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TRANSPORT OF FINELY DIVIDED SOLIDS

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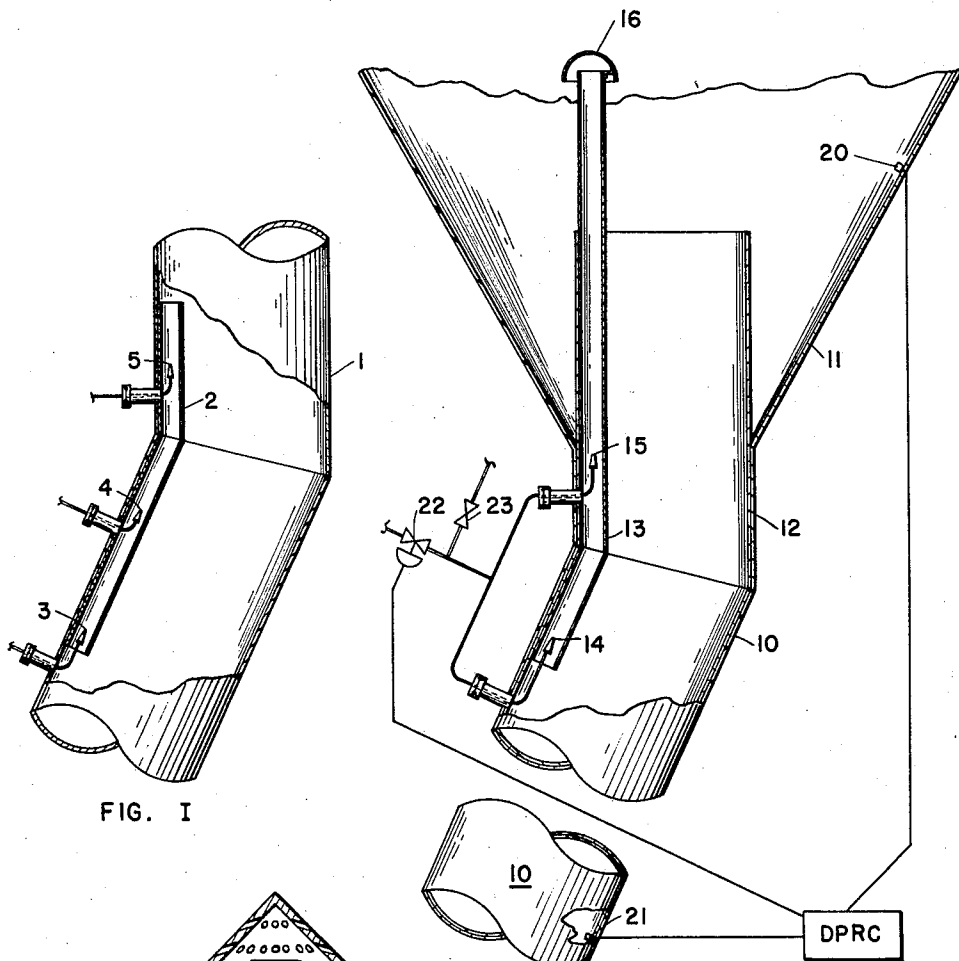


FIG. I

FIG. II

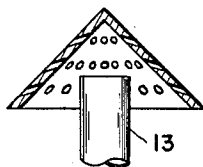


FIG. III

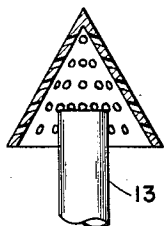


FIG. IV

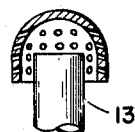


FIG. V

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TRANSPORT OF FINELY DIVIDED SOLIDS

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2 Claims. (Cl. 302—35)

This invention relates to the transport of finely divided solids by gravity flow through a conduit containing a bend.

It is well known that most solids when finely divided and somewhat aerated behave in many respects like a liquid. Thus, they seek their own level and exert a "hydrostatic" head. Such solids are frequently transferred from one vessel to another by pipeline. When it is desired to transport the solid from a higher elevation to a lower elevation it is the practice to effect the flow by the force of gravity. When it is desired to raise the solid from the lower elevation to a higher elevation it is the practice to effect the transport by the use of a carrier gas such as air, steam or the like. In the former case the density of the solid in the line is relatively high and in the latter case it is relatively low. In this latter case the gas injected to effect the transport works against a pressure head which is approximately equal to the weight of the solid in the line extending from the lower to the upper station. In order, therefore, to prevent the gas from backing up it is common to feed the solid at the lower station through a standpipe of sufficient height that the static head of the more dense solid therein is sufficient to overbalance the pressure head in the line leading from the lower to the upper station.

