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C. O. DAVIS

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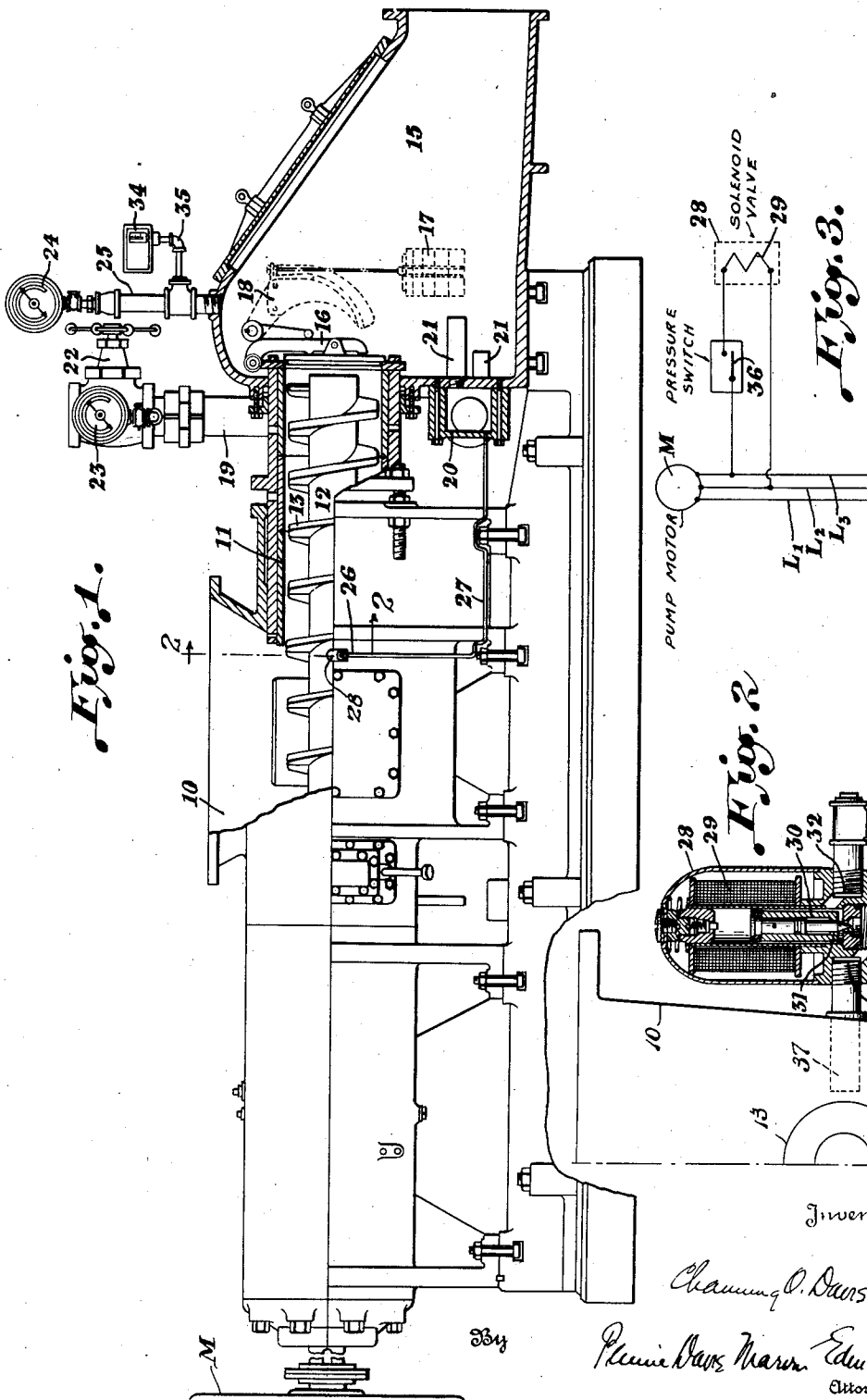


Fig. 1.

