1-1-2004

# Comparison of Rotary Valve and Blowtank Feed Rate Capacities

David B. Hastie
*University of Wollongong*, dhastie@uow.edu.au

Peter W. Wypych
*University of Wollongong*, peter_wypych@uow.edu.au

Ian Frew
*University of Wollongong*, ifrew@uow.edu.au

Christopher David Cook
*University of Wollongong*, chris_cook@uow.edu.au

https://ro.uow.edu.au/engpapers/1291

## Recommended Citation

Hastie, David B.; Wypych, Peter W.; Frew, Ian; and Cook, Christopher David: Comparison of Rotary Valve and Blowtank Feed Rate Capacities 2004, 371-376.
https://ro.uow.edu.au/engpapers/1291

# COMPARISON OF ROTARY VALVE AND BLOWTANK FEED RATE CAPACITIES

**DB Hastie, PW Wypych, I Frew and DM Cook**

Centre for Bulk Solids and Particulate Technologies, University of Wollongong
Northfields Avenue, Wollongong NSW 2522, Australia

**ABSTRACT** Rotary valves and blowtanks are widely used in industry for the pneumatic conveying of products, each having their pros and cons depending on the required application. This paper aims to show the differing results that can be obtained when conveying a product through a common pipeline using either a drop-through rotary valve or a bottom discharge blowtank. The rotary valve system has a number of issues, the main one being air leakage effects, whereas the blowtank system does not as it is an enclosed unit. The results of these experiments showed dramatic differences in product tonnage.

## 1 INTRODUCTION

Both rotary valves and blowtanks are widely used in industrial applications where the pneumatic transportation of materials such as poly pellets, grains and pharmaceuticals is required. Different applications call for the use of different equipment for such reasons as required tonnage, available space, cost, efficiency and product degradation.

### 1.1 Rotary Valves

In theory each rotor pocket of a "flood-fed" valve should fill completely as material is fed to it from the feed bin [1]. The feed rate can be calculated by using the following formula;

$$m_s = \rho_b \Psi N \tag{1}$$

This represents the maximum possible throughput of the rotary valve, as indicated by the straight line in Figure 1. This equation indicates that the rotor speed is the only variable needed to determine the feed rate as the other values are constant, however, the air leakage through the rotary valve can restrict the product flow thereby reducing the feed rate. Other influences will also affect the feed rate, such as; the product characteristics, rotor clearances and system pressure. This will result in the feed rate more likely resembling one of the curves shown in Figure 1.

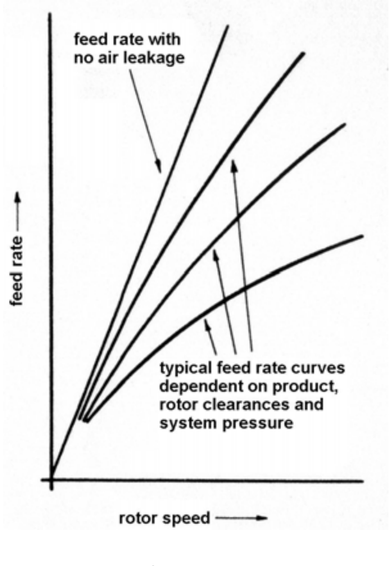

**Figure 1** Typical feed rate characteristics [1]

A lack of understanding when it comes to rotary valve air leakage can be detrimental at the design stage with the possibility of incorrectly sizing the air mover. For example, an oversized blower will result in extra cost and excessive conveying velocities and this can cause product and plant degradation. On the other hand an undersized blower may result in insufficient air velocity which could cause pipeline blockages.

### 1.2 Blowtanks

Blowtanks can operate at higher pressures than rotary valves and as a result can often convey over longer distances more reliably. There are a wide variety of feed arrangements for blowtanks: bottom discharge; top discharge; types that incorporate supplementary air to assist in conveying; and small single-slug batch conveyors. An advantage of using a blowtank is that it serves as the feeder and they are generally free of moving parts which can aid in the reduction of product degradation [1] and less maintenance is required.

## 2 TEST RIG

The test rig used comprises a 250mm NB drop-through rotary valve (8L capacity) and a 1m$^3$ bottom discharge blowtank which are interchangeable and connected to a stainless steel pipeline ($L$=37m, $L_v$=6.7m, $D$=98.4mm, five 1m long radius bends). Figure 2 shows the layout and dimensions. The feeding bin for the rotary valve, the blowtank and the receiving bin are all mounted on shear beam load cells to allow accurate measurement of feed rates through the system and were calibrated before testing commenced. A number of pressure transmitters are located along the pipeline and these were pressure checked and calibrated before testing. The various load cells and pressure meters as well as the annubar(s) for measuring the air mass flowrate are all connected to a data acquisition unit and PC for recording and later analysis.

