained and a substantially constant concentration of pulverizer material in suspension per unit quantity of air is maintained. Operation of the mill in this manner provides a ready control without a lag of the output or capacity over theh operating range while maintaining a substantially constant ratio of pulverized fuel to air leaving the mill at all times and irrespective of the output of the mill.

While the invention has been shown and described in connection with the regulation of the motor driving the feeding mechanism, it will be understood that it is not necessarily limited thereto. In certain instances, it may be desirable to keep the motor running at constant speed and to adjust the position of the shear plate on the disc type feeder shown. This may be done easily by connecting the servo-motor 133 shown in Fig. 8 to the shear plate.

Since many variations may be made in the forms of the invention herein disclosed, it will be understood that the invention is not to be limited excepting by the scope of the appended claims.

What is claimed is:

1. Pulverizing apparatus comprising a rotatable drum, feeding means for supplying material to be pulverized to the drum, a motor for driving the feeding means, means for controlling operation of the motor comprising a movable member, means providing separate chambers on opposite sides of said movable member, a tube connecting one of said chambers with the interior of the drum at a point at times within the body of material in the drum, a second tube connecting the other of said chambers with the interior of the drum at a point permanently outside the body of material in the drum, a switch actuated by said movable member, a solenoid actuated by said switch, and a pressure fluid servo-motor actuated by said solenoid.

2. A pulverizer comprising a closed revoluble drum, means for feeding material to the drum at a greater rate than it can be pulverized, a motor for driving said feeding means, a first tube and a second tube having openings in said drum, said tubes being adapted to conduct a limited amount of air from the atmosphere to the drum, means determined by the quantity of charge in said drum for rendering said second tube less effective to conduct air to the drum, a switch for starting and stopping said motor, said switch being adapted in its off-position to close a circuit for lighting a signal lamp, and a differential pressure responsive member connected to said tubes, said pressure responsive member being adapted to open said switch when the quantity of charge is greater than a predetermined maximum and to close said switch when the quantity of charge falls below a predetermined minimum.

3. In combination with pulverizing apparatus including an air-swept revoluble drum adapted to contain a body of material, indicating means including a plurality of pressure differential members, a first tube connected to all of said members and subject to variations in pressure of air sweeping the drum, a second tube connected to one of said members and having an opening adapted to be covered by the material in the drum, and a third tube connected to another of said members and having an opening adapted to be covered by the material in the drum, said second and third tubes being arranged to have their

openings closed by different quantities in the drum.

4. In combination with pulverizing apparatus including an air-swept revolvable drum supported on trunnions and adapted to contain a body of material, a short inwardly projecting conical extension on one of said trunnions adapted to receive overflow material from the drum, indicating means comprising a pressure differential member, a first conduit connected to said differential member and with an opening sometimes within the body of the overflow material from the drum within the conical trunnion extension, and a second conduit connecting said differential member with a point in said trunnion extension permanently outside the body of overflow material therein.

5. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, means for controlling the supply means to control the level of the material in the drum comprising a pressure responsive member connected to the supply means, a tube connecting said member with the drum below the maximum desired level of the material in the drum, and another tube connecting said member with the drum at a point above the maximum level of the material in the drum.

6. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, means for controlling the supply means to control the level of the material in the drum comprising a pressure responsive member connected to the supply means, a tube connecting said member with the drum at substantially the normal level of the material in the drum, and another tube connecting said member with the drum at a point above the maximum level of the material in the drum, said tubes having communication with the atmosphere so as to conduct air from the atmosphere into the drum.

7. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, means for controlling the supply means to control the level of the material in the drum comprising a pressure responsive member connected to the supply means, a tube connecting said member with the drum at substantially the normal level of the material in the drum, and another tube connecting said member with the drum at a point above the maximum level of the material in the drum, said tubes having communication with a source of air under pressure to conduct air therefrom into the drum.

