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Practical Aspects of Modern Pneumatic Conveying Systems

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Continuous development and improvements in pneumatic conveying techniques have provided a greater performance capability in terms of material types and conditions handled, power economy and wear resisting qualities. It is intented to summarize these developments and to provide a guide of performance capability measurements that the pratical engineer may like to consider before finalizing his requirement specifications.

1. INTRODUCTION

After considering this paper the reader may revise his ideas of the suitability of pneumatic conveying for a materials handling application, since part of this paper's objective is to provide a summary of system design developments and how pneumatic conveying system application capability has considerably grown in recent years.

However, to begin with, it is assumed that the fundamental choice of pneumatic conveying over mechanical conveying has already been made and consideration has been given to the obvious advantages this method of handling provides, particularly those relating to cleanliness and low capital cost.

As with most equipment, pneumatic conveying system development is continuous. Considerable recent effort has been applied however to achieve a greater spread of handling capability since it is well known that not all bulk materials may be successfully pneumatically conveyed and since it appears that the demands of the environmentalists to improve dust generating conditions must be met, most manufacturers have recognized the challenge.

Until very recently, the chief criticism of pneumatic conveying concerned pipewear, particularly with abrasive materials. Limitation of reliable operation with natural materials which do not maintain constant mechanical properties have also long since been a problem. Limitations with materials at high temperature and limitations with materials with high or varying moisture content have been difficult or impossible to overcome. The problems have been progressively solved with a new generation of equipment designs and it is the intention of this paper to update the reader and to equip him with a basic knowledge or judgment parameters that will assist his successful application of pneumatic conveying systems.

2. DEVELOPMENTS IN APPLICATION CAPABILITY

Until recently it has been considered possible only to pneumatically convey bulk materials that are capable of becoming fluidized; that is, separating each grain of material in a low pressure air stream to render a fluid condition. The fluid condition is in many cases maintained by regular injections of air at various locations in the system, both within the vessel and the conveying pipeline.

Dry materials that do not exhibit cohesive properties (a particle structure that interlocks the material even when dry) are obvious candidates for conveying in this way and early system designs were considered satisfactory if they achieved the objective of conveying the material without regard to pipewear, material degradation, material segregation, power cost or reception hopper filter requirements. The effect of this method on the material conveyed was either tolerated and regarded as an additional cost effect of the method of handling or was not tolerated and the material handling method abandoned. This approach to pneumatic conveying is considerably prevalent in the

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United States today.

With informed analysis of equipment and system designs available it is possible to establish in advance of commitment the desired level of success required for all materials requiring pneumatic conveying. Application success may be anticipated by careful consideration of the following important material conditions as they relate to pneumatic conveying.

2.1 Lump (Grain) Size and Distribution

The word lump more effectively describes the material particle size that the hitherto grain specification since modern system designs are capable of accepting large lumps beyond 3/4 in. (19 mm) without regard to the distribution of finer particles in the material. The maximum acceptable lump size is a function of the conveying line diameter; however, materials containing up to 3 in. (74 mm) in size have been successfully conveyed in coal handling systems for example, where a random and continually changing small particle size distribution is present as may be expected with a natural, unprocessed bulk material. Pneumatic conveying systems that rely on fluidizing the material during conveying cannot tolerate a large lump size, particularly when found with large volumes of fine material since the action of fluidizing segregates the material to cause large lump nesting and frequent pipeline blocking.

2.2 Moisture Content

Moisture is present in almost all materials so it is important to understand that a clear reference to "free" moisture is made when referring to this condition. Material containing "inherent" moisture is not significant if that inherent moisture does not affect the mechanical properties of the material. It should not be assumed that materials containing free moisture cannot be pneumatically conveyed. Referring back to the coal handling example: It is not uncommon for coal stockpiles to contain up to 20% free moisture by weight. Clearly, however, moisture does affect the mechanical properties of a material particularly its bulk density, angle of repose and flowability, so system designs that are dependent on constant conditions in these respects would be unsuitable for this application.

