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A FLOW DIVERTER-VALVE FOR GRANULAR SOLIDS

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IN NUCLEAR SCIENCE ABSTRACTS

J. C. Petrie and E. D. Cooper

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A B S T R A C T

The design and operating characteristics of a non-mechanical, pneumatically operated, solids flow diverter-valve are described. The device is useful in diverting the flow of granular solids from a common supply header to any one of several terminals. The absence of moving parts makes the device attractive for use where minimum maintenance is important.

A FLOW DIVERTER-VALVE FOR GRANULAR SOLIDS

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A FLOW DIVERTER-VALVE FOR GRANULAR SOLIDS

SUMMARY AND INTRODUCTION

A pneumatically operated device for controlling the rate and direction of flow of granular solids has been developed and tested for use at the Waste Calcining Facility at the Idaho Chemical Processing Plant. The flow diverter operates without mechanical apparatus, and depends on the angle of repose of the granular solids for its operating principle. The rate of flow of a small air stream injected into the diverter controls the rate of flow of granular solids through the diverter.

The solids flow diverter can be used for diverting the flow of most granular solids from a common header to any of several terminals. Properties of the solids, such as density, size, size range, and angle of repose, influence the design details for the flow diverter, but the basic operating principle remains the same. The absence of mechanical equipment makes the use of this flow diverter attractive where maintenance must be minimal or non-existent.

OPERATING PRINCIPLE OF FLOW DIVERTER BASED ON EARLIER WORK

A design was advanced by others for a solids flow control valve which has no moving parts⁽¹⁾. The first step in the present investigation was the fabrication and operation of a two-inch-diameter glass valve of that type. Details of the test stand are shown in Figure 1. The specific objective of the test was to determine the applicability of this type of valve for the control of granular solids produced in the Idaho Waste Calcining Facility (WCF).

The flow of solids from a vertical pipe is stopped at an off-set horizontal section by the angle of repose of the solids. A small stream of air or gas introduced at the mitered corner fluidizes these solids, thereby eliminating the angle of repose. The solids then flow through the horizontal off-set section to the vertical downcomer where gravity flow and the air stream carry the solids to the desired location. The baffle which covers about one-fourth of the mitered corner prevents air flow up the vertical pipe. Important design parameters are: angle of repose of the solids, dimensions of the pipe, length of the horizontal section, and point and direction of air introduction.

The purge or fluidizing air can be introduced into the valve either through a horizontal or vertical inlet (see Figure 1). Two operating parameters were judged important in determining the better location for the air inlet: (1) greater solids flow rate at a given air flow rate, and (2) minimum undisturbed accumulation of solids in the horizontal section of the valve. The horizontal entry was better than the vertical entry by both standards.

Figure 1
Two-Inch-Diameter Glass Valve

SOLIDS OF VARYING PROPERTIES TESTED

Three types of granular solids were tested, varying widely in size range and density. These solids are typical of those solids transferred from one location to another at the WCF⁽²⁾. Table I lists the properties of the solids.

Table I

PROPERTIES OF GRANULAR SOLIDS

<u>Property</u>	<u>Coarse Alumina</u>	<u>Fine Alumina</u>	<u>Silica Gel</u>
Bulk Density ^(a) , g/cc	1.0	0.4	0.8
Size Distribution, %			
Tyler Mesh, 14	3.2		91.9
16	4.3		6.0
20	9.1		1.7
24	11.8		0.4
28	20.2		
32	11.9		
35	12.5		
48	15.5		
65	8.2		
100	3.3		
150		1.0	
200		0.4	
-200		98.6	
Angle of Repose, °	30	0	30

(a) Bulk density given here is defined as the poured, untapped density.

The fine alumina is not a granular solid in the sense that coarse alumina and silica gel are. Fine alumina resembles household flour in that it is fluffy while being transported, yet packs when allowed to settle over a period of time. This material is difficult to handle or transport because of its tendency to pack. The combined coarse and fine alumina behaves as a granular solid.

