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**METHOD AND APPARATUS FOR TRANSFERRING
FINELY DIVIDED SOLIDS****Walter D. Ahner, Jr., Penn Hills Township, Allegheny
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tion, a corporation of Delaware****Filed Oct. 10, 1963, Ser. No. 315,277****10 Claims. (Cl. 302-42)**

This invention relates to an improved method and apparatus for pneumatically transferring finely-divided solids.

Although my invention is not thus limited, the method and apparatus are particularly useful in handling coal fines as they are injected into the tuyeres of a blast furnace. In conventional blast-furnace operation, iron ore, metallurgical coke and limestone flux are charged to the top of the furnace, while a hot-air blast is blown through the tuyeres. Metallurgical coke is costly. As a means for decreasing the quantity of coke required, it is known to inject coal fines into the tuyeres with the air blast. The rate at which coal fines are thus introduced must be closely controlled if the furnace is to operate efficiently. The quantities of coal introduced are too small to enable proper control to be attained with conventional mechanical feeders. Pressure changes within the furnace upset previous pneumatic handling systems. Nevertheless it is apparent the invention may be used elsewhere for overcoming similar problems.

An object of my invention is to provide an improved method and apparatus for transferring fines pneumatically and exercising accurate control of quantities despite recurring pressure changes.

A further object is to provide an improved method and apparatus of the foregoing type in which I automatically maintain a substantially constant pressure drop between the source and the delivery point, even though the pressure at the latter continually varies.

A more specific object is to provide an improved method and apparatus of this type in which the pressures at the source and at the delivery point are measured continuously, and the pressure at the source is adjusted automatically in accordance with variations in the pressure at the delivery point to maintain a substantially constant drop, thus assuring transfer of a substantially constant quantity of fines.

In the drawing:

FIGURE 1 is a diagrammatic view of a blast furnace equipped with a pneumatic apparatus for injecting coal fines into a tuyere constructed in accordance with my invention; and

FIGURE 2 is a vertical sectional view of the discharge end of the coal vessel.

FIGURE 1 shows diagrammatically and in horizontal section a portion of a conventional blast furnace which includes a wall 10, a bustle pipe 12, and a plurality of tuyeres 13. A hot-air blast is introduced to the furnace through the bustle pipe and tuyeres in the usual manner. I have not shown the remainder of the furnace, since it is not involved in my invention. A vessel 14 contains a supply of coal fines (preferably minus $\frac{1}{8}$ inch) for injection into one of the tuyeres to decrease the quantity of coke required to operate the furnace, as known in the art. I provide similar vessels (not shown) for each of the other tuyeres. The top of vessel 14 is closed. The lower end of the vessel has a portion 15 of reduced diameter to provide a discharge. As FIGURE 2 shows, the portion 15 of the vessel contains a downwardly directed conical sheet metal insert 16 and an orifice plate 17 below said insert. A transfer pipe 18 is connected to the bottom of the portion 15 and contains a valve 19 (FIGURE 1). Pipe 18 is

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connected to another transfer pipe 20, which leads to one tuyere 13.

In accordance with my invention, I introduce air to vessel 14 from a primary supply line 21, which has a first branch 22 leading to the top of the vessel and a second branch 23 leading to its reduced discharge portion 15. Air which enters the vessel through branch 22 supplies pressure which forces coal fines from the bottom of the vessel through the transfer pipe 18. Air which enters the vessel through branch 23 provides a fluidizing or cleaning action that insures a smooth flow of fines through the orifice. Line 21 contains an adjustable control valve 24 and a meter 25 for measuring the quantity of air flowing therethrough. A suitable meter is available commercially from Fischer and Porter Co., Hatboro, Pa., as the "Fischer-Porter Flowmeter," Catalog No. 10-A-9010. I also introduce air to the transfer pipe 20 through a secondary supply line 26 which contains an adjustable control valve 27 and a meter 28, similar to corresponding parts in the primary line 21. The secondary air supply conveys the coal fines through the transfer pipe 20 to the tuyere 13.

The quantity of fines transferred from vessel 14 to the tuyere 13 is a function of the drop in pressure therebetween. The pressure at the tuyere continually varies. To maintain the quantity of fines constant, I automatically vary the vessel pressure to compensate for variations at the tuyeres. For this purpose I connect a differential pressure controller 29 between two points whose pressure is representative of that at the tuyere and at the vessel. A suitable controller is available commercially from the Leslie Company of Lyndhurst, New Jersey, as the "Leslie Differential Pressure Control Pilot" and is described in a printed publication by the supplier, Bulletin 5302. I show one side of controller 29 connected to the blowstock of the tuyere via a line 30, whereby molten material and dust from the furnace do not plug the connection, and the intense heat of the furnace does not cause damage. I show the other side of controller 29 connected to the secondary air supply line 26 via a line 31. This connection is located intermediate valve 27 and the point at which line 26 joins the transfer pipe 20, where the pressure approximates that in vessel 14, but the air is relatively dust-free. Alternatively I can connect line 31 directly to vessel 14 or to the transfer pipe 18. I connect a bleeder or air outlet pipe 32 to vessel 14. The bleeder pipe contains an adjustable valve 33 which has an actuating device 34 connected to controller 29 via a line 35. Suitable valves and actuating devices likewise are available commercially from the Leslie Company, and are described in printed publications by the supplier, Bulletins 605A, 636, and 642. I introduce a set-point air pressure signal to the controller via a line 36, which signal is equivalent to pressure drop I desire to maintain between the vessel and tuyere.