2.3 Temperature Capability

Temperature changes in a material fed to a pneumatic conveying system may be significant if the temperature change affects the mechanical properties in a system dependent on maintaining constant mechanical properties in the material as exampled above.

Systems not vulnerable to mechanical property variation should not be affected but of course will be subject to a maximum temperature limitation imposed by the equipment design. Pneumatic conveying is successfully applied to high temperature materials, an example of which is coal ash from a boiler plant where temperatures of up to 900°F (480°C) may be accommodated reliably.

2.4 Cohesive Materials

Not all dry materials easily fall apart when they are separated by a mechanical or pneumatic device. They exhibit a tendency to cling together even with a nil free moisture condition. This reluctance to separate can be a serious setback to the fluidizing system which is dependent on intergrain separation. Wet materials also may become cohesive and for that reason they cannot be fluidized.

The cohesiveness of a material is not easily quantified and for the majority of applications a simple test can be done to determine if a material is cohesive or not. When squeezed together a cohesive material will form a solid lump; non-cohesive materials will simply fall apart.

2.5 Adhesive Materials

Adhesive materials are those materials that will adhere to surfaces. These can be particularly difficult to handle and special contact part coatings and pipework may be required.

Often materials which are adhesive will form a build-up inside the pressure vessel or pipework which will require periodic cleaning. Provided this is considered at the outset, an acceptable arrangement can be designed which allows quick access to the area to be cleaned.

2.6 Mechanical Properties

As with solid objects, bulk materials have mechanical properties which are important to their assessment for successful pneumatic conveying. Additional properties must also be found to assess their behavior inside the pipeline during conveying. The following information should be established before application consideration is taken too far:

a) Bulk density - weight of unit volume of material.

b) Angle of repose - the angle from the horizontal at which the material will fall away from itself.

c) Flowability - the free flowing character of the material.

d) Static electrical build-up - Certain materials such as very fine PVC powder will aggomerate with static build-up and become difficult to convey. There is also a possibility of an explosion in the receiving hopper if sparking occurs. A low velocity pneumatic conveying system will generate less static than a high velocity system.

e) Friability - the tendency of the material to break up or degrade during conveying.

f) Dust explosion concentration figure - Certain powders can explode at a particular concentration in air. This figure must obviously be avoided where possible or innert gas used for conveying.

2.7 Chemical Properties

The chemical properties are clearly of significant importance in establishing the contact material for the system. In addition, regard should be given to the materials tendency to either absorb moisture (hygroscopic) or release moisture (effervescent). Either of these conditions will considerably affect the mechanical properties and the conveying performance of the material in the pipeline. It is important to note that since pneumatic conveyors have demonstrated an ability to handle natural materials such as coal which is often wet, the chemical composition becomes significant if good equipment life is to be achieved.

Understanding your material is an essential first step in appreciating how it may behave in a pneumatic conveying system. The effect of its behavior will be significantly different depending on the system type chosen and these effects may or may not be acceptable, but the beginning of a controlled application assessment has taken place. The constant and fixed variables of your contribution to the partnership of material and system have been completed.

3. SYSTEM DESIGN TYPES

It is evident from discussion with pneumatic system users that clarification of terminology is vital if early classification of pneumatic conveying methods and good communication is achieved. There are countless pneumatic conveying system designs available and they do not all achieve the same purpose. Classification of these designs is outside the objective of this paper, but classification of concept and method is not, and an understanding of system design concepts is vital to a successful marriage of bulk material and system design.

Design types are prepared to provide certain conditions for the material in the pipeline. The conditions achieved may be harmful or harmless to the material and the equipment. The correct design type selection must be made with complete regard to the handling application requirements and an assumption that all system designs achieve the same results is a fundamental error.

It has been fashionable to categorize system design types into broad groups known as lean or dense phase pneumatic conveyors without understanding the meaning of these terms. The definitions of these groups are as follows:

Lean Phase Pneumatic Conveying System

A pneumatic conveying system in which the air/material ratio by volume is greater than 100:1.

