Macawber

PNEUMATIC CONVEYING USING GASES OTHER THAN AIR

by

John M. Bell
Macawber Engineering Inc.
Maryville, Tennessee

and

John Eric Powell
Macawber Engineering Inc.
Maryville, Tennessee

Introduction

Although the pneumatic conveying of materials through pipelines is usually associated with air as the conveying medium, other gases are increasingly being used, especially when the use of air can create dangerous or unstable conditions. The preclusion of air may be necessary, either to insure safe conditions within the conveying system, as for example, when conveying material which is incendive or explosive; or to avoid a reaction at the open discharge of the conveying system, such as a lance injecting material into a ladle. It, of course, is not the air that is objectionable, but its oxygen content which supports combustion as in burning, or rapidly as in an explosion. By definition, the word "pneumatic" is not confined to air, but includes all other gases.

Pneumatic Conveying of Explosive Dusts

The pneumatic conveying of explosive dusts does not preclude the use of air, however. Such products as coal, flour, cork, sugar, etc. are conveyed safely and successfully with pressurized air. In this regard, dust means particles of materials smaller than 0.016 inches in diameter, or those particles passing a No. 14 U.S. standard sieve, or 425 um, which relates to the limiting size and not the average size. Explosive dust means a dust which when dispersed is ignited by a spark, flame, heated coil, or in the Godbert-Greenwald furnace, at or below 730^{o}C. when tested in accordance with the equipment and procedures described in the Bureau of Mines Report 5624.

Pneumatic conveying systems handling coal, for example, normally contain dust at concentrations well above the explosive range, often having dust-to-air ratios in the region of 40:1. Exceptions to this general condition are at the start-up and shut-down, and also at the delivery point where the dust is separated from the air. Under these circumstances, the dust concentration is liable to be within the explosive range.

Although the conveying pipeline is normally strong enough to withstand the full pressure of an explosion, the delivery points will require explosion protection such as pressure relief venting. (1)

In a report published by the U.S. Bureau of Mines (2) which examined the safety aspects of pneumatically conveying coal in underground, gassy mines, using pressurized air, it was stated,

> "The primary safety concern has been the threat of explosion since methane and coal dust would be trapped within a pipeline and could spark or smoulder into flame during downtimes. Studies have shown, however, that an explosion is extremely unlikely if adequate precautions are taken. Pnematic conveying systems have proved to be safe, flexible, efficient and economic, all of which should be of great interest to mine management."

A further reference in this report mentions the expected increase in the use of pneumatic conveying equipment for transporting coal within underground coal mines. (5)

In a study headed by Professor Soo investigating long-distance, high-pressure air pneumatic conveying of coal and the possibility of methane gas being liberated during the conveying process, they found that even though coal dust particles below 20 um could be ignited in a tube with a 1:1 mass ratio, the flame was smothered by coarser particles. Since the pneumatic system proposed in the study handled coal smaller than .25" with a 10:1 coal to air mass ratio, they concluded that such a pneumatic system was safer than conventional systems.

Why Use a Gas Other than Air?

Obviously air is more readily available than any other gas, costs less to obtain and have available as a pressurized source. In most plants there is already available a supply of compressed air, and if not, the additional air compressor capacity installed for a pneumatic conveying system can also be utilized for other applications. However, air contains oxygen which supports combustion and has a major influence on the cause of an explosion. A reduction in the oxygen level, normally about 21% by volume, will reduce the effects of an explosion hazard. For highly explosive materials, such as powdered magnesium which has an explosive pressure rate of +10,000 lbs./sq. in./second, it is safer to eliminate oxygen entirely from the conveying medium by using an inert gas to convey the material and to purge the entire system of air. For such applications, the possible ignition source is also eliminated, such as friction sparking, by using lined pressure vessels and receiving bins, or manufacturing all the equipment or those components that are in contact with the explosive material from stainless steel. Static electricity sparking is eliminated by making sure the system components are made from conducting materials, are in continuous contact, and are adequately grounded.