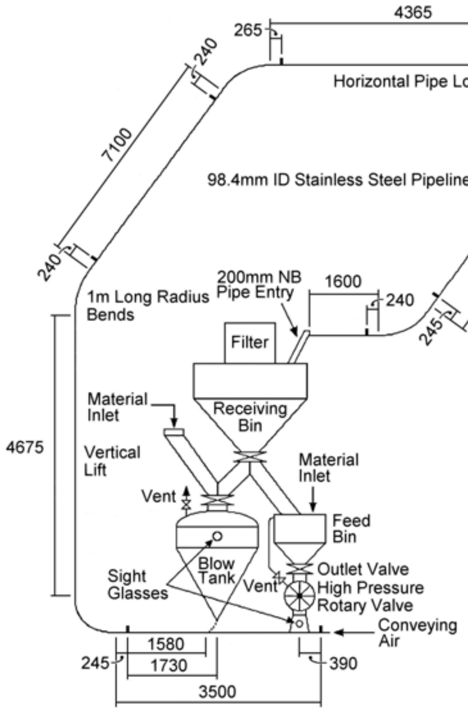

**Figure 2** Low-velocity test rig (dimensions in millimetres)

For testing with the rotary valve feeder, a wide range or air flows were used, selected by opening and closing a series of sonic nozzles to achieve the desired flow, and the rotary valve speed is controlled by a variable speed drive.

For testing with the blowtank feeder, the sonic nozzles are not used, instead a series of valves connected to the aeration cone and to the top air of the blowtank are adjusted to achieve the desired air mass flowrate. The combination of tests performed are displayed in Table 1. The blowtank is charged with product and the fill valve closed. As there is no shut off valve at the bottom of the blowtank the product fills the initial part of the pipeline as well as the blowtank and as the air is switched on, the pressure in the blowtank gradually increases to a point when the product begins to convey. Figure 3 shows the various air inlet points on the blowtank feeder used.

**Table 1** Test sets used for the blowtank

| Set 1 | Set 2 |
|---|---|
| 100% top air | 100% top air |
| 80% top air / 20% cone air | 80% top air / 20% conveying air |
| 60% top air / 40% cone air | 60% top air / 40% conveying air |
| 40% top air / 60% cone air | 40% top air / 60% conveying air |
| 20% top air / 80% cone air | 20% top air / 80% conveying air |
| 100% cone air | 100% conveying air |

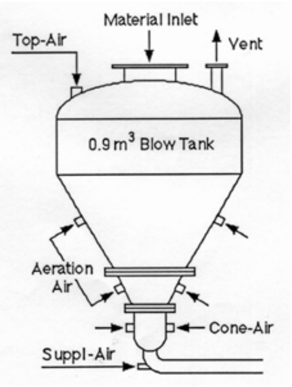

**Figure 3** Blowtank schematic showing top, cone and conveying air

## 3 RESULTS

For the tests using the rotary valve feeder, rotary valve air leakage is an issue. As the valve rotates, the empty pockets allow some of the supplied conveying air to travel up through the valve and into the feeding bin, this is called carry-over leakage. Air can also escape up through the rotary valve around the clearances of the rotors, which is known as clearance leakage. As well as reducing the actual air available for conveying, the air leaking up through the valve can restrict the flow of product into the valve, thus reducing the product feed rate. Previous work has been carried out with this particular rotary valve and a calibration curve for back pressure vs. rotary valve air leakage was produced. This curve allows the determination of the air mass flowrate being lost through the rotary valve for any given steady-state test. Figure 4 presents the results of the rotary valve testing, showing the pneumatic conveying characteristics for the air mass flowrate adjusted to take into account rotary valve air leakage.

In the dense phase conveying region of the rotary valve testing a highest mass flowrate of 1.55 kg/s (5.6 t/h) was achieved. At this point, increasing the rotary valve speed did not increase the mass flowrate any further, this could be due to such reasons as the pockets of the rotary valve being at maximum capacity and/or the result of rotary valve air leakage travelling up through the valve causing a restriction to flow.

