Introduction
Dynamic Air Inc. is a specialist in the pneumatic conveying of dry, bulk solids. Applications range from food to poison, from light fumed silica to heavy powdered metals. All these applications, however, have one thing in common, the necessity to control the conveying velocity in order to control particle degradation and conveying pipe wear, minimise air consumption, and eliminate pipe line plugging.

What is pneumatic conveying?
Pneumatic conveying is nothing more than creating a pressure differential along a pipeline and moving a bulk material along with the air as the air moves towards the area of lower pressure. This can be done with a vacuum inducer, or with compressed air being injected into one end of, or along the pipeline.

Dilute phase vs. dense phase
The two most distinct categories of pneumatic conveying can be described as either low pressure (dilute phase) or high pressure (dense phase) systems.

Dilute phase pneumatic conveying systems utilise pressure differentials less than 1 atmosphere. These systems use either positive or negative pressure to push or pull material through the conveying line at relatively high velocities (Figure 1). They are described as low pressure/high velocity systems which have a high air to material ratio.

Dense phase pneumatic conveying systems, utilise pressure differentials above 1 atmosphere. These systems use positive pressure to push materials through the conveying line at relatively low velocities (Figure 2). They are described as high pressure/low velocity systems which have a low air to material ratio.

Why dense phase?
By definition, dense phase pneumatic conveying simply means using a small amount of air to move a large amount of bulk material in closely associated slugs through a conveying line, much like extruding. Unlike dilute phase conveying systems that typically use larger amounts of air to move relatively small amounts of material at high velocities in suspension, dense phase offers the enormous advantage of efficiently pushing a much denser concentration of bulk solids at relatively low velocities through a conveying line.

Pneumatic conveying systems for cement
Cement plants need to transfer large quantities of material, often over long distances. As a result, the
power consumption of the conveying system is of prime importance. In pneumatic conveying, the power consumption is a function of the system design, transfer rate, and conveying length. A conveying system, therefore, that transfers 100 tph of cement over a distance of 200 m will use about the same power as a system of the same design and conveying the same material at a rate of 200 tph over a distance of 100 m. So, from this it is evident that the length of a pneumatic conveying system has the same impact on power consumption as the rate.

Traditionally, cement has been handled and conveyed by medium phase pneumatic conveying systems such as impeller screw pumps. These systems, however, are plagued with problems such as high maintenance and high air consumption. The impeller screw pump requires two motors to deliver cement: the screw drive motor, and the air compressor motor. In the case of the 100 tph and 200 m convey length example, the screw drive motor requires about 93 kW and the air compressor motor requires about 186 kW. So, the screw motor consumes one third of the total power of the system, or 50% of the power of the air compressor. If a pneumatic conveying system could be utilised that eliminates the screw motor, dramatic savings in power consumption would be observed.

Power consumption savings do not stop with the cost of electricity. There are also many other benefits associated with lower power consumption. First, if a conveying system uses less power, there is less maintenance. Compare the Formula 1 race car to the economy car. Which car needs more maintenance? Which car gets more life from the tyres? From the engine? Pneumatic conveying systems are no different. If two pneumatic conveying systems must convey the same material over the same distance, and one system uses less power than the other, then the lower power consumption system will have less wear, will need a smaller dust filter, and will create less pollution.

A new generation

Through research and development, a new dense phase pneumatic conveying concept has been born, the Dense Phase Full Line Concept with DC-5 Air Saver technology (Figure 3). The DC-5 Air Saver technology is a means by which compressed air is automatically injected along the conveying pipe in small amounts in response to the conditions inside the conveying pipe.

This new technology reduces the air consumption to the absolute minimum by allowing the system to convey with the conveying pipe line at maximum density. This means that the conveying pipe is as full as possible with cement, and not flowing dilute with cement as a vacuum cleaner would. This maximum density conveying technique has three main advantages. Firstly, because the conveying pipe line is so dense with cement, the air cannot slip past the cement, which is a common inefficiency in
pneumatic conveying systems. If the slip is eliminated, efficiency is improved. Secondly, when the conveying pipe is at maximum density, only a small percentage of the particles are in contact with the conveying pipe at any given time. The majority of the particles are in the interior of the pipe, therefore not abrading the pipe. So, this significantly decreases pipe wear. Thirdly, by increasing the pipe density, the conveying velocity can be decreased for a given transfer rate and pipe diameter. The transfer rate, $Q$, in kg/s can be expressed as:

$Q = \frac{p A v}{\rho}$

where

$p = \text{the conveying density in kg/m}^3$

$A = \text{the conveying pipe area in m}^2$

$v = \text{the conveying velocity in m/s}$

So, rearranging this, one has

$v = \frac{Q}{p A}$

If the conveying density is increased, therefore, while holding all of the other variables constant, the conveying velocity will decrease.

