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New Developments in Pneumatic Conveying

The Advantages of Controlled Line Loading

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SUMMARY

A simple means has been developed to reduce conveying velocities, reduce wear and power, and to increase the reliability of pneumatic conveying systems for powders. This paper describes the work carried out by Macawber Engineering and the advantages to be gained from the systems developed.

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New Developments in Pneumatic Conveying - Advantages of Controlled Line Loading**)

A simple means has been developed to reduce conveying velocities, reduce wear and power, and to increase the reliability of pneumatic conveying systems for powders. This paper describes the test work carried out at Macawber and the advantages to be gained from the systems developed.

By effectively feeding material into the conveying line in direct response to demand from the pipeline pressure, optimum conveying conditions can be achieved with marked reductions in power. High phase density is obtainable even with the low transport pressures available from Roots-type rotary piston blowers.

1. Introduction

There are now on the market a number of conveying systems which claim to offer high efficiencies, low velocities, and hence, low wear of the conveying pipeline. These systems, however, can be complex and expensive in their construction and may include pipes within pipes, by-pass pipes or line boosters. They may also be simple, high pressure blow tanks using high pressure air.

If low cost is important and the product is not particularly abrasive then a rotary valve system can be considered. However, rotary valve pneumatic conveyors are limited due to their dependence on relatively large pipeline diameters due to the low system pressure drop availability from the rotary valve of only 10 psi (0.7 bar) maximum. Also the lower limits of safe conveying velocity are very much dependent on the saltation velocity which may be from 30 to 100 ft./s (9 to 30 m/s) dependent upon the material being conveyed.

Yet another option is the screw pump which is traditionally used for cement, fly ash and similar powders. Their limitations are the pressure at which they can realistically operate of 20 - 30 psi (1.3 - 2 bar), the fairly narrow range of particle sizes that can be handled, and the need for a line velocity high enough to give a smooth, stable pressure gradient through the system. Since the material is mechanically forced into the pipeline, it is important to immediately move the material down the

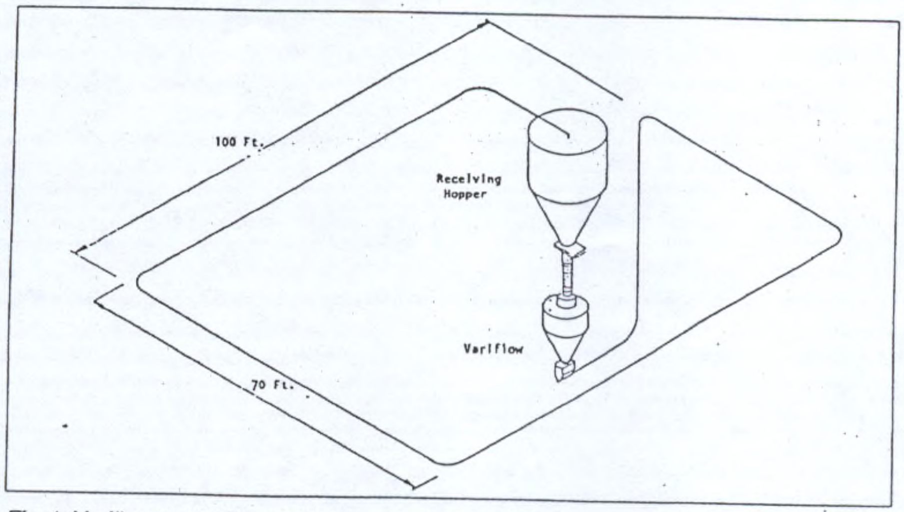

Fig. 1: Variflow test facility; total conveying distance 355 ft.

