LEVEL CONTROL SYSTEM FOR FLOWABLE SOLID MATERIALS

ABSTRACT: The invention relates to a level sensing and control system for regulating the high and low levels of a body of flowable solid material in a container or receiving tray, bin, tank or other receptacle. The system is applicable to loose solids in powdered, granular or other comminuted flowable form, and is particularly applicable to control the level of toner material utilized in electrostatic copying machines as in the illustrative embodiment disclosed herein. The system includes an open-ended vertical sensor tube disposed within the material container or receiver and which is connected intermediate its ends to a source of air or other pressure fluid which serves to trigger the system to cause automatic interruption of the material feed supply when a predetermined head of material is trapped in the tube, and to cause automatic operation of the material feed supply to replenish the material in the tray or receiver when the material level drops to a predetermined low level and allows the pressure fluid to freely escape from either or both ends of the sensor tube when the material reaches a predetermined low level. The positions of the opposite open ends of the sensor tube respectively define the high and low levels of the material deposited in the tray or receiver.
LEVEL CONTROL SYSTEM FOR FLOWABLE SOLID MATERIALS

The present invention relates to a control system for regulating the high and low levels of a body of flowable solid material when deposited in a receiver such as a tray, bin, tank or other container, and for automatically controlling the feed of additional material from a feed supply source when the level of the material in the receiver reaches a predetermined low point until the level is restored to a predetermined high point.

While my invention is generally applicable to many types of loose or flowable solids of granular and powdered form, it is more particularly concerned with powdery toners as used in electrostatic copying machines, but is not limited thereto. Such machines are customarily provided with a tray to receive a quantity of toner which is used in the copy-making process. A revolving drum is usually employed to pick up the toner from the tray and apply it to the surface of the copy paper as the copies are running through the machine. When the toner supply in the tray becomes depleted, the machine will no longer make good copies, and it becomes necessary to stop the machine until the toner supply in the tray is replenished. This must be performed by hand in the less expensive copying machines and is usually rather "messy" or untidy task.

In more expensive and sophisticated modes of these copying machines, the machines are also equipped with a supply hopper from which the toner can be supplied to the tray on demand. The feed of the toner from the supply hopper to the tray, when begun, usually continues for a predetermined length of time, as controlled by an appropriate time delay relay, or until a switch is manually actuated by the operator of the machine to stop the toner feed. During the operation of the supply hopper, the tray is usually vibrated so as to cause the toner to find a level and distribute it to a substantially uniform depth throughout the tray, but usually no provision is made to automatically stop the feed at any predetermined high level in the tray.

The primary object of my invention is to provide a simple and relatively inexpensive control system which is fully automatic and which is responsive to both a predetermined low level and a predetermined high level of a flowable solid material in a receiver or receptacle.

A further object of the invention is to provide an effective sensor which is responsive to both the low and high levels of the flowable solids in a receiver and which serves to activate and deactivate the feed of such solids to the receiver.

Other and further objects and advantages of the invention will be hereinafter described or will become apparent from the accompanying drawings, and the novel features thereof defined in the appended claims.

In the drawing:

FIG. 1 is a schematic diagram of a control system according to one illustrative embodiment of my invention as applied to a conventional electrostatic copying machine;

FIG. 2 is a cross-sectional view of the sensor tube and the toner material in which it is submersed at the high level point of the material in a receiver;

FIG. 3 is a view similar to FIG. 2, but depicting an intermediate level condition of the toner material;

FIG. 4 is a view similar to FIGS. 2 and 3, but depicting the low level condition of the toner material;

FIG. 5 is a perspective view of a modified sensor tube; and

FIG. 6 is a sectional view of a modified form of receiver and associated sensor representative of an application of the invention to a relatively deep bin, vat or other equivalent receptacle.

Like reference characters designate corresponding parts in the several figures of the drawing.

Referring to FIG. 1, the numeral 1 denotes a receiver having the form of a relatively shallow container or tray forming a part of a copying machine to receive the powdery toner which is required in the operation of the machine to make copies. Associated with the tray 1 is a rotatable drum 2 which picks up and applies the toner material to the copy paper during operation of the machine. When the tray is empty or the toner level therein drops to a low level where it can no longer be picked up by the drum 2, additional toner material can be added to the tray 1 from a toner supply hopper 3 of substantial capacity containing a reserve supply of tone. From the toner supply hopper 3, the toner material can be fed to the tray 1 by any suitable feed mechanism which is operable on demand. In the illustrative embodiment, the feed mechanism includes a worm 4 which is driven by a small electric motor M which is connected to the worm 4 by drive shaft 5. A chute 6 delivers the toner from the worm 4 to the tray 1. During operation of the feed mechanism, the tray 1 is preferably vibrated by suitable vibrating mechanism (not shown) which can be driven by the motor M or by any other appropriate operating means. By vibrating the tray 1, the toner material will be distributed in the tray, and seek a level so that the toner material will be substantially uniform in depth throughout the tray.