8. A pulverizer comprising a rotatable drum, pulverizing means in the drum, means for feeding material to be pulverized into the drum, suction means connected to said drum, a hollow member having a relatively small opening disposed in the drum intermediate the desired maximum and minimum levels of the material and adapted to be obstructed by material in the drum, a second hollow member having an opening disposed in the drum above the maximum desired level of the material, pressure responsive means connected to both hollow members and operable by the pressure difference between said members, and means actuated by said pressure responsive means for controlling the feeding means to regulate the level of the material in the drum.

9. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, control means for the supply means, and means comprising a plurality of tubes connecting the control means with the interior of the drum for controlling said control means in accordance with the level of the material in the drum, one of said tubes having its drum end disposed intermediate the maximum and minimum levels of the material in the drum and another of said tubes having its drum end disposed above the maximum level of the material in the drum.

10. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, control means for the supply means, and means comprising a plurality of tubes connecting the control means with the interior of the drum for controlling said control means in accordance with the level of the material in the drum, one of said tubes having its drum end disposed intermediate the maximum and minimum levels of the material in the drum and another of said tubes having its drum end disposed above the maximum level of the material in the drum, said tubes having communication with the atmosphere to permit the flow of air through the tubes into the drum.

11. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, and means for indicating the quantity of the material in the drum including a plurality of tubes connecting the indicating means with the interior of the drum and responsive to the level of the material therein, one of said tubes having its drum end disposed intermediate the maximum and minimum levels of the material in the drum and another tube having its drum end disposed above the maximum level of the material in the drum.

12. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, pressure responsive means for indicating the quantity of the material in the drum, and means comprising a plurality of tubes connecting the indicating means with the interior of the drum and responsive to the level of the material therein, one of said tubes having its drum end disposed intermediate the maximum and minimum levels of the material in the drum and another tube having its drum end disposed above the maximum level of the material in the drum.

13. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, means for indicating the quantity of the material in the drum comprising a first and second pressure responsive device, a first pipe connected with each device and with the interior of the drum at a point above the maximum level of the material in the drum, a second pipe connected with each device and with the interior of the the drum at a point below the maximum level of the material therein, and a third pipe connected to the second device and with the inte-

rior of the drum at a point above the minimum level of the material in the drum.

14. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, means for indicating the quantity of the material in the drum comprising a first and second U-tube, an indicating material in each U-tube, a first pipe connected with one leg of each U-tube and with the interior of the drum at a point above the maximum level of the material in the drum, a second pipe connected with the other leg of the first U-tube and with the interior of the drum at a point below the maximum level of the material in the drum, and a third pipe connected with the other leg of the second U-tube and with the interior of the drum at a point above the minimum level of the material in the drum.

15. Pulverizing apparatus comprising a drum, means to supply material to the drum, means in the drum for pulverizing the material therein, means causing air to flow through the drum, control means for the supply means, means comprising a plurality of tubes connecting the control means with the interior of the drum for controlling said control means in accordance with the level of the material in the drum, one of said tubes having its drum end disposed intermediate the maximum and minimum levels of the material in the drum and another of said tubes having its drum end disposed above the maximum level of the material in the drum, and means for supplying air under pressure to said tubes at their ends opposite their drum ends.

16. A pulverizer comprising a closed revoluble drum, means for feeding material to the drum at a greater rate than it can be pulverized, a motor for driving said feeding means, a first tube and a second tube having openings in said drum, said tubes being adapted to conduct a limited amount of air from the atmosphere to the drum, the openings in said first tube being disposed above the maximum desired level of the material in the drum, means determined by the quantity of charge in said drum for rendering said second tube less effective to conduct air to the drum, a switch for starting and stopping said motor, and a differential pressure responsive member connected to said tubes, said pressure responsive member being adapted to open said switch when the quantity of charge is greater than a predetermined maximum and to close said switch when the quantity of charge falls below a predetermined minimum.