In operation, I determine the pressure drop needed to deliver the optimum quantity of coal fines from vessel 14 to tuyere 13 and adjust the set-point pressure applied via line 36 to controller 29 accordingly. I also adjust valves 24 and 27 in the primary and secondary air supply lines 21 and 26 to furnish the proper quantities of air to vessel 14 and to the transfer pipe 20 for delivering solids from the vessel to the tuyere. The primary air rate must be at a level high enough to insure the required pressure drop when the pressure at the tuyere is at a maximum. With coal feed rates between 1600 and 2800 pounds an hour, the range normally encountered in blast furnace operation, the pressure in the vessel should be in the range of 40 to 60 p.s.i.g. The secondary air supply merely aids in transferring fines discharged from the vessel, and is under sufficient pressure to maintain a superficial gas velocity in pipe 20 of at least 10 feet per second.

In some applications, where the primary air supply is at a sufficient velocity to transfer the fines, I may eliminate the secondary air supply.

Whenever the apparatus is operating, valve 33 remains partially open, whereby some air continuously escapes from vessel 14. As long as a constant quantity of air is introduced to the vessel from the primary air supply 21, the pressure inside the vessel is a function of the rate at which air escapes. When there is a change in pressure at the tuyere 13, the pressure applied to one side of the differential pressure controller 29 via line 30 changes. For the moment, the difference between this pressure and that applied to the opposite side via line 31 deviates from the set-point pressure on line 36. The controller automatically operates the actuating device 34 to adjust valve 33 in a direction to bring the system back into balance. Consequently pressure in vessel 14 is adjusted to maintain the pressure drop between the vessel and the tuyere at the set-point level, whereby the proper quantity of fines continues to reach the tuyere.

From the foregoing description, it is seen that my invention affords a simple method and apparatus for transferring finely divided solids pneumatically, and maintaining a constant rate of transfer despite pressure variations. As applied to a blast furnace, the invention enables coal fines to be injected into the tuyeres with sufficiently precise control to enable the furnace to operate efficiently, yet conserve coke.

While I have shown and described only a single embodiment of my invention, it is apparent that modifications may arise. Therefore, I do not wish to be limited to the disclosure set forth but only by the scope of the appended claims.

I claim:

1. In a process in which finely divided solids are contained in a closed vessel and transferred pneumatically therefrom to a delivery point where the pressure is lower than that in said vessel but subject to variations, the combination therewith of a method of controlling the rate at which the solids are transferred comprising introducing air at a constant rate from a primary supply to said vessel to pressurize it and force solids to discharge therefrom, continuously introducing air from a secondary supply to solids discharging from said vessel to convey the solids to said delivery point, continuously bleeding air from said vessel, the pressure within said vessel being a function of the rate at which air escapes therefrom, measuring pressures representative of those in said vessel and at said delivery point, and adjusting the rate at which air escapes in accordance with variations in pressure at said delivery point to maintain the pressure in said vessel at a value such that the pressure drop between said vessel and said delivery point is substantially constant.

2. A method as defined in claim 1 in which the pressure representative of that in said vessel is measured in the secondary air supply ahead of the location where the secondary air joins the solids, whereby the pressure approximates that in the vessel but the air is relatively dust-free.

3. In a blast-furnace operation in which coal fines are contained in a closed vessel and injected into a tuyere of the furnace, the pressure at the tuyere being subject to variations, the combination therewith of a method of transferring the fines from the vessel to the tuyere and controlling the rate of transfer comprising introducing air to said vessel to pressurize the vessel and force fines to discharge therefrom, pneumatically conveying fines discharge from said vessel to the tuyere, measuring pressures representative of those in said vessel and at the tuyere, and adjusting the pressure in said vessel in accordance with variations in the pressure at the tuyere to maintain the pressure in said vessel at a value such that the pressure drop between said vessel and said tuyere is substantially constant.