Frequently, the line constituting this standpipe has for one reason or another a bend which may be abrupt or curved. For example, this standpipe frequently slopes downward from a vertically disposed hopper vessel so that the solid in descending changes direction from a vertical direction to an inclined direction on passing from the hopper into the inclined line. In other cases the standpipe line may descend vertically for a few feet and then bend to a path anywhere from 15 to 70° from the vertical. It is in situations such as these where my invention finds application.

By means of gamma ray analysis of the densities of the solid in such downcoming lines it has been found that when this line involves a bend of 15° or greater from the vertical there is an appreciable distance in which the density of the solid is considerably below that which would be expected. This is a serious shortcoming, especially at high flow rates, because any loss in density decreases the pressure head at the low point and this can lead to reversal of the carrier gas flow from the rising section of the transfer line.

While this defect in existing installations may be noted when the bend in the down flowing line is 15° or greater it will be appreciated that gravity flow is never attempted at an angle so close to the horizontal that the solid must flow downward at an angle less than its angle of repose. Therefore, an angle of about 70° from the vertical is about the upper limit of tilt and the tilt is generally not more than 45°.

I have found by trial that the described loss in static head in gravity flow lines involving an appreciable change in the direction of flow, i.e. bend may be remedied by applying in the bend of such lines within the line itself

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and on the inside of the bend a second open ended conduit or relatively small cross section through which a reverse flow of gas from the outside is forced.

Also I have developed an arrangement and system of control whereby the operation of the inner conduit, and hence the main conduit, may be made most efficient. Broadly speaking, I accomplish the objective by passing through an inner conduit on the inside of the bend a reverse flow of gas from a point below the bend to a point above the bend. The preferred method of providing this reverse flow of gas is by means of one or more jets of relatively high pressure gas from an outside source, injected at one or more points along the length within the inner conduit in a direction opposite to that of the flow of the solids in the main conduit. When such gas injection is used it is arranged to educt gas from one or more points along the length of the inner conduit on the top side of the main conduit within and/or below the bend. Two or more of such inner conduits of the same or varying lengths may be used but one is normally sufficient. The cross section of the inner conduit is normally between about $\frac{1}{100}$ and $\frac{1}{4}$ of the cross section of the main conduit.

My invention will now be further described with reference to the accompanying drawing and to a specific example.

In the drawing Fig. I illustrates a section of a gravity flow transfer line containing a bend.

Fig. II illustrates part of an inclined gravity flow line connected to the bottom of a hopper vessel.

Figs. III, IV, and V illustrate details of baffle arrangements which may be applied over the upper end of the inner conduit.

Referring to Fig. I there is illustrated diagrammatically a part of a gravity flow line 1 containing a bend. This line is about 2 feet in diameter. Tack welded to the inside of the bend within the line is second open-ended line 2 which extends from a point somewhat below the bend to a point slightly above it. This line is constructed of 6 inch pipe. In the particular case illustrated three gas injection nozzles 3, 4 and 5, all pointed along the line in an upward direction, are provided. These nozzles are located within the inner conduit tube. During operation any suitable gas is injected by one or more of these nozzles.

Fig. II illustrates diagrammatically a modification in which the inclined standpipe 10 takes off from a hopper vessel 11, after a short coupling piece 12, at an angle of about 25° from the vertical. Here the inner conduit 13 supported in the upper side of the conduit 10 extends somewhat less below the bend than above it. It is entirely possible that the upper end of the inner conduit be further extended. In this case two gas injection nozzles 14 and 15 within the inner conduit are shown. Either one or both may be used during operation depending upon the requirements.

Since in the cases illustrated in Figs. I and II the upper end of the inner conduit is obviously below the level of the finely divided solid in the line of Fig. I or the hopper of Fig. II (a condition that is not essential), it is desirable, but also not essential, to cover the upper open end of the inner conduit with a baffle or hat which allows the gas injected in reverse flow to rise against the down flowing solid without the solid filling the inner conduit. If sufficient gas flow is maintained through the jets by means of the nozzles it is impossible for the inner conduit to fill with solid flowing down. However, in the interest of economy it is not desirable to maintain high gas flows in the inner conduit except when necessary. The upper end of the inner conduit may therefore be provided with a hat 16 which may be supported in any convenient manner. To avoid complications about insignificant matters

the means for supporting the hat are not shown in Figs. III, IV and V. Bars welded to the pipe and to the hat are sufficient.