Medium Phase Pneumatic Conveying System

A pneumatic conveying system in which the air/material ratio by volume is between 100:1 and 25:1.

Dense Phase Pneumatic Conveying System

A pneumatic conveying system in which the air/material ratio by volume is less than 25:1.

For example, a dense phase system will require less than 25 cub ft. of air or other conveying medium to convey one cub ft. of material, compared with more than 100 cub ft. of air for the same application in a lean phase pneumatic conveying system.

This air/material ratio is clearly the ultimate measure of performance efficiency in terms of power consumption, since the lower the ratio the lower the energy expended to handle unit volumes of material. Both air and material measures are expressed in the same terms which is loose material unpacked and free air consumed to transfer the material volume. The air/material ratio by volume is used to compare system methods and the air/material by weight is used to compare specific applications when subject material bulk densities are known.

The ability of a system to achieve a low air/material ratio is commendable but not the only criteria of performance as will be seen later, but to begin with, it may be more easily understood if the common systems design types available are related to this measure.

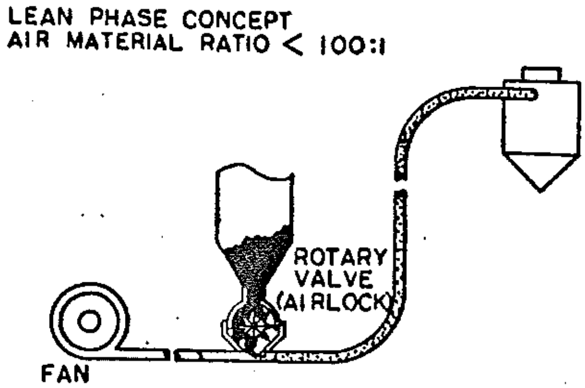

Fig. 1 Lean Phase pneumatic conveying system concept characterized by high air volumes at low pressure produce high material velocities.

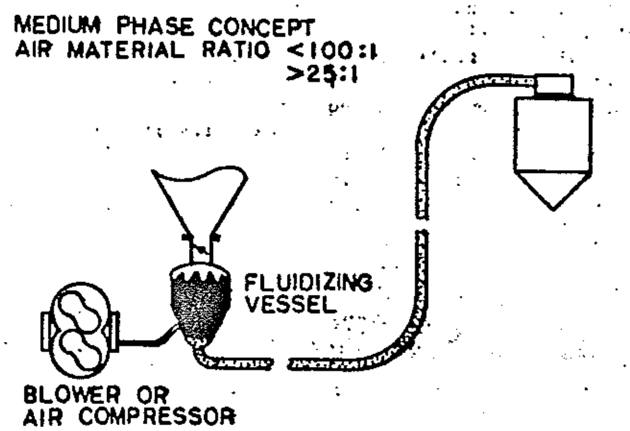

Fig. 2 Medium Phase pneumatic conveying system concept characterized by high air volumes at medium pressures producing high material velocities.

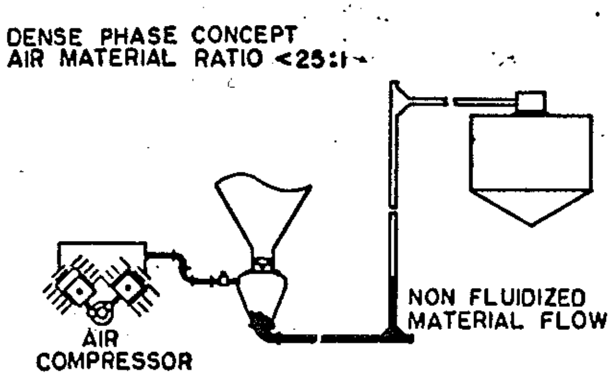

Fig. 3 Dense Phase pneumatic conveying system concept characterized by lower air volumes at high pressures producing low material velocities.

Practical design types do not of course conveniently fall into the concept sketches shown and in practice, various methods of air introduction into or behind the materials are employed to achieve the designers performance intentions.

In assessing design types and understanding how they achieve good performance criteria, detailed sketches of some well known methods are shown for comparison.