4. In a blast furnace operation in which coal fines are

contained in a closed vessel and injected into a tuyere of the furnace, the pressure at the tuyere being subject to variation, the combination therewith of a method of transferring the fines from the vessel to the tuyere and controlling the rate of transfer comprising introducing air at a constant rate from a primary supply to said vessel to pressurize it and force fines to discharge therefrom, continuously introducing air from a secondary supply to fines discharging from said vessel to convey the fines to the tuyere, continuously bleeding air from said vessel, the pressure within said vessel being a function of the rate at which air escapes therefrom, measuring pressures representative of those in said vessel and at the tuyere, and adjusting the rate at which air escapes in accordance with variations in pressure at the tuyere to maintain a substantially constant pressure drop between said vessel and the tuyere.

5. In a pneumatic installation for handling finely divided solids, which installation includes a closed vessel adapted to contain the solids, a device to which the solids are transferred from said vessel and from which they discharge, the pressure at said device being subject to variations, and piping connecting said vessel and said device, the combination therewith of apparatus for controlling the rate at which the solids are transferred, said apparatus comprising means for introducing air at a constant rate to said vessel to force solids therefrom into said piping and thence to said device, means for continuously bleeding air from said vessel, the pressure within said vessel being a function of the rate at which air escapes therefrom, means operatively connected with said installation for measuring pressures representative of those in said vessel and at the discharge of said device, and means operatively connected with said measuring means for adjusting the quantity of air escaping from said vessel in accordance with variations in pressure at said device to maintain the pressure in said vessel at a value such that the pressure drop between said vessel and the discharge of said device is substantially constant.

6. In a pneumatic installation for handling finely divided solids, which installation includes a closed vessel adapted to contain the solids, a device to which the solids are transferred from said vessel and from which they discharge, the pressure at said device being subject to variations, and piping connecting said vessel and said device, the combination therewith of apparatus for controlling the rate at which the solids are transferred, said apparatus comprising means for introducing air from a primary supply at a constant rate to said vessel to force solids therefrom into said piping, means for introducing air from a secondary supply to said piping to convey the solids to said device, means for continuously bleeding air from said vessel, the pressure within said vessel being a function of the rate at which air escapes therefrom, means operatively connected with said installation for measuring pressures representative of those in said vessel and at the discharge of said device, means operatively connected with said measuring means for comparing the two pressures, and means operatively connected with said comparing means for adjusting the quantity of air escaping from said vessel in accordance with variations in pressure at said device to maintain the pressure in said vessel at a value such that the pressure drop between said vessel and the discharge of said device is substantially constant.

7. A combination as defined in claim 6 in which said installation is a blast furnace and said device is a tuyere of the furnace.

8. A combination as defined in claim 6 in which said vessel has orifice-forming means in its lower end through which solids discharge into said piping, and including additional means for introducing air from said primary supply to said vessel in the vicinity of said orifice-forming means to fluidize the solids to assure a smooth flow thereof.

9. In a blast furnace operation in which coal fines are contained in a closed vessel and injected into a tuyere of the furnace, the pressure at the tuyere being subject to variation, the combination therewith of a method of transferring the fines from the vessel to the tuyere and controlling the rate of transfer comprising introducing air at a constant rate from a primary supply to both the upper and lower portions of said vessel, the air introduced to the upper portion serving to pressurize the vessel and force the fines to discharge from the bottom thereof, the air introduced to the lower portion serving to fluidize the fines as they discharge, continuously introducing air from a secondary supply to the fines after they discharge from said vessel to convey the fines to said tuyere, continuously bleeding air from said vessel, the pressure within said vessel being a function of the rate at which air is bled therefrom, measuring the pressure of air introduced from said secondary supply before it reaches the fines, measuring the pressure at said tuyere, and adjusting the rate at which air is bled from said vessel in accordance with variations in pressure at the tuyere to maintain a substantially constant pressure difference between the two locations at which pressure is measured.

10. In a blast furnace installation which includes a blast furnace having a tuyere, the pressure at said tuyere being subject to variations, a closed vessel adapted to contain coal fines for injection into the furnace through said tuyere, and piping connecting said vessel and said tuyere, the combination therewith of an apparatus for transferring the coal fines through said piping from said vessel to said tuyere and controlling the rate of transfer, said apparatus comprising a primary air supply, means for introducing air at a constant rate from said primary sup-

ply to both the upper and lower portions of said vessel, the air introduced to the upper portion serving to pressurize the vessel and force the fines to discharge from the bottom thereof into said piping, the air introduced to the lower portion serving to fluidize the fines as they discharge, a secondary air supply, means for introducing air from said secondary supply to said piping to convey the fines to said tuyere, means connected to said vessel for continuously bleeding air therefrom, the pressure within said vessel being a function of the rate at which air is bled therefrom, means connected to said piping for measuring the pressure of the air from said secondary supply before it reaches the fines, means connected to said tuyere for measuring the tuyere pressure, means connected to both said measuring means for comparing the pressures, and means connecting said comparing means with said bleeding means for adjusting the rate at which air is bled from said vessel to maintain a substantially constant pressure difference between the two locations at which pressure is measured.

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