Fig. 2

Fig. 3.

Inventor

Charles O. Davis

Plumley Davis, Warren, Edwards,
Attorneys

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CONVEYING APPARATUS

Channing O. Davis, Allentown, Pa., assignor to
Fuller Company, Catasauqua, Pa., a corpora-
tion of Delaware

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5 Claims. (Cl. 302—50)

This invention relates to the conveying of pulverized or finely divided material such as Portland cement, pulverized limestone, powdered coal, soda ash, et cetera, in a system in which the material is continuously conveyed through a closed conduit or pipe line to which the material is substantially continuously supplied and in which it is advanced through a short length of the conduit, at the inlet end, by mechanical pressure, and air or other gas is injected beyond the advancing means to aerate the material, whereby the material is conveyed through the remainder of the conduit by the pressure of the expanding gas and the displacement of material into the system. More particularly, the invention is concerned with a novel apparatus for conveying such materials through closed conduits or pipe lines when the material to be conveyed is supplied at variable rates and sometimes at greater than normal densities, at times greater than the maximum capacity of the system, the safe operating load of the motor driving the material advancing means, or both.

The apparatus of the invention is related to the subject matter set forth in the application of Joseph H. Morrow, Serial No. 349,538, filed August 2, 1940, and also constitutes an improvement on the conveying system of the type described in the Kinyon Patent 1,553,539 and later improvement patents, all of which are set forth in this earlier-filed application.

The Kinyon system and improvements thereof are well-known in the art and comprise, briefly, the introduction of the pulverulent material in various manners into a cylindrical barrel connected at one end to a transport line. A rapidly rotating impeller screw advances and compacts the material in the barrel to form a seal, and at a point beyond the seal air is introduced into the material to aerate it and cause the material to flow through the transport line by displacement of material into the system and the expansion of the air. The density of the seal required varies considerably under different conditions of operation, and care is taken to provide a seal which is no denser than is necessary, since the use of a seal of greater density than is necessary results in power losses and excessive wear of the parts, due to friction, and at times may place such a strain upon the driving mechanism as to cause a complete breakdown, as will be developed later.

If the supply of specific material to the pump of a given system is to be constant both for volume and density throughout operation, it is a

simple matter to calculate the pressure and volume of air required, with relation to the maximum conveying distance, and to provide for a seal of sufficient density to resist this pressure and prevent rearward escape of air, and to calculate the motor power required to advance the material and overcome the resistance of the seal and back pressure of the system. In such a system, the device is so constructed or adjusted that, under normal operating conditions, a seal will be formed which will resist the maximum back-pressure developed when conveying to the farthest point in the line, and the motor driving the pump is selected to furnish the power required for such condition without over-loading.

A serious problem, however, is presented in the use of such conveying systems when the supply of the material entering the system increases substantially above normal, since such an increase may cause serious damage and overloads. The chief cause of this increase in material supply is a change in characteristics of the material from that normally expected, namely, an increase in density under certain conditions. There are a number of reasons why the density may increase, the common cause being that, if the material is stored for any considerable length of time, the normal quantity of air admixed with the material gradually escapes. Also the density, and thus the rate at which the material is supplied to the conduit is increased by the sudden breakdown of an arch formed in the hopper or feed line of the conveyor. When such conditions are anticipated, it has been the practice to use a larger motor than necessary for the normal load, but this does not completely solve the problem because it will operate at an unfavorable power factor most of the time and, if the overload of the system is more than momentary, incomplete aeration of the material due to the deficiency in compressed air will ultimately overload the system and motor.