A further reason for not using air arises when the material being conveyed is to be delivered directly into the process and not to a silo or bin. For example, when conveying additives to molten steel in a ladle through a lance, or to a reactor where the infusion of oxygen would generate unwanted thermal reactions. The virtual elimination of moisture content when using a bottled source of inert gas as compared with a supply of untreated, compressed air is also an advantage in eliminating the potential danger of flash steam.

Inert Gases

An inert gas by definition is one which does not enter into known chemical combinations. The four gases which meet this strict definition are: helium, neon, argon and krypton. In the broader definition of an inert gas, as that which does not support combustion, we include in addition to the four above: nitrogen and carbon dioxide. Also considered are flue gases or other gases produced as a result of combustion. The reactivity of the material to be conveyed with the gas selected must be considered, however.

Of the inert gases available, only nitrogen, argon and carbon dioxide are usually considered as the conveying medium in a pneumatic conveying system. This is mainly due to the readily available supply of these gases in sufficient quantity at an economic cost for the volumes required to operate a pneumatic conveying system. These gases are supplied in high pressure cylinders from commercial resources, or can be generated at the plant and compressed to the pressure required for conveying. Nitrogen, for example, is often a by-product of other processes. Further details of these three inert gases and that of air for comparison are given in Table I. As can be seen, argon and carbon dioxide have a much higher density than air, and can therefore have a significant impact on the conveying capabilities of a pneumatic system.

Selection of Equipment

Standard type of pneumatic conveying equipment can be adapted for a system utilizing inert gas, but will depend on the application. If the inert gas is being used to avoid a reaction with oxygen at the discharge of the material into the process, then no additions to standard equipment are required, other than to insure the system is purged of air. For example, prior to introducing an additive material lance into a steel ladle.

When the conveying system is completely contained and the discharge is into a bin or silo, it may have to be designed not only to withstand the gas pressure when conveying, but also the final pressure and rate of pressure increase in the event of an explosion. To prevent the ingress of air and allow the system to be purged under vacuum, all seals on shafts to valves, etc. must be designed to hold pressure both ways. Caution must also prevail when designing the receiving hoppers, as they may require additional strength to withstand the vacuum during the purge compared to the pressure when conveying.

Additional valves will be required to isolate the system when undergoing pressure and vacuum tests, especially at the outlet to the filter on the receiving hopper. As a further precaution, it may be required to manufacture all contact parts in stainless steel, or have these coated with a non-sparking material. This latter method is not fully reliable as the coating material will probably wear in time, leaving the carbon steel exposed.

Dense-phase conveying has an advantage in conditions which require the use of an inert gas as the conveying medium. This is due to:

(1) A smaller volume of gas is required to move a given quantity of material which is an advantage when considering the economics of generating the gas.

(2) The material will transfer at a low velocity, so further eliminating the danger from frictional sparking, static electricity build-up, and wear of the pipe and elbows. There is less disturbance at the discharge as compared with dilute phase conveying, especially if this is directed into a process or into a ladle containing molten metal.

(3) Controlled flow of the material to within 2%.

(4) When the vessel completes the cycle, the flow of exhaust gas is controlled, unlike for example, a rotating valve.

(5) The system can be purged under vacuum by closing the in-feed valve of the vessel and exhaust valve at the receiving hopper.

(6) The system can be pressurized above normal conveying pressure to detect leaks, whereas a rotating valve feeder could not hold the pressure for the time required for a test.

(7) The small quantity of gas used can be exhausted to atmosphere, safely without detrimental effect after passing through the dust filter.

The conveying system must always operate above atmospheric pressure to insure that any undetected leaks in the pipeline are of the gas flowing outwards, not air, hence oxygen, inwards.