Activation and deactivation of the motor M is preferably controlled by a pressure switch 7 which may be of any conventional type such as one of the low pressure switches produced by Fairchild Controls, a division of Fairchild Camera & Instrument Corp., of Hicksville, Long Island, N.Y. Such switches are extremely sensitive and are available in modes which will operate at pressures as low as 0.02 p.s.i. One or more diaphragms 8 are provided in the switch to actuate the switch contacts 9 which are normally open when the diaphragm is not subjected to pressure.

The pressure switch is operatively connected to a time delay relay 10 of any suitable type such as manufactured by Potter & Brumfield and identified as their CU series, solid state type, style 41, and which includes double-acting switch contacts 11. The contacts of this time delay switch, when the relay is actuated by the pressure switch 7, serve to close an electric power circuit 12 to the motor M, and the circuit may include an appropriate indicator lamp (not shown) to indicate that the toner feed mechanism is operating. When the time delay relay is deactivated by closing of the pressure switch contacts 9, the switch contacts 11 of the time delay relay will open the motor circuit and close a circuit 13 which includes an indicator lamp 14 which indicates an ample supply of toner material is available in tray 1.

To make the toner supply fully automatic and responsive to predetermined high and low levels of toner material in tray 1, my system includes a level detector or sensor 15 which is operatively connected to the pressure switch 7. As illustrated, the sensor 15 has the form of an open-ended tube or cylinder which is suitably anchored to the tray 1 in an upright or vertical position, with the upper open end of the tube being exposed on a plane corresponding to a predetermined high level of the toner in the tray, and its lower open end being disposed near the bottom of the tray or on any plane corresponding to a predetermined low toner level.

At a point intermediate the upper and lower open ends of the sensor tube 15, it is provided with a laterally extended short pipe 16 which is in open communication with the interior of the hollow sensor tube 15, and the outer end of the pipe 16 is connected by a conduit 17 to pressure switch 7. A source of pressure fluid, such as air, designated by the arrow 18, is connected at 19 to the conduit 17 at a point between the sensor tube 15 and the pressure switch 7. A valve 20 is preferably provided in the air supply line to enable the airflow to be regulated or cut off if desired. Air under pressure is usually provided in copying machines to cool the high intensity lamps of the machine, so it is readily available for my control system and can be readily obtainable from a separate source of supply such as a conventional inexpensive air pump or bubbler commonly used for fish tanks or aquariums.

Assuming that the tray 1 is empty or the toner level therein is below the lower end of sensor tube 15, the air admitted from source 18 into the conduit 17 will freely escape from the open ends of sensor tube 15 without acting on pressure switch 7, and the normally open switch contacts 9 of the pressure switch
will remain open. However, the motor switch contacts 11 of time-delay relay 10, being normally closed, the motor will be energized, thereby causing the feed mechanism of supply hopper 3 to feed toner from the hopper to the tray 1 until the toner level in the tray reaches the level of the upper open end of the sensor tube 15. At this stage, as illustrated in FIG. 2, the sensor material will flow into the tube 15 until the tube is filled. Under these conditions air in conduit 17 can no longer freely escape from either end of sensor tube 15, and consequently, a back pressure will build up in the conduit 17 and cause operation of pressure switch 7, closing the normally open switch contacts 9 and activating the time-delay relay 10. After a delay of several seconds, which is sufficient to prevent chatter or rattling of the relay switch 11, the relay circuit contacts of the relay switch will open the motor circuit 12 and stop the motor M. This automatically stops the feed of toner from the supply hopper 3 to the tray 1, which occurs when the toner in the tray reaches the predetermined high level.

As the toner in the tray 1 is used up, the toner level progressively falls, but unlike a liquid, the toner level within the sensor tube 15 does not equalize itself with the toner level externally of the sensor tube. On the contrary, the sensor tube remains filled, as indicated in FIG. 3, until the toner level in the tray falls below the open bottom end of the tube 15, at which time the toner material in the sensor tube will drop out but will not empty in action, as represented in FIG. 4. When this occurs, the air in conduit 17 can freely escape from either the top end or the bottom end of the sensor tube, or from both ends, resulting in a drop in pressure on the pressure switch 7, allowing the switch contacts 9 thereof to open and deactivate the relay switch 10 and close the circuit 12 to the motor M, thereby causing more toner material to be fed from the supply hopper 3 to the tray 1 until the toner level in the tray again rises to the predetermined high level and overflows into the upper end of the sensor tube to refill the tube. As the tube refills, escape of air therefrom is blocked when the toner in the tube builds up enough to resist the passage of air therethrough, and when the air can no longer freely escape from either end of the tube, the air pressure in conduit 17 builds up enough to activate the pressure switch to reclose the switch 9. This stops the feed of toner material from the supply hopper 3 to the tray 1 until the toner level in the tray again approaches or falls below the lower end of the sensor tube and the feed control cycle is automatically repeated.