Benefits of velocity control

Velocity control is another byproduct of this new technology. Since compressed air is injected along the conveying pipe, the DC-5 Air Saver technology can provide very accurate control of the conveying velocity. This is important for three reasons. Firstly, similar to a car, energy efficiency in a pneumatic conveying system is velocity dependent. In general, the slower the conveying velocity, the better the air efficiency (Figure 4). Secondly, pipe wear increases with velocity, and is proportional to the velocity cubed. So, if the velocity is doubled, the wear increases eight times. Thus, even small reductions in velocity can provide dramatic improvements in pipe wear. Thirdly, and maybe the least intuitive, is that a slower conveying velocity reduces the chance of convey pipe plugging. Most would think the opposite. After all, if one does not want a car to get stuck in the mud, one had better go very fast through it. The opposite is true for pneumatic conveying systems. The reason for this is that a pneumatic conveying system must change directions through the use of pipe bends. When the conveyed material reaches the pipe bend, it decelerates due to the friction of the bend. If the material is moving too fast when entering the bend, it will decelerate rapidly, causing the conveyed material to compact like a brick, and form a plug. If the conveying velocity is very slow, however, the deceleration will be negligible. A simple illustration of this can be provided. At the speed of a Formula 1 race car, one must brake hard at every turn. If you rode a bicycle on the same track, though, one would hardly notice the turn since the bicycle speed is so slow. This is what the pneumatic conveying system is trying to achieve.

Improved reliability

Finally, the DC-5 Air Saver technology has provided another very significant benefit, reliability. As the compressed air is injected along the conveying pipe line, should the system tend to block or plug, the DC-5 Air Saver technology automatically adjusts the compressed air distribution to break the plug. The system automatically reacts to the conveying conditions and can provide tremendous leverage to dislodge a blockage at any point along the conveying pipe. Although most tend to focus on the air efficiency aspect of the conveying system, reliability is maybe of even more importance. A robust conveying system will allow the conveying system to function even when the material to be conveyed is not ideal.

How does it work?

A series of air inlet controls, called DC-5 Air Savers, are mounted on the conveying line. Each one allows part of the conveying air to enter the conveying line. They have the dual purpose of being able to control the conveying velocity, as well as prevent system plugging. In effect, the Air Saver will reduce the total resistance of the system. The effect of each provides an incremental force. The total number of Air Savers acting in unison produces a significant total force. The Full Line Concept™ (with the DC-5 Air Savers) operates as follows: Material fills the transporter from a storage silo through an inflatable seated butterfly valve. Displaced air is vented up through a vent valve to allow easier filling. Once the transporter is filled, as signalled by a high level control or weighing device, the inlet and vent valves close and seal. Then the outlet valve opens and compressed air is introduced into the transporter to displace the conveyed material. All other compressed air used for conveying is added through the DC-5 Air Savers spaced along the conveying line.

When the transporter is completely empty, as signalled by a low level control in the transporter, the compressed air is turned off and material stops in the conveying line. Since the conveying line does not purge...

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itself clean, the high velocity normally seen in the conventional type system during the purge cycle is totally eliminated, thus making the Full Line Concept system ideal for abrasive and/or fragile materials.

Also, since the line always remains full, there is no time lost in emptying and filling the conveying line. Air consumption is drastically reduced making the system ideal for long conveying line distances and where a single material is being conveyed. The system can, however, operate as a conventional system when the conveying line needs to be purged for maintenance or if product changeover is necessary.

Other components

The valves that seal the transporter must be able to open and close on cement, and be able to provide a bubble-tight seal. Even the smallest of leaks will progressively damage the valve as the air (and abrasive cement) exit the small leak at sonic velocity. The use of inflatable seat valves such as the Posi-flate butterfly valve (Figure 5) have dramatically improved the reliability of pneumatic conveying systems by allowing 1 to 3 million cycles between service intervals.

The method of joining the pipe seems like an insignificant point, but it is critical from an air efficiency point of view. A typical flanged joint, for example, allows joint misalignment. On a long conveying system, this adds up to significantly more pressure drop (and horsepower). So, the use of self-aligning couplings such as the Tuf-Lok pipe coupling (Figure 6) ensures that the piping system is perfectly aligned and smooth on the interior joints.

The PLC control system is maybe one of the most important components of a pneumatic conveying system. It is the brains of the system. Proper monitoring and control of the system, therefore, is vital to the system functioning as designed. A modern pneumatic conveying system should have PLC controlled pressure regulation. This means that the PLC can change the system pressure automatically in response to the operation. For example, if a pneumatic conveying system needs to convey to two destinations, one that is 30 m in length and another that is 300 m in length, the pneumatic conveying system should operate at a lower pressure for the 30 m length destination.

Selection of dust filtration equipment

At the end of every pneumatic conveying system must be a dust filter. The cement dust must be separated from the air. Dust filtration requirements for dense phase pneumatic conveying systems are different than for central dust collection systems. For example, a dense phase pneumatic conveying system does not provide a steady state air flow to the dust filter. In a dense phase pneumatic conveying system, the conveyed material flows in slugs separated by pockets of air. These pockets of air are pressurised. When these air pockets reach the destination silo they rapidly depressurise, resulting in high instantaneous air flow to the dust filter. Thus, it is important that the dust filter is designed to accommodate this situation. In general, dust filters with venturi cleaning mechanisms should be avoided because of the high pressure drop associated with them. Modern conveying systems use cartridge filters (Figure 7) to reduce pollution, reduce space, and provide easier maintenance. Dust filters, such as the one shown in Figure 7, can provide filtration efficiencies of 99.999%, and typically provide emissions below 5 mg/m³.

Conclusion

As cement producers become more concerned with the energy efficiency, as well as the reliability of their conveying systems, they will demand more advanced conveying systems to reduce their operating costs. A supplier of pneumatic conveying systems today, therefore, has to provide a high technology solution to move material reliably and with the minimum amount of compressed air. Although slightly more costly, the savings in operating costs often pay for the advanced technology pneumatic conveying system in just a few years.