

## **Ask Joe! Column**

### **Dense Phase Conveying, Is It The Right Choice?**

Guest article by Tim Singer of Pneu Solutions

Pneumatic transportation of powders and bulk solids through pipelines has numerous advantages when compared to the alternative modes available today. Many materials can be transported over one-half of a mile. The systems have a relatively long life expectancy with low maintenance costs. Product contamination is eliminated and fines emissions to the environment are minimal.

One type of technology used to pneumatically transport these materials is Dense Phase. It has been around for quite a while, but was typically only used to transport just a few materials like cement and fly ash. Over the last ten years, there have been a rapidly growing number of pneumatic conveying installations that are using the dense phase technology to transport a very wide range of materials from dog food to plastic pellets.

Dense phase installations have grown rapidly in the market because of the cost savings for the producers of the products and materials that we consume. The producers of foods, plastics, pharmaceuticals, building materials, and dry chemicals are all global suppliers. The material handling systems that are necessary to move these products are designed to transport millions of tons annually. By reducing product waste by only a fraction of a percent, any money spent to make improvements to these systems will quickly be recovered.

#### **What are the applications for dense phase?**

Assuming the product is a candidate for the dense phase conveying method (product candidates can be a topic for discussion of their own), the number one reason to apply a dense phase design is because the product being handled is highly friable. Many products within the food industry fall into this category. As an example, if a consumer opens a bag of cheese puffs and finds that half of them are broken into little pieces, they will quickly change product brands to someone with whole cheese puffs. Degradation to the final product is a highly important priority to any manufacturer of goods.

The next best application for dense phase is on abrasive materials. The higher velocities associated with dilute phase conveying can lead to rapid pipe wear. Many materials are so abrasive that they can wear a hole in a pipe elbow in just a few weeks. Many minerals and chemicals fall into this category. The pipe wear can also result in a contamination problem because the pipe material will become mixed with the product.

There is really only one other main reason for selecting dense phase. This is typically found within the plastics and petrochemical industry. Some of the softer plastics, such as polypropylene and polyethylene, will smear onto the pipe wall when the product slides along the outer wall of an elbow in a dilute phase transport system. The plastics will actually melt from the frictional contact with the pipe wall and will leave a long thin layer of material. The layers are peeled off into strips and re-entrained into the system. These strips are commonly referred to as a "streamers" and they will quickly build up in awkward places and stop product flow. The build-up of these streamers is usually referred to as "bird-nests" because of the way they look when they are finally removed from the process. Dense phase transportation will eliminate the streamers that are commonly associated with dilute phase conveying. There are several other methods to greatly reduce the streamer generation and they may be a more cost effective solution. These other methods would be a separate topic for discussion.

#### **How does dense phase work?**

How does dense phase transportation achieve the stated advantages over dilute phase conveying? During the pneumatic transport process, the products are accelerated to a design velocity, come in contact the pipe walls,

change direction in bends, and fall back to the original resting state at the destination point. As one can probably imagine, some products hold up better than others during this process. In all cases, though, the percent of material breakage is very much proportional to the average velocity of the product in the pipeline. The main principle of a dense phase conveying system is to slow down the velocity of the product in the pipe to a point that is below the speed at which the product breaks or degrades. In a dense phase system, the velocity range at the source can be as low as 3 to 5 miles per hour for the majority of products. The product velocity at the destination is always a function of the system differential pressure. Because of the compressibility of the air or gas used as the conveying medium, the gas will expand as it moves to the end of the pipeline and the product velocity will increase accordingly. The terminal velocities of a dense phase system can vary, but in most cases they rarely exceed 20 miles per hour (mph). In a typical dilute phase system, the starting velocities begin at about 40 mph while the terminal velocities can reach 100 mph.

A natural phenomenon occurs within the pipe as the velocities are reduced from dilute phase mode to dense phase mode. In a dilute phase conveying system, the product is transported by lift, or suspension, of the individual particles in the gas stream. As the gas velocity is subsequently reduced, the larger particles cannot sustain this lift and they begin to fall from suspension to the bottom of the pipe. The technical term used in the industry that describes the velocity at which particles fall from suspension from the gas stream (in horizontal pipes) is "saltation velocity". The best, single description for identifying if a system is dense phase is whether the product velocities in the pipe are designed to be operating below the saltation velocity. Most systems will operate erratically when velocities are just below the saltation point causing rapidly changing conveying pressures. The pressure fluctuations result in acceleration and deceleration of the product and will cause excessive product damage. A system operating in this manner is usually described as operating in an unstable dense phase mode. A further reduction in gas velocity will create the natural combination of wavelike-flow and plug-flow of product as it moves throughout the pipes. The system pressures are much higher and still fluctuate somewhat, but are controllable and consistent. This condition is described as stable dense phase conveying.

### **What are the potential problems with dense phase design?**

Many operating problems occur as a result of poor planning, inexperience, or little understanding of how dense phase systems work. When a dense phase system is applied properly, designed correctly, commissioned by a qualified start-up engineer, and has the proper operation and maintenance procedures, these systems will work very well for many years. Below are some of the reasons that can create problems down the road.