It will be apparent from the foregoing that the length of the sensor corresponds to the range in height of the toner in the tray, and the length, together with the diameter of the tube, are so proportioned as to assure retention of the toner in the sensor tube as the toner level in the tray drops from the high level and ultimately drops out of the bottom of the tube when the tray is empty or nearly so. These dimensions of the sensor tube may be varied according to the nature and consistency of the material being used in the tray or as applied to other types of receivers for other powdery or granular materials of a flowable solid character. Under some conditions, it may be necessary or more expedient to invert the sensor tube, as indicated at 15° in FIG. 5, with the lateral air pipe 16° being positioned at a higher elevation than in FIGS. 1 to 4. When the level control system is used in other adaptations involving a relatively deep receiver, tank, vat or similar receptacle, the sensor tube would be relatively long, as indicated at 15° in FIG. 6 in which the receiver is represented as a tank or vat I. Here again, the elevation at which the laterally extended air pipe 16° is positioned should depend upon the nature and consistency of the materials to be deposited in the receiver and the desired high and low levels of the materials.

The simplicity of my control system makes it suitable for manufacture and sale in either a preassembled form or as a "kit" which can be assembled by the purchaser himself with the aid of a few tools and with the exercise of little or no skill.

While the specific details of one illustrative form of my invention have been shown and described herein, it is not con-

fined thereto, and other changes or alterations can be made without departing from the spirit thereof as defined in the appended claims.

1. A level control system for flowable solid materials, comprising a receiver, material supply means associated with said receiver for depositing therein upon demand a predetermined quantity of flowable solid material when the material level in the receiver reaches a predetermined low level, pressure responsive means for automatically activating the material supply means when the material reaches the predetermined low level in the receiver and for deactivating the material supply means when the material reaches a predetermined high level, a source of pressure fluid operatively connected to the pressure responsive means, and intermittently operable material entrapping and discharging sensor means disposed in the receiver and responsive to the material level therein and to the presence or absence of material trapped in the sensor means for establishing and releasing the operating pressure of the fluid pressure source acting on the pressure responsive means aforesaid.

2. A system as defined in claim 1, wherein the material supply means is power driven, and the pressure responsive means includes a pressure-operated switch, and a time-delay relay operatively connected to said switch and to the power driven supply means for controlling operation of said material supply means.

3. A system as defined in claim 1, wherein the pressure fluid source is operatively interconnected with the pressure responsive means and the sensor means at an intermediate point therebetween.

4. A system as defined in claim 1, wherein the sensor means comprises a vertically extended hollow member open at its upper and lower ends to respectively admit and discharge a quantity of the material deposited in the receiver.

5. A system as defined in claim 1, wherein the sensor means comprises a vertically extended hollow member open at its upper and lower ends to respectively admit and discharge a quantity of the material deposited in the receiver, and in the interior of said hollow member being in communication with the pressure fluid source at a point intermediate its upper and lower ends.

6. A system as defined in claim 4, wherein the upper open end of the hollow member terminates on a plane substantially corresponding to the predetermined high level point of the material to be deposited in the receiver.

7. A system as defined in claim 4, wherein the lower open end of the hollow member terminates on a plane substantially corresponding to the predetermined low level point of the material to be deposited in the receiver.

8. A system as defined in claim 4, wherein the sensor means comprises a vertical open-ended tubular member fixedly disposed in the receiver and operatively connected intermediate its open ends to the source of pressure fluid.

9. A system as defined in claim 1, wherein the sensor means comprises a vertical open-ended tubular member fixedly disposed in the receiver and operatively connected intermediate its open ends to a source of pressure fluid, the diameter and length of said tubular member being so proportioned that the depth of flowable material in the receiver must at least reach the upper open end of the tube to cause the tube to be filled with the flowable material and retain the same therein until the material level falls below the lower open end of the tube to allow self-dumping of the material from the tube.

10. A system as defined in claim 1, wherein the sensor means comprises a vertical open-ended tubular member fixedly disposed in the receiver and operatively connected intermediate its open ends to the source of pressure fluid, the diameter and length of said tubular member being so proportioned that the depth of flowable material in the receiver must at least reach the upper open end of the tube to cause the tube to be filled with the flowable material and retain the same therein until the material level falls below the lower open end
of the tube to allow self-dumping of the material from the tube, said pressure fluid causing activation of the pressure responsive means incident to blockage of both ends of the sensor tube by solid materials when standing in the sensor tube and obstructing the escape of pressure fluid from either end of the sensor tube.

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