The performance criteria of material velocity is now also considered since this component considerably affects the material in the pipeline and the pipeline itself.

Consistent with the clients transfer requirements for the material, it is important that low velocity is employed to prevent material degradation and pipeline bore erosion. Fluidized systems by virtue of their operating principle of suspending particles in an air flow rely on very high velocities to maintain movement. The minimum velocity that a system of this kind can achieve in any application depends on the mass of the largest grain of material it is conveying.

If the conveying velocity falls below the minimum safe velocity, 'saltation' or drop out occurs and material begins to deposit in the bottom of the pipework eventually blocking the pipe. As an example the minimum safe horizontal conveying velocity for dry sand of 100 afs is 3600 ft. per min (18 m/sec).

This velocity commonly encountered in sand pneumatic conveying systems is the cause of such high wear rates for pipework and equipment.

Velocity alone in these examples is not the sole cause of pipewear. There also exists considerable intergranular activity in these systems which may cause material degradation and fines increase.

MOVING DUNE EFFECT IN
FLUIDIZED (MEDIUM PHASE) SYSTEM

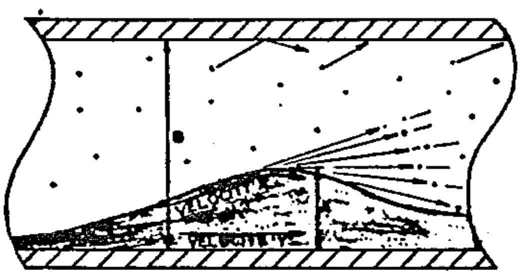

Fig. 4 Inside pipeline of Lean Phase System transferring sand at 3600 ft/min (18 m/sec).

DUNE EFFECT ELIMINATED
IN DENSE PHASE SYSTEM

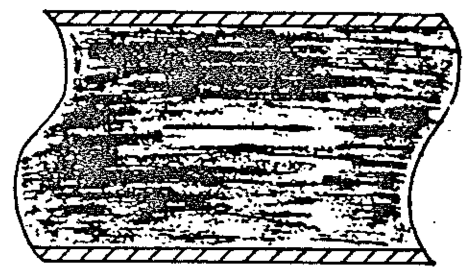

Fig. 5 Inside pipeline of Dense Phase system transferring sand at 500 ft/min (2.5 m/sec).

MEDIUM-PHASE SYSTEM

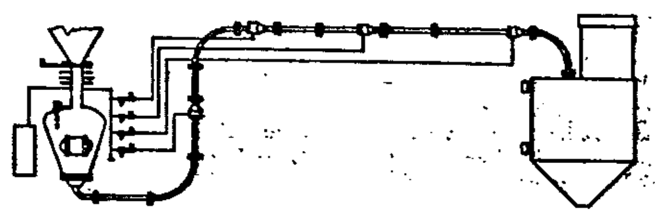

Fig. 6 In the design type shown in Fig. 6 the pressure vessel volume is not specifically matched to the diameter of the pipeline. Large or small volumes of material are propelled along the pipe in a fluidized or semi-fluidized nature. Pipeline boosters inject air at certain points to maintain momentum and material air mixture. Heavyweight pipe and reinforced long radius bends are a common feature to resist wear caused by high material velocity.

DENSE-PHASE SYSTEM

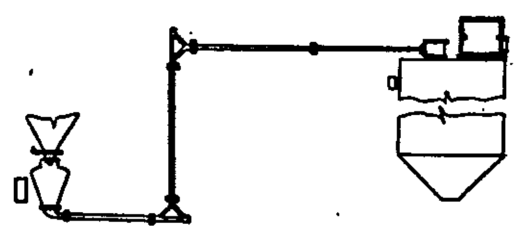

Fig. 7 In the design type shown in Fig. 7 the pressure vessel volume is specifically matched to the diameter of the pipeline. Fixed volumes of material are pushed along the pipeline in a non-fluidized condition at low velocity. Pipeline material is lightweight and long radius bends are not required. Pipeline and turning point wear is not a problem. Pipeline boosters are not required.