In such systems, the overloads may become excessive, and even though the motor may be larger than necessary for the normal capacity, it may be incapable of forcing the material into the pipe line. Similarly, the density of the material may be moderately excessive for prolonged periods, and the screw motor will continue to run under overload conditions. In the latter case, the increased density of the seal is reflected almost instantly by the development of a high back pressure in the discharge line of the system, resulting from the excess of incompletely aerated material, and this increased back pres-

sure offers considerable resistance to the injection of air and the air supply pressure must be increased to maintain the same volume flow. In some types of installations, the increase in air supply pressure will not increase the volume flow in order to aerate the excessive quantity of material. The necessity for high inlet pressure of the air supply greatly increases the cost of compressing the air, as the compressor power input increases rapidly, and the compressor efficiency decreases rapidly due to air slippage, as the pressure is raised. The compressor unit usually serves a plurality of pumps, and in order to cause even the normal quantity of air flow into the material in the pump offering increased resistance, higher pressures throughout the entire system are necessary.

The present invention is, accordingly, directed to the provision of a system for conveying pulverized or finely divided material which operates on the Kinyon principle and performs economically for all conditions of variable material supply greater than the full capacity of the system. The new system automatically controls the quantity and characteristics of the material entering the conduit or pipe line when the supply increases above normal and thus maintains a uniform rate of conveying within the system's normal capacity. The new system uses relatively low transport line and inlet pressures with a minimum differential between them under all conditions of variable material supply, thus effecting economies in power represented by compressor pressure and input to the pump motor, because of the decreases in force represented by back pressures which the pump must overcome, and in the friction of the material advanced by the screw. The new system accordingly affords the advantage of continuous conveying, with excellent economy.

In the operation of the new apparatus, pulverulent or finely divided material is supplied to the conduit through which it is to be conveyed, pressure is applied to the material within the conduit to advance and compact the same, and immediately beyond the point of pressure application air or other gas is injected into the conduit in sufficient quantity to fluidize the material. Through the combined action of the pressure applied and the natural expansion of air injected, the material is caused to flow through the conduit. When the rate at which the material is supplied to the conduit increases above that normally expected, and for which the system is adapted, additional air or other gas is injected into the material in the vicinity of the inlet to the conduit or barrel in order to restore it to its normal density i. e. that which was anticipated when the system was designed. Since the actual quantity of material being advanced by the impeller screw, or other mechanical means, at any time is reflected in transport line pressure almost immediately, the air, supplied to decrease the density of the material by limited aeration, is controlled by mechanism responsive to a predetermined transport line pressure. Operation of the air injector means may be caused to operate upon an increase in transport line above normal pressure and is usually set at a point about 5 pounds above normal. Upon the entrance of abnormally dense material, resulting in an increase in line pressure to or above the predetermined point, aeration of the supply is initiated and mixture of the air and material is completed almost in-

stantly by the agitating effect of the rapidly rotating screw. As this material of substantially normal density enters the transport line the pressure therein immediately begins to return to normal for which the system has been set. The flow of material through the transport line is very rapid, usually about 1500 feet per minute, so that, shortly after the pre-aerated material enters the system the line pressure returns to normal. Immediately after the aeration of the material supply starts, the load on the screw motor drops to a predetermined safe limit and operates under such conditions during the entire period of increased material supply. Should the abnormal density condition of the material supply continue more than momentarily the air is supplied constantly until the line pressure returns to normal. Should the pressure return to normal during this period, the air supply will be cut off and under certain conditions the air will be supplied as a series of injections to limit the quantity of air supplied to the minimum necessary to overcome the condition. The apparatus is made adjustable whereby the material is conveyed consistently at the maximum capacity corresponding to the most efficient motor operating load. By so aerating the material at times of increased density the rate at which the material is conveyed is maintained substantially uniform regardless of increases in material supply. By use of the present apparatus, it is therefore possible to start the system and leave it unattended with assurance that a constant and uniform rate of conveying will be maintained, and that the system will not be called upon to handle material in such a quantity as to result in damage to or stoppage of the system.

For a better understanding of the invention reference is made to the accompanying drawing illustrating apparatus suitable for the practice of the new method. In the drawing:

Fig. 1 is a side elevation partly in section of one form of the device.

Fig. 2 is a detail section taken on line 2-2 of Fig. 1.