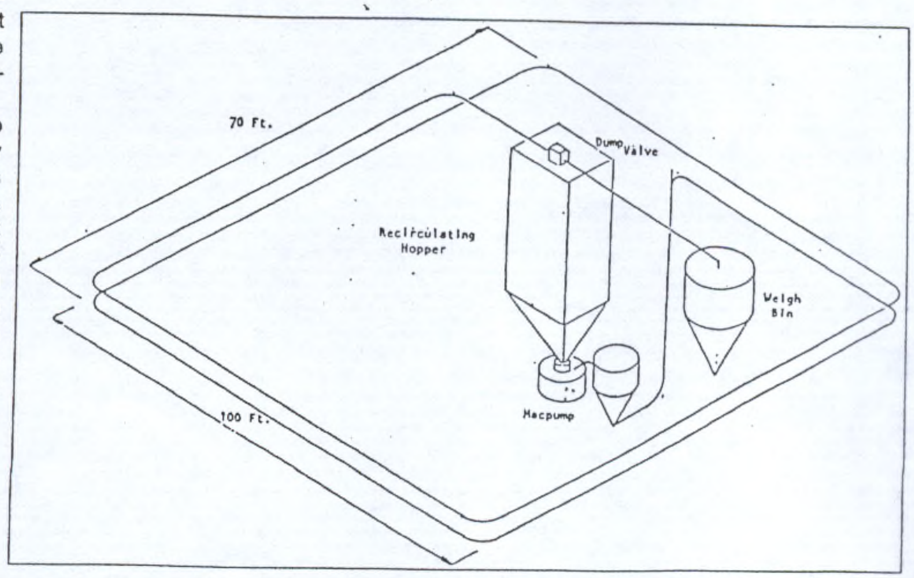

Fig. 2: Macpump test facility; total conveying distance 700 ft.

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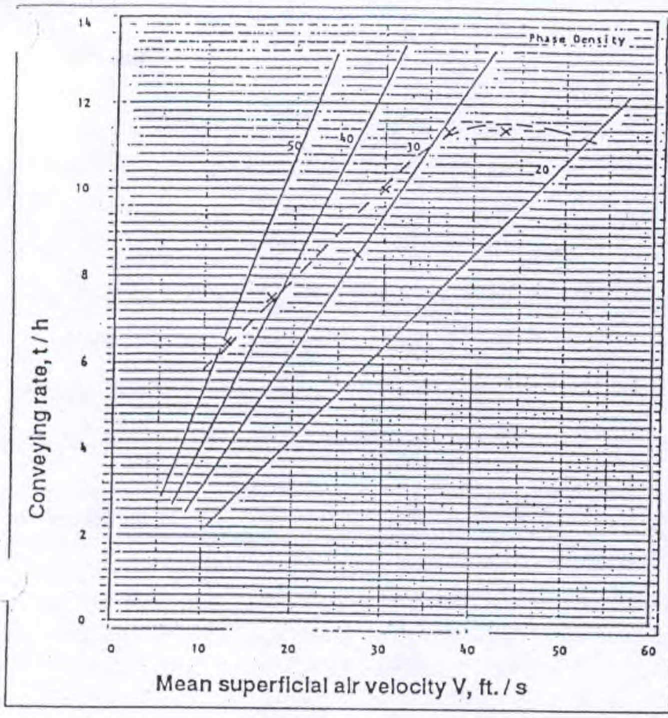