4. SUMMARY OF PERFORMANCE CRITERIA

In assessing system design types the following aspects of performance, briefly referred to in the previous section must be carefully considered. It is the system designers responsibility to justify their performance claims with supportive calculations, test data and documentation.

4.1 Velocity

A high velocity in excess of 2000 f.p.m.(10 m/sec) may be expected with a medium or lean phase system, may not be a disadvantage with certain materials, particularly those that do not have a high grain hardness or are likely to suffer degradation. It is a considerable disadvantage to systems required to handle abrasive materials.

For batching type dense or medium phase systems, the conveying velocity can be from 100 to 800 ft/min (0.5 to 4 m/sec) dependent on material characteristics. Granular materials such as sand travel at the lowest speeds; larger granular material such as coal and fine light materials travel at the higher speeds.

For continuous lean phase systems the minimum safe conveying velocity must be maintained, typical examples of these are:

Fine Dry Powders 2500-3500 ft/min (12.6 - 17.7 m/sec)
Coarse Particles 3500-4000 ft/min (17.7 - 20.2 m/sec)
Large Particles (lumps) 4500-6000 ft/min (22.7 - 30.3 m/sec)

To check the conditions in the conveying line the following simple formula may be used: where $Q = V \times A$

Q = Quanity of conveying air at the conveying pressure cfm;
V = Conveying velocity;
A = Area of pipe in square feet.

4.2 Air Consumption

An accurate calculation of air consumption is necessary to achieve the efficiency measure air/material ratio. For compressed air operated designs operating from a main compressed air supply, air consumption may be obtained from:

a. Air flow meters installed at the supply to the system running a test on the subject material in which case careful attention to pressure and temperature conditions at the meter should be made in calculating the actual flow.

b. Using a nomograph to estimate the flow to the system. This is an approximate method since air consumption fluctuations during the conveying cycle will not be recorded.

The object of careful measurement is to obtain the true free air consumed during the entire operating cycle. This should not be confused with the rate of compressed air to be supplied to the system. The rate of consumption is a variable value during the conveying cycle and may be a high value during a particular part of the cycle. Provision should be made to meet this requirement of system operation which may suggest the use of an air reservoir adjacent to the system to prevent supply air pressure drop into the system at the moment of maximum demand.

For fan or blower driven continuous systems air volumes are clearly shown on the air generating equipment, and power consumption readings to the prime mover may also be directly related to air supplied. This method also applies to compressed air systems operating from captive air compressors.

4.3 Air Material Ratio

A definition of this criteria and its obvious importance has already been given, so an example from a typical installation is worked through:

Application: Dry Sand 95 lb/ft.cub (1520 kg/m.cub)
Conveying Distance: 100 ft. (30 m.) 4 in. (100 mm) conveying pipe.

Dense Phase
Air Consumption: 120 s.c.f.m. (3.4 m. cub/min)
Transfer Rate: 15 tons/hr
Transfer Pressure: 40 p.s.i. (2.8 kg/cm^2)
Air Mat. Ratio: $\frac{\text{cub.ft.of air per hr x bulk density}}{\text{lb per hr conveyed}} = \underline{22.8 \text{ to } 1}$

Medium Phase
Air Consumption: 313 s.c.f.m. (10.96 m/cub/min)
Transfer Rate: 10 tons/hr
Transfer Pressure: 20 p.s.i. (1.4 kg/cm^2)
Air/Mat. Ratio: $\frac{313 \times 60 \times 95}{20000} = \underline{89.2 \text{ to } 1}$

4.4 Degradation

This criteria is often important but sadly often overlooked in the most sensitive applications. The phenomena of material grain erosion and break up will occur with any material and is expected to be greater when conveying velocity is highest. A full conveying test on the subject material is the only definite way to determine the extent of degradation. The conveying test should be carried out on a pipe system containing pipe length and bends closely resembling the actual requirements. Results obtained should be set against the system transfer capacity and actual velocity used to ensure that all appropriate aspects of the application have been imposed on the test. Samples of tested materials should be taken over a number of cycles since an empty test rig at the beginning of a test will not reveal results of practical value.