Fig. 3 is a schematic wiring diagram for the control of the valve of Fig. 2.

The apparatus illustrated will be seen to include a hopper 10 adapted to receive a continuous supply of material from any suitable source not shown. The material entering the hopper 10 is advanced and compacted in a barrel 11 by the rotation of a shaft 12 having screw flights 13 thereon and extending through the hopper and into the barrel. The end of the shaft remote from the barrel 11 is suitably supported in bearings and the end thereof extends through the bearing head and terminates in a keyway 14 adapted to be coupled to any suitable prime mover, such as an electric motor M.

Rapid rotation of the screw advances the material through the barrel to the mixing chamber 15. The material in its movement through the barrel is compacted to form a seal adjacent the terminal flight of the screw, the flights of which progressively decrease in pitch near the terminal end. A flap valve 16 normally closes the end of the barrel and is assisted to its closed position by counter-weight 17 operating through bell crank 18, this valve insuring the compacting of the material at the terminal flight of the screw, and under normal operating conditions with the screw advancing a uniform

supply of material, this valve is lifted from its seat by the flow of material.

The material issuing from the barrel into the mixing chamber 15 is aerated by blasts of compressed air supplied through air line 19, manifold 20 and injector pipes 21. The air supply to the mixing chamber is controlled by valve 22 and air pressure gauge 23 registers the pressure in this line. A pressure gauge 24 connected to the mixing chamber by pipe 25 registers the pressure in the discharge line.

When abnormally dense material enters the hopper 10 and is advanced and compacted by the screw, a heavy overload is placed upon the driving motor for the screw, and as this dense material enters the discharge line the back pressure increases, thereby placing an additional load upon the means supplying the compressed air. To overcome this overload condition, an aerating means denoted generally at 26 automatically acts, when the pressure in the discharge line reaches a predetermined point, to reduce the density of the material being confined in the barrel and thus reduce the load upon the motor driving the screw, and the load upon the means supplying the compressed air.

The aerating means comprises a pipe line 27 having one end connected to the manifold 20 and its other end 37 placed adjacent the screw flights 13 at a point near the barrel opening, in order that, the material supplied may be aerated prior to confinement within the barrel. As the flow of air to the material is necessary only at those times when the material supply is greater than that normally expected, a solenoid operated valve indicated generally at 28 permits the passage of air through the line only upon energization of its operating coil 29 to raise the armature 30 carrying the valve needle 31 thus permitting free flow of the air between the inlet 32 and outlet 33.

A pressure operated means 34 of well known construction controls the operation of the solenoid operated valve 28, and is connected to pipe 25 by line 35 in a manner to be subjected to fluctuations in the discharge line pressure. A switch 36 contained in the pressure means 34 is adapted in its closed position to complete the circuit to the operating coil 29 of the valve. This pressure means may be adjusted to operate within a narrow range of differential, and in this manner, upon the entrance of abnormally dense material into the discharge line, the resulting increase in pressure within this line is almost immediately reflected in operation of the switch 34 to complete the circuit to the operating coil of the solenoid valve to permit the injection of air to the material supply. The fact that there is a slight lag between the entrance of the abnormally dense material to the barrel and the increase in discharge line pressure is advantageous, as such increased material supply may be only temporary and the system will continue to operate normally without the injection of aerating air.

One possible connection of the operating coil 29 of the valve to the power lines of the motor has been illustrated schematically in Fig. 3. In the illustration shown, power lines L1, L2 and L3 are provided for the screw motor M. The operating coil 29 of the solenoid valve 28 is connected across the power lines L2 and L3 and the switch 36 is included in this circuit. The switch 36 is normally open and is operated to its closed position to permit energization of the coil 29 upon increase of the pressure in the discharge line above

a predetermined point by means of the pressure-operated control 34. Should the motor M require a line current of such magnitude that it would destroy the operating coil 29, the connection of this coil across the line L2 and L3 may include any well known means to reduce the current to the coil.