The first step in the decision process is to review the application. The following questions must be answered before proceeding down the dense phase path. Is the material a good candidate for dense phase? What problems lay ahead because of the physical material characteristics? Does the decision for selecting dense phase over dilute phase fall into one of the three categories stated above: product degradation, pipeline erosion, or streamer formation (with plastic pellets)? If the main reason for selecting a dense phase system does not fall into one of these categories, then an alternate solution for a dilute phase equivalent design should be sought.

There are many possibilities in designing a dense phase system. This should not be left to the beginner or novice person. The single pressure vessel design, stacked vessel design, side-by-side vessel design, high pressure rotary feeders are just some of the ways to introduce material into the pipeline. Each method has certain advantages over the next one. The gas source can be from a screw compressor, piston compressor, plant air, or other sources. The gas flow control equipment is highly dependent on the source of the motive gas. This scenario creates many combinations when selecting the proper gas control system. One can begin to see that this is not an easy task to put together the best system and only persons who are trained and experienced with all the possible combinations will make the correct choices.

Dense phase systems are more complicated than dilute phase systems to control properly and it is not an intuitive process. The reason being primarily because of the narrow operating window in which the systems will

perform with stability. It is necessary to constantly change the gas amounts for varying conditions in the system. Therefore, the heart of all dense phase systems is the gas control device. It must be flexible and accurate. In addition, the owner/operator of the system must have a good in-depth knowledge of the dense phase process in order to troubleshoot and correct problems if they occur. A lack of training by the customer can have negative results on system performance.

Much information is needed for proper design. Dense phase systems are not as flexible as dilute phase systems when it comes to varying product transfer capacities, varying products, or varying product grades that result in dissimilar physical product characteristics. Even product temperature variations need to be known at the design stage and incorporated into the system design. The system designer can build in some additional flexibility, but they need to know the customer's process and process requirements for the transport system. It is extremely important for the system designer to have an understanding of the total process leading into and out of the conveying system.

### **Are dense phase systems meeting customer's expectations?**

How have these systems been performing over these latter years? Many systems are working great. There have been some common complaints about these systems, though, such as: line plugging, not making design rate, excessive product breakage, or destroying pipe supports. Why are there so many problems associated with this type of technology? The majority of the complaints associated with these systems stems from fact that they are not operating in a stable dense phase mode. The gas flow may be too high. It may be too low. How does one know which? How does one get back to the correct gas flow? These questions can be answered, but are mostly specific to the individual system configuration.

Line plugging is the most common problem associated with dense phase systems. The lines can plug because of either too much or too little gas flow. If the product is permeable, such as a pelleted material, a line plug is typically associated with too little airflow. If the product is a fine powder, however, the lines can plug from either too little or too much gas flow. For this reason, it is crucial to know how much gas is being supplied to the system at all times.

Excessive product breakage is the next problem. As mentioned already, this is a direct function of velocity of the product. This is typically a result of too much gas flow into the system. Many times there are other physical design modifications that can be made to the system that will help reduce degradation.

Not reaching the design transfer rate is a common problem. This is usually because the system has reached a maximum convey pressure or differential pressure for some reason. The number one cause is that the product being transferred is not performing in the actual installation as it was expected to do according to the manufacturer. Because of the nature of dense phase, the pressure drop in the line is highly dependent on the physical properties of the material (and the transfer rate). Friction between the product and the pipe walls create a much higher pressure in the line as compared to dilute phase. Therefore, small changes in friction coefficients between the pipe surface and the product (adhesive forces) can have large effects on the line pressure. The manner in which the product interlocks with itself (cohesive forces) as it moves through the pipe will, also, have a large affect on system pressure drop. These two forces are not the only variables for determining convey pressure, but they are the most predominant ones.

The pipes shake enough to break the supports. This problem has a two-part solution. The natural phenomenon of dense phase is to make the waves and plugs. When these plugs change direction in an elbow, it will produce two reaction forces onto the pipe at that point. First, an impact force from the plug hitting the elbow, because it wants to move in a straight line. Second, a centripetal force is induced into the pipe and supports as the mass of product changes direction. These two forces occur at every elbow and each time a plug comes through it. The cycle time between plugs is typically on the order of magnitude of one every 30 seconds. If the

system were run continuously for 24 hours per day, this is equivalent to over one million cycles annually. In general, larger pipe diameters mean larger magnitude of reaction forces. Most of the problems start to occur with convey pipe diameters as small as 3 inches.

The first solution to the problem is to give special attention to the design of the pipe support system. The conveying system supplier should supply the expected magnitude of these dynamic reaction forces to the engineers who are designing the piping and structural steel systems. It is then the responsibility of the piping designers to follow through with this information to determine fatigues, moments, stresses, pipe anchoring designs, and steel support configurations. The second part to the solution of this problem is to establish periodic maintenance inspections on these systems. They must be operating in a stable dense phase mode. A system that is not operating with the correct airflow can induce dramatically larger forces into the pipe supports. If left unattended, this situation can accelerate the destruction of a piping system.

### **About the Author**

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