HORIZONTAL AIR INLET BETTER THAN VERTICAL INLET

Figures 2 and 3 show that, for a given air flow rate, the solids flow rate is greater for horizontal entry of air than for vertical entry. This difference can be attributed to the jetting action caused by the horizontal entry. Much of the energy of the air stream from the vertical entry is lost when the air stream strikes the top of the horizontal section. In contrast, the energy of the air stream from the horizontal entry is expended in the direction of solids flow along the horizontal section. An accumulation of undisturbed solids between the vertical entry and the vertical discharge pipe resulted in more solids being held in the valve when the vertical entry was used than was the case when the horizontal entry was used.

Figure 2
Coarse Alumina Flow Rates
Through the Glass Valve

Figure 3
Coarse and Fine Alumina Flow
Rates Through the Glass Valve

SOLIDS PROPERTIES AFFECT VALVE OPERATING CHARACTERISTICS

Properties of the solids have a definite effect on the solids flow rate and operating characteristics of the solids flow control valve. Size or size distribution and density were the most important properties of the three materials tested: (1) coarse alumina, (2) various mixtures of coarse and fine alumina, and (3) silica gel.

The flow rate of fine alumina cannot be controlled. The flour-like solids flowed through the valve, even with the air purge shut off.

Flow rates determined for var-

Figure 4

Flow Rates for Mixtures of Coarse And Fine Alumina Through The Glass Valve

ious mixtures of coarse and fine alumina are shown in Figure 4. The leveling off seen in the flow rate curves for the mixtures is attributed to bridging of the solids in the reservoir above the valve, caused by compaction of the fine alumina.

A definite on-off operating characteristic can be seen in Figure 5 which shows the flow rates determined for silica gel. The narrow size range and relatively large particles contributed to the on-off characteristic. Similar on-off operating characteristics can be seen in Figures 2 and 3 which show the solids flow rates determined

Figure 5

Silica Gel Flow Rates Through the Glass Valve

for coarse alumina. The on-off effect is not as great for the alumina, probably because of the wider size distribution and smaller particle sizes.

DIVERTER-VALVE DESIGN DEVELOPED FOR THE WCF

A diverter-valve was needed at the underground storage bins serving the WCF. Combined coarse and fine alumina are transported by air from the fluidized bed calciner to the storage bins⁽²⁾. There the solids are directed into one of seven bins, the choice of which depends on other considerations. Two of the seven bins required controlled entry of solids so that special calcined wastes could be stored separately.

Figure 6 schematically shows the solids-diverter valve assembly above the storage bins. Solids are separated from the transport air by a cyclone located above the bins. The solids accumulate in the apparatus shown in Figure 6. Five of the storage bins will be filled by overflow from the central accumulator; the order of filling has been determined by the location of the overflow lines on the accumulator. Flow to the two remaining bins can be stopped or started at will by stopping or starting the air flow into the box at the bottom of the control accumulator.

The diverter-valve operates on the same principle as the glass valve described earlier. An air purge causes the solids to flow through the diverter-valve to the selected bin. The air purge inlet line terminates at the intersection of the wall of the box and the horizontal discharge pipe. The wall of the box serves as a baffle to prevent air flow up the vertical accumulator.

FULL-SCALE MODEL OF THE DIVERTER-VALVE TESTED

A full-scale model of the diverter-valve was fabricated of glass and steel and tested to demonstrate operability, determine solids flow rates, and determine possible erosion characteristics. In addition, the location of the air purge line relative to the cross section of the horizontal pipe was optimized.

Figure 7 shows the locations of the purge air line which were

Figure 6
Application of Flow Diverter-Valve at the WCF

Figure 7
Possible Air Inlet Locations
Relative to Cross Section of the
Horizontal Discharge Pipe

tested. In all cases, the air purge line terminated at the junction between the box and the horizontal discharge pipe. The best location, B in Figure 7, was selected as the one which yielded the maximum solids flow rate for a given purge air rate and indicated the least erosion. Particles swirled when locations A or D were tested using a glass horizontal discharge pipe, whereas no swirling was noted when locations B or C were tested. Locations A and D were eliminated because the swirling particles could cause erosion. Location B gave a higher solids flow rate for a given air flow rate than did location C.