Consideration must also be given when selecting the in-feed equipment to the material delivery arrangements. If the material is being delivered to a bin, a dense feed vessel is suitable, such as the Macawber **Denseveyor**. If a controlled flow is required as when delivering into a process, a variable feed vessel is required, controlled by the operator, such as the Macawber **Controlveyor**. Where line loading is a critical factor, self-adjusting feeders may be considered, such as the Macawber **Variflow** (3).

Attention must also be given to the electrical control panels which require to be purged if there are external problems with explosive airborne dust, or alternatively, suitable explosion-proof enclosures are required.

Typical Installations

Four installations as examples of pneumatic conveying systems using gases other than air are detailed below. Two are using nitrogen and two using argon. For each gas we have selected one application where the material is delivered to a hopper with a dense phase transfer vessel, and one application where the feed rate is remotely controlled by the operator.

Installation 1 - Nitrogen Gas

Calcium carbide. 60 lbs./cu. ft. To be conveyed at the controlled rate of 5 to 25 lbs./minute within 2% of the control setting using nitrogen as the conveying medium.

This is the feed to a cupola at a ductile iron foundry in Ohio. The quantity of calcium carbide injected is critical, and a plugged line warning indicator was included in the controls. The equipment used in this application is a Macawber **Controlveyor** Model LVBP Injector Assembly with 4" Dome Valves and includes a sight glass for visual inspection of the product flow. Continuous feed to the injector unit is maintained from a double pressure vessel arrangement which replenishes the material without losing line pressure.

The material is conveyed using plant-supplied nitrogen, regulated to 10 psig, with an average consumption of 30 scfm. A 1" diameter pipeline approximately 100 ft. long including elbows conveys the material to the cupola. As a note of interest, coke breeze is also conveyed at this plant, again using the same equipment but utilizing dry, compressed air, and selected because of the critical flow control of the material to the process.

Installation 2 - Nitrogen Gas

SIPX. 30 to 40 lbs./cu. ft. To be conveyed at the rate of 100 lbs./minute to a reactor with a back pressure of 15 psig. The material varies in size from 1/2" square by 1/8" thick to powder. It is hygroscopic and agglomerates easily.

This plant is located in Texas. The feeding vessel, a Macawber **Denseveyor** 3/4 is epoxy coated, as is the 4 ft. diameter receiving hopper located above the reactor. The nitrogen is supplied at 80 psig from the plant and is regulated to the conveying pressure. Approximately 35 scfm of nitrogen is required to convey the material 50 ft. through a 3" diameter stainless steel pipeline including two 90° elbows. At the completion of each conveying cycle, the line has to be purged. The conveying and purge cycles, in addition to the stop/start of the in-feed screw feeder to the **Denseveyor** are controlled from a PLC in the control panel. The spent nitrogen is released to atmosphere through a dust suppression filter unit mounted on the receiving hopper.

Installation 3 - Argon Gas

Desulfax materials to be injected into a deep ladle by means of a lance at a controlled rate. The argon gas is supplied at 300 psig and is regulated to the conveying pressure. The operator has control over the material flow rate by adjusting the speed of the feed drive motor of the Macawber injector vessel, **Controlveyor** Model 3/4-3. Safety interlocks are provided with the equipment to insure air is not induced into the gas flow.

Should the argon supply pressure fall below 300 psig, an alarm warns the operator to change the gas cylinder. A flow meter also alarms when the flow is reduced, indicating the lance discharge is restricted. The whole assembly is contained within a frame for mobility, and can either be transported by overhead crane or has receptions for a forklift.

Installation 4 - Argon Gas

Magnesium powder. 45 lbs./cu. ft. Up to 100 mesh size at 535°F. To be conveyed at 1000 lbs./hour over 260 ft. to two reception hoppers. The product is used for road accident warning flares, and as decoy for heat-seeking missiles when injected into the tailburners of combat aircraft.