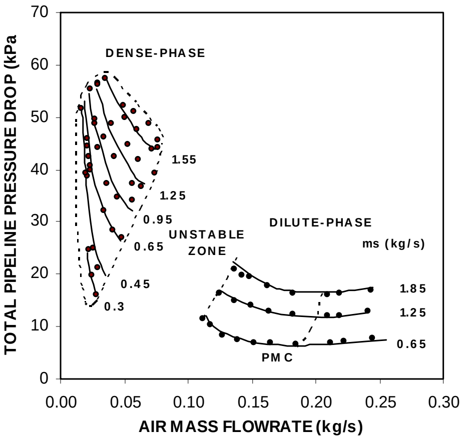

**Figure 4** Extended PCC for plastic pellets, 98.4mm ID × 37m long stainless steel LVSF pipeline (conveying air mass flowrate based on rotary valve air leakage)

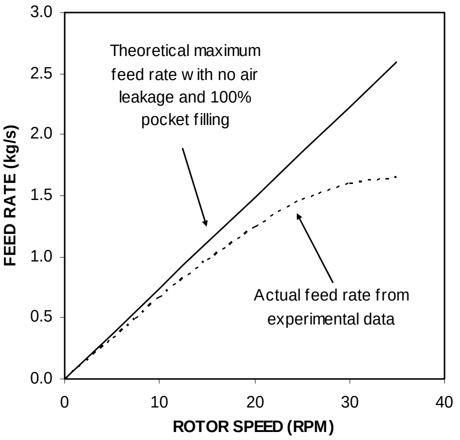

**Figure 5** Feed rate characteristics of the experimental rotary valve

Referring back to Figure 1, calculations were made and experimental data was recorded to produce a similar graph to represent the rotary valve used in this testing. Figure 5 shows the results of this and it can clearly be seen that the experimental results differ quite markedly from the theoretical output that the rotary valve should be able to deliver to the system, especially as the rotary valve speed increases.

When using the blowtank, two arrangements of air input were used, the first being a combination of top air and cone air. For the cases of 100% top air and 100% cone air, two distinct lines of data resulted, but it must also be noted that as the air mass flowrate was reduced, the solids mass flowrate also reduced. For the tests of 80%, 60%, 40% and 20% top air, there was very little difference in the pressures generated in the pipeline for the range of air mass flowrates used. This can be seen in Figure 6 and indicates very little control over the blowtank discharge characteristics. From the tests carried out, curves of similar solids mass flowrate have been overlaid on the figure.

The second case is a combination of top air and conveying air. Like the previous case, there are two distinct lines of data resulting from the tests for 100% top air and 100% conveying air and again solids mass flowrate reduces as the air mass flowrate is reduced. For the tests of 80%, 60%, 40% and 20% top air, there was a noticeable difference with the pipeline pressures as can be seen in Figure 7. From the tests carried out, curves of similar solids mass flowrate have been overlaid on the figure.

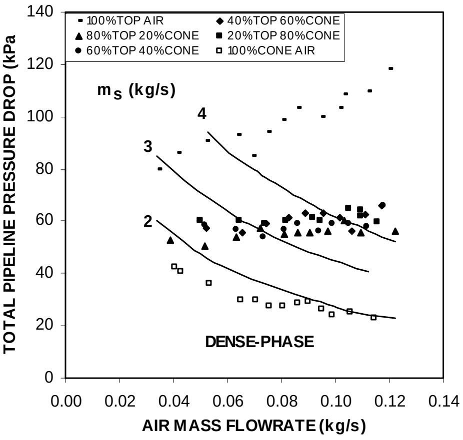

**Figure 6** PCC for plastic pellets, 98.4mm ID x 37m stainless steel pipeline (LVSF blowtank, top/cone air)

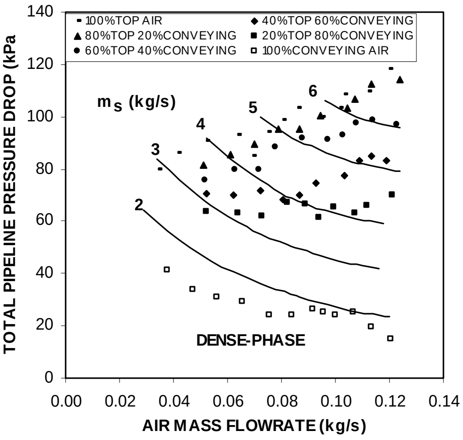

**Figure 7** PCC for plastic pellets, 98.4mm ID x 37m stainless steel pipeline (LVSF blowtank, top/conveying air)

Also on Figure 7, although there is a better spread of data, there is still a region that no data were recorded (eg. Total pipeline pressure drop = 40 to 50 kPa). However, it is believed that the selection of additional air flow combinations (eg. 10% top air and 90% conveying air) would have resulted in data in this region.