The interior of the glass discharge pipe was painted to provide a surface for an accelerated erosion test. Areas in the discharge pipe that could be eroded in actual operation would be indicated by areas of significant paint removal. This technique yielded a qualitative indication of erosion in brief tests. The reliability of this technique was demonstrated in other short-term erosion tests⁽³⁾ in which negligible paint removal in a 15-minute period was found to correspond to negligible long-term erosion of stainless-steel in service. Erosion using location B should be minimal because little or no paint was removed during tests of two hours duration.

Two modes of operation using location B were tested. In the first mode, a blast of air was used to clear the horizontal section of solids. The air rate was then reduced to handle the required solids flow rate. For the second mode of operation, the purge rate was simply started at the desired rate; this mode resulted in a small accumulation of solids in the horizontal discharge pipe.

SOLIDS FLOW RATES DEPEND ON LENGTH OF HORIZONTAL DISCHARGE PIPE

Because of the geometry between the location of the diverter-valve and the inlets to the solid storage bins, the length of the two horizontal discharge pipes was different, one being 8-1/2 inches in length, and the other 6-1/4 inches. The difference in length of the horizontal discharge pipe caused the differences in the flow rates shown in Figures 8 and 9.

Figure 8 shows the flow rates determined for a mixture of coarse and fine alumina, typical of that produced at the WCF. The solids flow diverter-valve will adequately control solids flow rates from 100 to 1500 lbs/hr.

Figure 9 shows the flow rates determined for transfer of the silica gel. The on-off operating characteristic noted during testing of the glass valve is evident in Figure 9.

DIVERTER-VALVE DESIGN CAN BE EXTENDED FOR MULTIPLE OUTLETS

It is frequently desirable to divert a stream of solids to any one of several locations. In the earlier work⁽¹⁾, only one outlet was used, making the device a simple valve. Two designs have been developed that provide essentially an infinite number of possible outlets by extending the use of the operating principle discussed previously. Basic features of both designs are shown in Figure 10.

In Figure 10A, solids from above the valve fall into the central accumulator until the solids level builds up to the level of the desired flow diverter. A small flow of air introduced to the horizontal section interrupts the angle of repose, causing solids to flow into the connecting transfer line. Solids flow could be diverted in any random order as required by the process demands.

In Figure 10B, solids are likewise delivered to a central accumulator. The number of outlets from the box at the bottom of the assembly is determined by the number of sides on the box. A round

Figure 8
Alumina Flow Rates Through
Full Scale Model Of
Flow Diverter-Valve

Figure 9
Silica Gel Flow Rates
Through Full Scale Model
Of Flow Diverter-Valve

10A

10B

Figure 10 Alternate Designs for Flow Diverter-Valve

assembly would work equally as well as the multi-sided box. In both designs the air purge line would terminate at the junction between the wall of the accumulator and the horizontal discharge pipe.

Many other design variations are possible, including stacking diverters together in a manner similar to manifolding of valves common to most processes. The possibilities for arrangement of an assembly using this basic design are virtually unlimited.

Although the diverter-valve is applicable to streams of free flowing granular-type solids, no method for predicting the performance of this type of device is known. Therefore, tests must be made to determine exact performance characteristics for each particular application.

REFERENCES

1. J. W. Gerhart, Development of a Valve for the Control of Streams Composed of Powdered or Granular Solids, HW-54330, (November 1957).
2. L. T. Lakey, J. R. Bower (eds.), ICPP Waste Calcining Facility Safety Analysis Report, IDO-14620-Rev. 1, (December 1963).
3. J. C. Petrie, D. E. Black, Development of Air Distributor Caps For A Fluidized Bed Process, A paper prepared for presentation at the 58th National Meeting of the American Institute of Chemical Engineers, Dallas, Texas, February 1966.

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