Magnesium powder is extremely reactive (as is aluminum dust), and when conveyed pneumatically, great care has to be taken as it is difficult, or near impossible, to vent the system successfully if an explosion occurs under optimum conditions. Also fires involving magnesium are difficult to extinguish. Therefore, it is imperative that ignitions or fires involving magnesium should not be permitted. Hence the choice of argon as the conveying medium, in addition to all contact parts being manufactured from 304 stainless steel.

The argon gas is supplied at 80 psig with an available flow rate of 25 scfm, and is readily available at this plant, being also used for other processes. To insure that air (oxygen) is not present in the vessel, pipelines or hopper, detectors are strategically located in the system. Prior to start-up the whole system is sealed off and vacuated to 25" Hg., then purged with argon under pressure.

Special care was taken during the manufacture of the feed vessel and hoppers. The welding was continually inspected. No sharp edges or depressions were left where the magnesium powder could accumulate. All equipment was hydraulically pressure tested to one and a half times the maximum working pressure, and the **Dome Valve** shaft seals were designed to hold vacuum as well as pressure. Two engineers from the client were on hand continuously for the inspection and testing of the equipment. On one occasion, welding of the receiving hoppers continued for 24 hours uninterrupted to insure the quality was consistent.

Other special precautions included; the level probes were of the capacitance type for hazardous locations, inspection covers were designed for removal by personnel expecting to be wearing a self-breathing helmet and safety coveralls, and Viton seals were used due to the high temperature of the material. This was a most exacting project, but we were proud to supply equipment directly involved in the defense of our country.

Conclusion

Pneumatic conveying using gases other than air has many advantages in processes in which air or oxygen is detrimental or dangerous. If a supply of an inert gas such as nitrogen, argon or carbon dioxide is readily available, the economics are acceptable as often these gases are stored at a pressure much higher than required for conveying, and hence the cost of an air compressor is substituted.

PNEUMATIC CONVEYING USING GASES OTHER THAN AIR
by John M. Bell and John Eric Powell

In most applications, off-the-shelf conveying equipment can be used, occasionally with minor modifications. The final criteria is, if magnesium powder can be safety transported in a pneumatic conveying system, then anything of a reactive nature can.

PNEUMATIC CONVEYING USING GASES OTHER THAN AIR
by John M. Bell and John Eric Powell

REFERENCES

1. K. N. Palmer, Dust Explosions and Fires, Chapman and Hall, London, 1973.

2. E. T. Bowers, "Safety Aspects of Pneumatic Transport", U.S. Bureau of Mines Information Circular 9006, 1985.

3. Brian Snowdon and Michael F. Crawley, "New Developments in Pneumatic Conveying - Advantages of Controlled Line Loading", Powder and Bulk Solids Handling and Processing, Rosemont, IL, May 1987.

4. S. L. Soo, J. A. Ferguson, S. C. Pan, "Feasibility of Pneumatic Transport of Coal", Proc. 3d. Intersoc. Conference on Transport, Atlanta, GA, July 1975.

5. J. E. Powell, "Vertical Hoisting Using Pneuamtic Conveying System", 4th International Symposium on Freight Pipelines, Atlantic City, NJ, October 1982.

TABLE I

Gas	Density #/cu. ft.	Specific Vol cu. ft./lb.	Remarks
Air	0.0763	13.106	"Free"
Argon	0.1053	9.497	1% of earth's atmosphere obtained by fractionation
Carbon dioxide	0.1166	8.576	Formed during combustion
Nitrogen	0.0738	13.55	79% of air by volume

TABLE II

EXPLOSIVE CHARACTERISTICS OF METAL DUSTS

TYPE OF DUST	IGNITION TEMPERATURE OF DUST CLOUD °C.	MAXIMUM EXPLOSION PRESSURE P.S.I.G.	MAXIMUM RATE OF PRESSURE RISE LB./SQ. IN./SEC.
Magnesium	520	94	10,000+
Aluminum	650	100	10,000+
Silicon	780	106	10,000+
Titanium	460	80	10,000+
Zirconium	20	65	9,000