It was thought that the pressures in the vertical pipe for both the rotary valve tests and blowtank tests could have had a significant influence on the total pipeline pressure. Hence, the pressure readings from the pressure tapping point directly after the vertical were taken for comparison purposes. Figures 8 and 9 show the results of the comparisons of the rotary valve vs. blowtank top air/cone air and rotary valve vs. top air/conveying air respectively for just the horizontal part of the pipeline, L = 25.3 m.

The rotary valve data displayed in Figure 8 and Figure 9 is the dense phase portion of the results shown in Figure 4. It can clearly be seen that even though there is an overlap with the data from the rotary valve and the blowtank in both Figure 8 and Figure 9, a lower solids mass flowrate was obtained for a higher pressure using the rotary valve. At the same time there is no possible way that the rotary valve can generate the same solids mass flowrates that are possible using the blowtank.

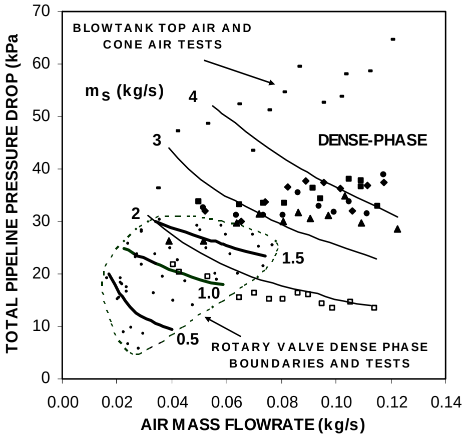

**Figure 8** Comparison of PCC for plastic pellets, 98.4mm ID x 25.3m long stainless steel pipeline LVSF blowtank (top/cone air) and rotary valve

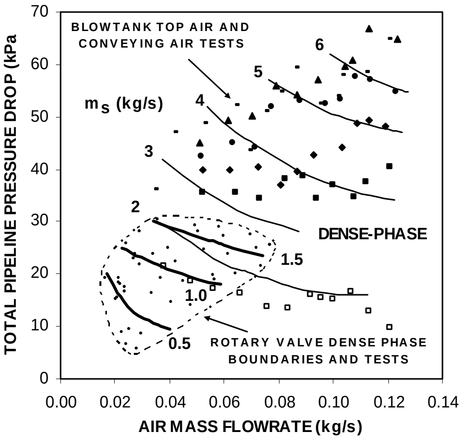

**Figure 9** Comparison of PCC for plastic pellets, 98.4mm ID x 25.3m long stainless steel pipeline LVSF blowtank (top/conveying air) and rotary valve

Another interesting observation is that in terms of air flow, the dense-phase regime for the blowtank was far more extensive than the rotary valve (eg. the maximum air flow for the blowtank was approximately 0.12 kg/s and for the rotary valve 0.04 to 0.08 kg/s).

It was believed that the maximum possible solids feed rate from this valve had been achieved when no higher than 1.55 kg/s was possible regardless of the rotary valve speed or air mass flowrate. It was thought that by using a rotary valve with a larger swept volume, a higher solids mass flowrate could be obtained. With no larger valve available and major modifications to the rig needed even if there was, reference has been made to a previous series of tests using a horizontal pipeline to investigate this likelihood.

In the previous testing [2], the same 250mm NB rotary valve was used, as well as a 320mm NB rotary valve (16L capacity) in an attempt to achieve higher solids mass flowrates due to the larger swept volume of the larger valve. After producing pneumatic conveying characteristics for each valve connected to the same pipeline (stainless steel, L=21m, D=98.4mm NB), shown in Figure 10 and Figure 11 respectively, it was found that for the dense-phase regime, very similar upper feed limitation values were obtained. For the 250mm NB valve, a maximum feed rate of approximately 1.9 kg/s (6.8 t/h) was achieved with 2.2 kg/s being the highest feed rate and for the 320mm NB valve, a maximum feed rate of approximately 1.8 kg/s (6.5 t/h) was achieved with 1.9 kg/s being the highest feed rate.