4.5 Reception Hopper Dust Suppression

High velocity fluidized systems will generate larger volumes of dust laden air at reception (terminal) points than low velocity non-fluidizing systems. Capital cost considerations are important if high efficiency and operating reliability is to be achieved in suppressing large volumes of fine airborne dust particles which indeed may lead to a secondary handling system.

The selection of the appropriate reception hopper filter arrangement should be made with regard to the material application requirements. For example:

i) Is it permissable to allow fines to pass into the reception hopper or must they be separated?

ii) Is the material grain fineness so great that continuous clean reverse jet filters are required or will a simple automatic clean, vent unit be acceptable?

iii) Does the process into which the material is being delivered require (i) and (ii) plus continuous gas evacuation?

iv) In a multiple reception hopper arrangement will the preceding considerations prevent the use of a single common filter unit?

v) Is the filter media compatable with the material fines it will be handling?

4.6 Handling Capacity

From a practical test in which results of material velocity are carefully taken capacity graphs may be easily produced and an example of these is shown. Handling capacity and associated air volume consumption should be supported by calculations and not merely as a statement by the manufacturer. Care and caution should be taken when interpreting test circuit results to assess capacity for larger systems operating with the same material.

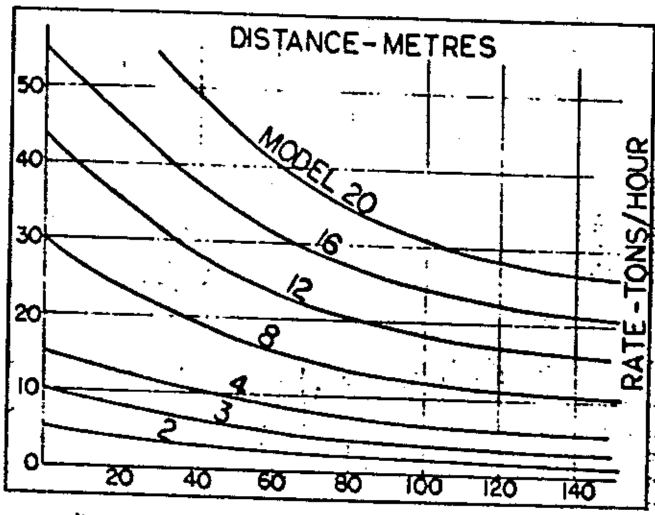

Fig. 8 Example of performance graph. The material tested producing this graph was cement clinkers from kiln described as hard rounded various sizes up to 1 in. (25 mm) without much fine dust.

4.7 Temperature

The system performance criteria relating to temperature is based on the mechanical design aspects of the equipment rather than its operating concept. Sensitive areas of the equipment operating at high temperature concern the pressure vessel closing valve since in compressed air operated equipment this is the only moving part of the machine in which component tolerances will be subject to significant thermal expansion. A closing valve relying on 0.002 in. (0.05mm) clearance on a seat at ambient temperature will find a different condition prevailing at that clearance when the temperature reaches 900°F (480°C)

4.8 Related Process or Distribution Control Considerations

The pneumatic conveying system rarely works in isolation. It is required to form a link between processes or to undertake a distribution responsibility in conjunction with material consumption demands. Control equipment simplicity is paramount to ensure operator acceptance and acceptable capital cost. For example, a multi-hopper distribution system that is entirely automatic which uses only one level probe in each reception hopper is more attractive than a similar system doing the same job but requiring two level probes in the reception hopper.

4.9 Wear Resistance, Maintenance Requirements and System Life

This performance criteria is equally important to the pneumatic conveyor as with any other item of plant or equipment. Of most obvious interest is the pipework as discussed previously. But how does the engineer assess anticipated life in the pipework without reference installations to guide him? Again, the importance of understanding the system design and its ability to control velocity. The system manufacturer has a clear responsibility to provide an estimate of pipe wear rate related to tonnage handled through the system and it should not be unreasonable for the manufacturer to grant an undertaking in this respect.