Fig. 3: Variflow tests in low velocity range cement

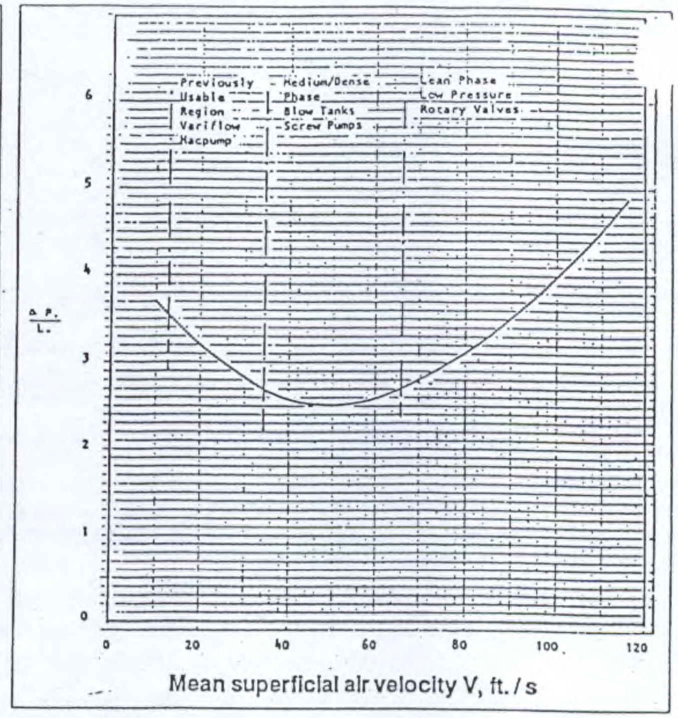

Fig. 4: Typical velocity/pressure drop relationship for a constant feed rate

line to avoid choking at the pump outlet. The same rule also applies to lean phase systems using rotary valves.

The objectives of the work carried out by Macawber were:

- To produce a low cost system that could be used in place of a rotary valve and at the same time gain the benefit of using a low cost 15 psi (1 bar) rotary piston blower which would be used at its maximum running pressure to achieve higher tonnage rates for a given line size than are possible with the lower pressures used with rotary valves. This low pressure system was designated the Variflow.
- To produce a high pressure, continuous feeding system capable of replacing screw pumps which would overcome the high power costs, maintenance costs and other limitations associated with them, and at the same time use the existing medium pressure compressors of 20 - 40 psi (1.4 - 2.7 bar) normally installed and operating with a screw pump. This higher pressure system was designated the Macpump.

From these requirements, two systems have been developed:

- Variflow: For low pressure, semi-continuous operation with continuous air flow.
- Macpump: For medium and high pressure, continuous operation over medium and long distances.

For both systems it was decided that a material feed control device would be needed to control the line pressure and obtain maximum conveying rates from the pressures available.

During the test work it soon became clear that control of the line loading not only gave optimum performance from the pressures available, but also allowed the system to operate in regions of pressure, phase density and velocity that are traditionally "no go" areas.

This paper describes some of the test work and compares the results with other systems available.

2. Test equipment

At Macawber's research and test facilities in Maryville, Tennessee, full scale working systems were constructed. Fig. 1 shows the test and demonstration facility for the Variflow. Fig. 2 shows the test and demonstration facility for the Macpump.

Although a number of materials have been tested, the examples shown for both systems are for cement since this is a common material with sufficient data available from other sources to make comparisons with the various alternative systems.

3. Variflow tests

The Variflow is a semi-continuous batch machine with continuous air flow and modulated batch feed of the material into the pipeline. The material feed rate into the pipeline is controlled by a discharge valve which is line pressure controlled in its open to closed position by the conveying line pressure.

As the valve opens and becomes loaded with material, the pressure differential down the line increases to the set point, and the valve closes an amount dependent on the line pressure. The valve modulates and maintains the line pressure close to the chosen level.

Fig. 3 shows the result of a number of tests and shows the very low velocity at which the system will reliably convey, with phase densities in excess of 40 to 1 and with only 15 psi (1 bar) conveying pressure.

4. Macpump tests

The Macpump is a continuous feed system which has two vessels, the Dispe ing Vessel which is similar to the Var. vessel with an outlet valve controlled by conveying line pressure, and a Transfer Vessel which replenishes the material level in the Dispensing Vessel by batch transfer on demand from a level control in the Dispensing Vessel. The Macpump works at a higher pressure than the Variflow and is designed with a low material feed inlet height, and is configured as a direct replacement for screw pumps.

The tests results for this machine show a similar ability to convey at low velocities and with high phase densities. With a system length of 700 ft. (213 m) and using only 18 psi (1.24 bar) pressure differential, a phase density in excess of 40 to 1 was achieved with mean air velocities of 17 ft/s (5.1 m/s). Fig. 5 shows the permanent test Macpump facility.

5. Comparisons with other systems

Development and test work over a period of 24 months using full size test loops at Macawber's test facility in Maryville / Tennessee has produced the following comparative data, and is shown here with regard to cement powder (Tables 1 + 2).