17. A pulverizer comprising a rotatable shell, pulverizing means in the shell, means for feeding material to be pulverized thereinto, the shell having an air inlet and an outlet above the maximum desired level of the material therein, means causing air to flow into the shell through the inlet and over the surface of the material therein and through the outlet carrying pulverized material in suspension, and means for indicating the quantity of material in the drum operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum including movable means common to each of said members and continuously subject to the pressures therein, one of said latter points being disposed in the drum below the maximum desired level of the material therein.

18. A pulverizer comprising a rotatable shell, pulverizing means in the shell, means for supplying material to be pulverized thereinto, the shell having an air inlet and an outlet above the maximum desired level of the material therein, means causing air to flow into the shell through the inlet and over the surface of the material therein and through the outlet carrying pulverized material in suspension, and means for controlling the supply means operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum including movable means common to each of said members and continuously subject to the pressures therein, one of said latter points being disposed in the drum below the maximum desired level of the material therein.

19. A pulverized comprising a drum, means for supplying material to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, and means for controlling the supply means operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum including movable means common to each of said members and continuously subject to the pressures therein, one of said latter points being disposed in the drum below the maximum desired level of the material therein.

20. A pulverizer comprising a drum, means for supplying material to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, and means for controlling the supply means operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum, one of said latter points being disposed in the drum below the maximum desired level of the material in the drum and another of said points being disposed in the drum above said maximum desired level.

21. A pulverizer comprising a drum, means for supplying material to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, and means for indicating the quantity of material in the drum operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum including movable means common to each of said members and continuously subject to the pressures therein, one of said latter points being disposed in the drum below the maximum desired level of the material therein.

22. A pulverizer comprising a drum, means for supplying material to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, and means for indicating the quantity of material in the drum operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the drum, one of said latter points being disposed in the drum below the maximum desired level of the material therein and another of said points being disposed in the drum above said maximum desired level.

23. The method of pulverising material in a mill which comprises supplying material to the mill to be pulverized, supplying air to the mill, causing air carrying pulverized material in suspension to flow out of the mill, causing relatively

small quantities of air to flow in separate confined streams between points within and without the mill respectively, a portion of one of said streams being below the maximum desired level of material in the mill, varying the flow of air through the latter stream by obstructive action of the material in the mill as the level of the material therein varies while maintaining at all times free flow of air through another confined stream, and controlling the supply of material to the mill by the differences in pressure of the streams resulting from the variations in the flow of said one stream due to the obstructive action of the material in the mill with respect to the free flow in said other stream.

24. The method of pulverizing material in a mill which comprises supplying material to the mill to be pulverized, supplying air to the mill, causing air carrying pulverized material in suspension to flow out of the mill, causing relatively small quantities of air to flow in separate confined streams between points within and without the mill respectively, a portion of one of said streams being below the maximum desired level of material in the mill, varying the flow of air through the latter stream by obstructive action of the material in the mill as the level of the material therein varies while maintaining at all times free flow of air through another confined stream, and operating means to indicate the level of the material in the mill by the differences in pressure of the streams resulting from the variations in the flow of said one stream due to the obstructive action of the material in the mill with respect to the free flow in said other stream.

25. Apparatus for holding material comprising a container, means for supplying material to the container, means for removing material from the container, and means for controlling the supply means so as to maintain a substantially constant level of material in the container operated by the difference in pressure between members conducting separate, relatively small quantities of air between points outside of and within the container including movable means common to each of said members and continuously subject to the pressures therein, one of said latter points being disposed in the container below the desired level of material therein.

26. Apparatus for holding material comprising a container, means for supplying material to the container, means for removing material from the container, and means for controlling the supply means so as to maintain a substantially constant level of material in the container operated by the difference in pressure between members conducting separate, relatively small quantities of air betwen points outside of and within the container, one of said latter points being disposed in the container below the maximum desired level of material therein and another of said points being disposed in the container above said maximum desired level.