5. APPLICATION CRITERIA

To provide a practical base from which to consider the foregoing information a typical application specification is prepared. The specification package is designed to test the equipment supplier's knowledge of his own product's ability to meet your requirements and to provide him with a complete understanding of the material for his consideration. The prospective suppliers answers should be supported with calculations and adequate descriptive notes to fully explain the system operating concept and method.

Inquiry Specification

Positive pressure pneumatic conveying system required to transfer bulk abrasive cleaning media known as "knockout 2", from process completion to multiple storage in accordance with the following requirements:

Material:

Knockout 2 Refined steel/copper slag;
Bulk density 126 lb/ft³ (2016 kg/m³) ± 5 lb/ft³ (80 kg/m³)
Grain size: Band
1. 70% 2mm - 2.5mm
2. 20% 1mm - 2 mm
3. 10% below 1 mm.

Bands 2 and 3 not to exceed 25% and 15% respectively after pneumatic conveying.
Moisture content: Inherent - nil, free - nil.
Angle of repose: 50°
Flowability rate:
750 lb/min ± 50 lb/min through a 2 in. hole
(278 kg/min ± 140 kg/min through a 50 mm hole)
Temperature: Between ambient and 320°F (160°C)
Chemical properties: Innert when stored in nonferrous or plastic containers. Subject to slow oxidation when in contact with ferrous materials.

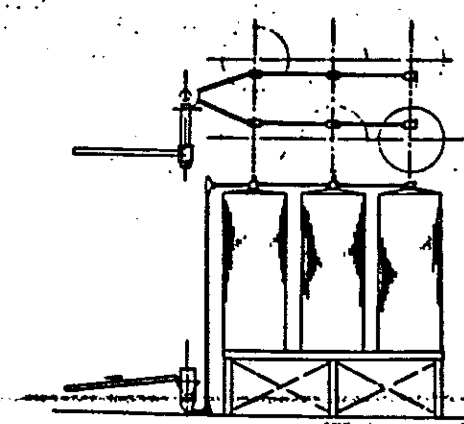

Fig. 9 Sketch of application inquiry for knockout 2 distribution to storage.

Application

See attached sketch. Material is continuously discharged from final process screen to belt conveyor feeding pneumatic conveying system. Discharge rate is 25 tons/hr ± 5 tons/hr. The pneumatic conveyor is required to cycle continuously and automatically as and when material is supplied to six storage hoppers as shown. It is required to maintain the level of material in the upper 25% volume of the storage silo irrespective of demand pattern at any silo. Demand from any storage silo will not exceed a rate of 5 tons/hr in a maximum 20-minute period collectively and will not exceed a rate of 25 tons/hr in a 20-hour period.

Compressed air may be available from plant services. However, separate air compressor facilities should be shown as a separate item.

Information Required

1. Air consumption of system when operating continuously expressed as:

a) total free air consumed at atmosphere pressure per minute;
b) peak demand rate, expressed as standard cub ft per minute;
c) period and frequency of peak demand rate;
d) supply pressure at machine;
e) maximum conveying pressure in system.

2. Air material ratio by weight. Show tolerance and supporting calculations.

3. Material velocity in pipeline.

a) Indicate highest and lowest velocity and location in system where highest velocity will occur;
b) Explain basis for velocity statement i.e. reference installation/calculation/experience/test. Show calculations.

4. Storage Silo Dust Suppression Equipment.

a) Filter media type,
b) Media area.

5. Material Degradation. State degradation expected after conveying and basis for statement i.e. reference installation/calculation/experience/test.

6. Pipeline Wear. State wear rate expected at pipe bends and straight lengths and basis of statement i.e. reference installation/calculation/experience/test.

7. Handling capacity. Provide calculations supporting statement of equipment to meet transfer capacity requirements.

8. Other information required relates to:

a) Method of operation,
b) Equipment maintenance requirements,
c) Method of system control to satisfy application requirements,
d) Detailed description of system components,
e) Equipment contact material,
f) Extent and scope of warranty,
g) Price and delivery,
h) Terms and conditions.