With both low and high pressure systems, it can be seen that significant velocity and power reductions are possible with the Variflow and Macpump. Since there is no fundamental difference in the conveying lines between the various systems, i.e. no external air source or internal conveying aids, etc., the reason for the ability to run at such low speeds must be within the mechanism of material feed and line pressure control.

Rotary valves, blow tanks and screw pumps have one basic fundamental common feature. They all positively introduce material into the conveying line without regard for the consequence. This results in the typical pressure drop in air velocity graph shown in Fig. 4 which has been reproduced by many researchers.

The "unstable" region is usually at a point just below the minimum pressure drop point for a given feed rate. It is chosen based on the difficulty that the researcher has in getting the equipment to work without pressure instabilities or pipe blockages.

These unstable regions occur because the material feed rate is fixed, and the air pressure is allowed to respond to line conditions produced by the material flow. With screw pumps or rotary valves, any hold-up due to plug formation will immed-iately cause bunching up and consolida-tion of the material with a rapid increase in line pressure as the air flow slows down due to the increase in friction caused by the consolidated plug. Fluctuations in line pressure occur with eventual line blockage.

Blow tanks suffer a more complex problem when trying to work within the "unstable" region. Control of the material flow rate from the tank is set by proportions of air to the tank for fluidizing and dilution air added into the conveying line near to the blow tank. Pressure fluctuations in the line caused by working at low velocities can lead to the same plug formation as for the positive feed devices. Since these pressure surges are also seen in the blow tank, the result is surging of the material and changing material feed rates into the conveying line.

The use of an effective material feed control valve linked to the line pressure allows a selected line pressure to be held within close limits. The material feed is controlled to increase material feed if the pressure falls, and decrease material feed if the pressure rises. Any tendency for the line pressure to increase due to plug formation in one part of the system is instantly counteracted by a reduction in material feed, thus avoiding any momentary overpressures that will cause plug compactions and subsequent pipe blockages or erratic conditions.

Table 1: Low pressure systems

System type	P PSIG	Pipe dia. ins.	Phase density	Mean conveying velocity, ft/s	Air consumption SCFM	Power requirement kW
Rotary valve	12	10	5.7	63	2,570	149
Rotary valve	7	12	4.1	63	3,520	160
Variflow	15	8	20.6	25.5	710	55

Table 2: Medium pressure continuous systems

System type	P PSIG	Pipe dia. ins.	Phase density	Mean conveying velocity ft/s	Air consumption SCFM	Power required kW	Total power kW
Screw pump	28	7	10.9	42	1,340	115	139*
Continuous twin blow tanks	40	5	19.5	41	754	94	94
Macpump	35	5	38	24	390	45	45

* includes screw motor

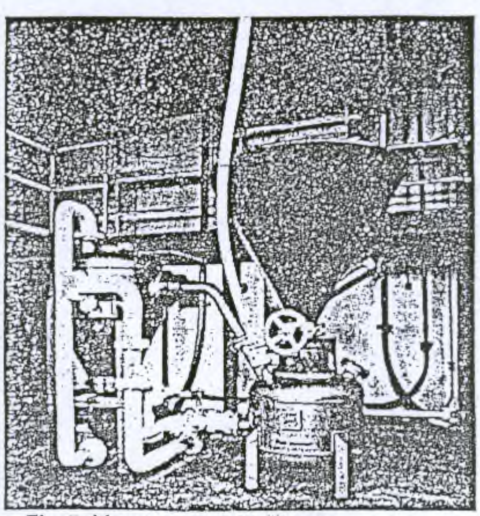

Fig. 5: Macpump test facility

6. Conclusions

The results clearly show that it is possible to greatly reduce the air and power requirements for conveying powders by applying a line loading arrangement as fitted to the Variflow and Macpump, and that the previously designated "unstable area" can become "stable" by using this technique. The self-compensating system obtains the maximum possible conveying rate from the pressure and air flow available. It compensates for changes in material density, particle size and general handling characteristics. Blockages are avoided since the line cannot become overloaded, and the pipeline remains a simple, low-cost item without the complexities which other techniques use to operate at low velocities.

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