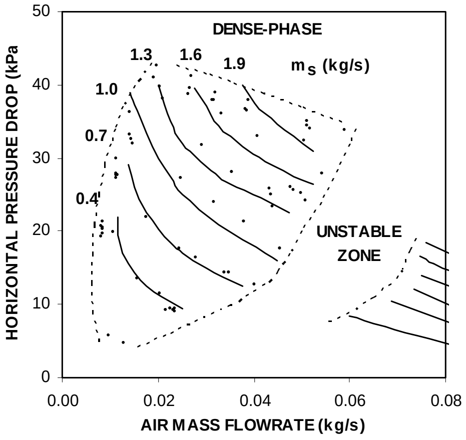

**Figure 10** Dense-phase PCC for plastic pellets, 98.4mm ID x 21m stainless steel horizontal pipeline, 250mm NB rotary valve

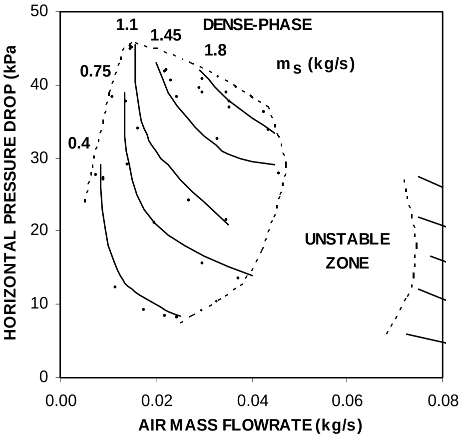

**Figure 11** Dense-phase PCC for plastic pellets, 98.4mm ID x 21m stainless steel horizontal pipeline, 320mm NB rotary valve

These similar results would seem to indicate that regardless of the size of the rotary valve used, the system has reached a choking condition for which no higher feed rate is possible.

The 250mm NB rotary valve achieved a solids feed rate of approximately 1.9 kg/s in the horizontal pipeline but only 1.55 kg/s in the LVSF rig. A number of factors would be contributing to this, including: the influence of pipeline length; vertical lift and bend effects. Taking this into account, it was assumed that if the larger 320mm NB rotary valve had been used on the LVSF rig, a similar maximum solids feed rate of 1.55 kg/s would have been achieved.

Referring to Figure 7, a substantially higher solids feed rate, approximately 6 kg/s, was achieved in the blowtank compared to that possible using the rotary valve which would indicate that the system is not in fact choked when using the rotary valve but is a result of the mechanisms present in this form of pneumatic conveying. The main mechanisms are: gravity feeding of product into the rotary valve; and the rotary valve air leakage causing restriction to flow, which increases as back pressure increases. Also the discrete pockets of product entering the feeding shoe from the rotary valve which are then required to coalesce to form dense phase slugs of product before it can be conveyed is another mechanism present.

The feeding technique of the blowtank varies to that of the rotary valve by the top air pressurising the charge of product and thus forcing the product into the pipeline under pressure. As a result, the product fills the entire pipeline bore and divides into discrete slugs and is conveyed along the pipeline.

## 4 CONCLUSION

From the testing carried out in this program it has been found that the blowtank used can generate far higher solids mass flowrates than the rotary valve for the same air mass flowrates. There are two reasons for this. Firstly the rotary valve is, in essence, a restriction to the product feeding into the pipeline. The vanes of the rotary valve meter the product into the system whereas the blowtank feeds directly and continuously into the pipeline with no interference at the feed point. Secondly the higher pressures generated in the blowtank before conveying commences promotes higher solids mass flowrates, whereas in a rotary valve, the topside of the valve is at atmospheric pressure which only allows for gravity filling of the rotary valve.

It has also been found that: blowtank performance and control depends strongly on the method of aeration; the dense-phase regime obtained with the blowtank is far more extensive than that obtained with the rotary valve.

Further investigations may be made in the future into ways to increase the solids feed rate of the rotary valve, one of which could be by minimising the influence of rotary valve air leakage.

## 5 NOMENCLATURE

| | | |
|---|---|---|
| $L$ | length | m |
| $L_v$ | length of vertical | m |
| $m_s$ | solids mass flowrate | kg $s^{-1}$ |
| $\rho_b$ | loose-poured bulk density | kg $m^{-3}$ |
| $v$ | volume of one rotor pocket | $m^3$ |
| $n$ | number of rotor pockets | |
| $N$ | rotor speed | RPM |
| $\Psi$ | swept volume (=vn) | $m^3$/rev |

## 6 REFERENCES

[1] Woodcock, CR and Mason, JS. “Bulk Solids Handling: An Introduction to the Practice and Technology”. Chapman and Hall, 1987, pp 408 - 431.

[2] Wypych, PW, Hastie, DB and Yi, J. “Prediction Of Optimal Operating Conditions For Dense-Phase Pneumatic Conveying Systems”. Annual Report December 2003, International Fine Particle Research Institute, pp 103.