27. Pulverizing apparatus comprising a drum, pulverizing means in the drum, means for supplying material to be pulverized to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, means controlled by the level of the material in the drum for controlling the means for supplying material to the drum to maintain a substantially constant quantity of material in the drum to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in the drum a substantially constant concentration of pulverized material in suspension per unit quantity of air, and means operable independently of the supply of material to the drum for varying the flow of air through the drum to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

28. Pulverizing apparatus comprising a drum, pulverizing means in the drum, means for supplying material to be pulverized to the drum, means including a fan arranged to operate at different speeds for causing air to flow into the drum and out thereof carrying pulverized material in suspension, means controlled by the level of the material in the drum for controlling the means for supplying material to the drum to maintain a substantially constant quantity of material in the drum to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in the drum a substantially constant concentration of pulverized material in suspension per unit quantity of air, and means operable independently of the supply of material to the drum for varying the speed of the fan to vary the flow of air through the drum to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

29. Pulverizing apparatus comprising a drum, pulverizing means in the drum, means for supplying material to be pulverized to the drum, an exhauster fan having its suction connected with the drum, an air inlet opening through which air is supplied to the drum, means operable independently of the supply of material to the drum for controlling the flow area of the air inlet opening, and means controlled by the level of the material in the drum for controlling the means for supplying material to the drum to maintain a substantially constant quantity of material in the drum to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in the drum a substantially constant concentration of pulverized material in suspension per unit quantity of air, the arrangement being such that by varying the flow area of said air inlet opening the flow of air through the drum may be varied to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

30. Pulverizing apparatus comprising a drum, pulverizing means in the drum, means for supplying material to be pulverized to the drum, an exhauster fan having its suction connected with the drum, means for driving the fan, means for varying the speed of the fan, an air inlet opening through which air is supplied to the drum, means operable independently of the supply of material to the drum for controlling the flow area of the air inlet opening, and means controlled by the level of the material in the drum for controlling the means for supplying material to the drum to maintain a substantially constant quantity of material in the drum to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in the drum a substantially

constant concentration of pulverized material in suspension per unit quantity of air, the arrangement being such that by varying the flow area of said air inlet opening and by varying the speed of the fan the flow of air through the drum may be varied to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

31. Pulverizing apparatus comprising a rotatable drum, means for rotating the drum, pulverizing means in the drum, means for supplying material to be pulverized to the drum, means causing air to flow into the drum and out thereof carrying pulverized material in suspension, means controlled by the level of the material in the drum for controlling the means for supplying material to the drum to maintain a substantially constant quantity of material in the drum to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in the drum a substantially constant concentration of pulverized material in suspension per unit quantity of air, and means operable independently of the supply of material to the drum for varying the flow of air through the drum to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

32. The method of pulverizing material which comprises supplying material to be pulverized to a pulverizing zone, causing air to flow into and out of said zone carrying pulverized material in suspension, controlling the supply of material to said zone automatically in response to variations in the level of the material in said zone to maintain a substantially constant quantity of material in said zone to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in said zone a substantially constant concentration of pulverized material in suspension per unit quantity of air, and varying the flow of air through the drum independently of the supply of material to the drum to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag.

33. The method of pulverizing material which comprises supplying material to be pulverized to a pulverizing zone, causing air to be drawn into said zone through an inlet opening and to be withdrawn from the mill carrying pulverized material in suspension, controlling the supply of material to said zone in response to variations in level of the material in said zone to maintain a substantially constant quantity of material in said zone to maintain a substantially constant state of agitation therein irrespective of the withdrawal of pulverized material therefrom thereby to maintain in said zone a substantially constant concentration of pulverized material in suspension per unit quantity of air, varying the flow of air through the drum independently of the supply of material to the drum to vary the quantity of pulverized material withdrawn from the drum whereby the output of pulverized material from the drum may be varied substantially without a lag, and varying the flow area of said inlet opening to maintain a substantially constant suction in the mill irrespective of the flow of air therethrough.

MARTIN FRISCH.