The hat 16 may be curved as illustrated diagrammatically in Fig. II and in more detail in Fig. V but is preferably of either a flat cone or steep cone as illustrated in Figs. III and IV. The lower ends of the cones may be sufficiently below the top of the inner line 13 to overcome the tendency of the solid to flow under the bottom of the cone into the inner conduit.

As illustrated in Figs. III, IV and V the cone or hat may be advantageously perforated with perforations slanting downward from the inside out to prevent any appreciable amount of the solid from entering under the hood covering the upper end of the inner conduit.

Any and nearly all gas which passes upward in the conduit 2 of Fig. I or 13 of Fig. II passes up through the finely divided solid in the form of bubbles and is released at the top of the body of finely divided solids. If however the inner line is continued upward to beyond the level of the finely divided solid such gas naturally does not pass into contact with the body of the finely divided solid. The finely divided solid may of course be aerated upward of the bend to maintain it a free flowing condition.

If the hats illustrated in Figs. II, III, IV and V are not used or properly designed there can occur situations in which the inner line becomes filled with downwardly moving solid and in some cases this can occur without warning when the gas injected is near the minimum to prevent such occurrence. For this contingency, which need not be encountered unless the design is intentionally so arranged for maximum economy, there is a good safeguard which is to provide the system with automatic controls as illustrated in Fig. II. In this system a pressure tap 20 is coupled with a pressure tap 21 through a differential pressure recorder controller instrument of known design arranged in known manner to actuate a control valve. In this case the valve controlled by the differential pressure recorder controller is a valve 22 allowing high pressure gas to enter the jets in the inner line. In any case where the density in line 10 between the pressure points 21 and 20 drops below a set level due to drop in density in line 10 between these points the differential pressure recorder controller opens valve 22 and thereby allows high pressure gas to blow out the inner line 13 and thus re-establish the desired condition. In the meantime, low pressure gas is continuously passed in a desired amount by valve 23.

Example

In a commercial operation a silica-alumina composite in the form of a powder passing a 100 mesh U.S. standard sieve was transferred by gravity flow at a rate of about 40 tons per minute from a first vessel through a standpipe 42 inches in inside diameter containing a bend from the vertical of about 35°. The arrangement was otherwise as illustrated in Fig. II except that the inner conduit and baffle were absent. The dimensions may be seen

from Fig. II which in the original Bristol board is to a scale of $\frac{3}{8}$ inch equals one foot. It was found that the density of the solid flowing in this standpipe was about 5.3 pounds per cubic foot. Consequently the solid exerted only a small "hydrostatic" head, i.e. 0.035 pound per square inch per foot.

An open ended inner conduit (6 inch pipe) 13 with a single nozzle 14 for gas injection and without the baffle 16, but otherwise as shown in Fig. II, was then installed. Continuing the same operation, steam was injected by the nozzle 14 at different rates and the densities in the standpipe were measured with the following results:

Gas to Nozzle, lb. mols per hour	Density, pounds per cu. ft.			
0	5.3	5.1	5.6	
0.72	9.8	13.1	10.7	15.9
2.5	17.8	16.4		

It will be apparent that even the relatively small flow of 0.72 pound mols of gas per hour approximately doubled the density in the line.

I hereby claim as my invention:

1. In the transport of a solid in finely divided condition in a conduit by gravity flow through a bend of at least 15° the improvement which comprises passing gas from an exterior source counter-current to said finely divided solid through a second open ended conduit within the first said conduit on the upper side of said bend from a point below said bend to a point on the upper side of said bend to aspirate gas from the first said conduit below said bend and retain the open ended conduit substantially free of descending solids.

2. In apparatus for the transport of finely divided solids from a supply vessel by means of a carrier gas, said apparatus comprising a standpipe line designed to build up a pressure head of the downflowing solid so that at the base of said standpipe line the pressure head of the solid exceeds the pressure of the carrier gas, and said standpipe line being at least in part inclined from the vertical by at least 15°, the combination of a bent open-ended conduit having its lower extremity within the inclined portion of said standpipe line near the upper side thereof and its upper extremity above said inclined portion of said standpipe line, and conduit and nozzle means for injecting gas under pressure from an outside source to within said open-ended conduit in an upward direction, said parts being arranged to aspirate gas from the upper part of said standpipe line in the inclined portion thereof, thereby eliminating a zone of low density in the inclined portion of the standpipe line.

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