When the system illustrated encounters an abnormally dense material, the overload of the screw motor results in practically instantaneous rise in the motor current, and since the dense material travels from the feed end of the barrel through the seal and into the discharge line rapidly because of the high speed of the screw, the entrance of this abnormally dense material is reflected almost immediately in the increased discharge line pressure. The reaction of the pressure controlled switch to an increased load is substantially instantaneous and operation of the aerating mechanism is effective without delay, so that the duration of extreme overload of the screw motor is extremely short, and no detrimental effect upon this motor results. The system may be started and left to run without an attendant with assurance that material of varying density will be handled without the possibility of damage to the motor, and that a flow of a uniform quantity of material will take place. By the maintenance of a uniform flow through the conduit, the difference between the inlet pressures and the line pressures may be maintained with a minimum differential, and savings are thus made in the compressor cost.

I claim:

1. An apparatus for conveying pulverulent material of variable density which comprises in combination, a conduit through which the material is advanced, means directing the material to the conduit, pressure applying means within the conduit to advance and compact the material, a motor driving the pressure applying means, a gas injector beyond the point of application of pressure to aerate the material and assist in its flow through the conduit, normally inoperative means to aerate the material prior to its entering the conduit, and means responsive to predetermined pressures in the conduit beyond the point of application of pressure for controlling the operation of the last named aerating means.

2. An apparatus for conveying pulverulent material of variable density which comprises in combination, a conduit through which the material is advanced, means directing material to the conduit, a screw conveyor within the conduit for applying pressure to advance and compact the material, a motor having a driving connection with the screw conveyor, a gas injector beyond the point of application of pressure to aerate the material, a second gas injector adjacent the conduit entrance to aerate the material, a pipe line connecting the second injector to a source of air supply, a valve in the pipe line, and means responsive to predetermined pressures in the conduit beyond the screw conveyor for controlling the operation of the valve.

3. Apparatus for conveying pulverulent material of variable density which comprises in combination a conduit through which the material is advanced, means directing material to the conduit, a screw conveyor within the conduit for applying pressure to advance and compact the material, an electric motor having driving connection with the screw conveyor, a gas injector beyond the point of application of pressure to aerate the material, a second gas injector adjacent the

conduit entrance to aerate the material, a pipe line connecting the second injector to a source of gas supply, a valve in said pipe line, a solenoid controlling the opening and closing of the valve, and means responsive to predetermined pressures in the conduit beyond the screw conveyor for controlling operation of the solenoid.

4. A pump for conveying pulverulent material comprising a barrel in which the material is advanced and compacted to form an air seal, a discharge line connected to the barrel, a rapidly rotated impeller screw to advance and compact the material and discharge the same into the discharge line, an electric motor to drive the impeller screw, means to inject air into the material at a point adjacent to but beyond the point of seal formation, an air supply conduit opening into the apparatus near the entrance to the barrel, a valve in the conduit, electrical means for operating the valve, and means responsive to predetermined pressures developed beyond the point of seal for controlling the circuit to the last named electrical means whereby upon increase in the discharge line pressure above a predetermined point the circuit is completed to cause

opening of the valve to partially aerate the material to decrease its density and its rate of advance by the screw.

5. An apparatus for conveying pulverulent material of variable density which comprises in combination, a conduit through which the material is advanced, means directing material to the conduit, a screw conveyor within the conduit for applying pressure to advance and compact the material, an electric motor having a driving connection with the screw conveyor, a gas injector beyond the point of application of pressure to aerate the material, a second gas injector adjacent the conduit entrance to aerate the material, a pipe line connecting the second injector to a source of gas supply, a valve in said pipe line, a solenoid controlling the opening and closing of the valve, a switch in the power circuit of the solenoid, operable upon a predetermined rise in the pressure in the conduit at a point beyond the screw conveyor, to connect the operating coil of the solenoid valve to a source of power whereby the valve is opened and gas injected into the material supply.

CHANNING O. DAVIS.