The specification format shown if not used in its entirety would be a useful check list of application and equipment considerations, particularly for those applications for which previous pneumatic conveying experience is not available.

6. PRACTICAL ASPECTS OF SYSTEM ADOPTION

Apart from conveying system design and material type application considerations to which we have been addressing ourselves in attempting to achieve a good partnership for any bulk handling task, there are other considerations anciliary to the main task of forming a good partnership which should be discussed. Perhaps obvious to the experienced but nevertheless they are worthy of summary to remind the initiated and to encourage the inexperienced.

6.1 Full Conveying Tests for Material Samples

If it is decided to conduct handling trials, a study of the test facilities should be made before commitment is made. Test rigs should provide meaningful information and should represent as close as possible your own pipe routing. A study of previous material tests conducted on the rig from the manufacturers standard test reports will clearly show the extent of the study on your material to be expected. Inadequate standard reporting on tests by the manufacturer will reveal the extent of their knowledge of the subject.

It is important to ensure that the test rig is free from previously tested materials and line clean out facilities should already have been fitted and used as a standard facility between tests.

Instrumentation on the test rig should include a means of measuring as accurately as possible the volume of air consumed for each conveying cycle without which it will not be possible to arrive at the important efficiency criteria air/material ratio previously mentioned. Cycle times should be accurately timed in order to clock theoretical velocities and in carrying this out consideration should be given to the batch size in the pipeline bearing in mind that a total cycle time for a volume of material to pass along a pipeline does not represent the true period that a representative particle spends traveling along the line.

6.2 Material Feed and Introduction into Conveying System

Since it is well understood that bulk materials do not behave like fluids, it will be accepted that merely providing a large supply of material above the start of the conveying system will not necessarily meet the requirements of the system design and the material type being conveyed.

Unless the pneumatic conveying system vessel for positive pressure batching type designs is equipped with a vessel closing valve, purpose designed to close and seal through the column of material fed from above, then special consideration should be given to the valve design and arrangement being provided to arrest the flow of material before the vessel pressure sealing valve is closed. This is an important area of system design and application engineering since most equipment faults occur at this point which normally represents the only moving part of the pneumatic conveying system.

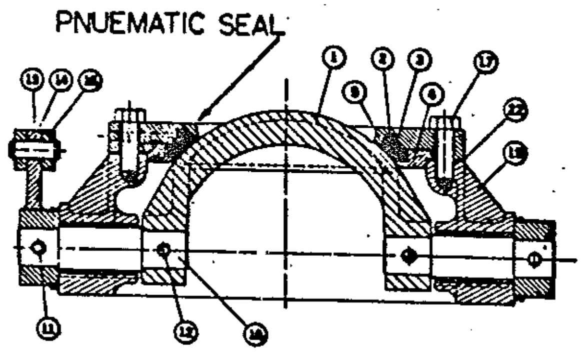

Fig. 10 This is an example of a purpose designed valve for closing and sealing through moving or static columns of abrasive bulk materials widely used in pneumatic conveying equipment.

The mechanical characteristics of the material to be conveyed and how they apply to the material in the static stored condition will indicate the most suitable method for feeding into the pneumatic conveying system. Cohesive or moist materials with low flowability may require mechanical assistance into the system and proper attention to this area should be given. Correct application of vibrating or screw conveyors is equally important to the success of the overall handling scheme.

6.3 Pipe Routing, Reception Points and Pipeline Valve Locations

Easy access to pipework may not be of primary importance with a very low velocity dense phase system where pipeline life can be expected to be considerable. Provision should however be made to ensure easy access to pipeline distribution valves where routine annual maintenance will be required.

At the reception points good location planning of dumping or terminal points with level probes and dust filtering connections will be beneficial. Provide good access around pipeline valves. Use hopper top mounted valves in preference to pipeline supported valves wherever possible to provide easy access to the valve and to avoid valve support requirements.

7. CONCLUSION

At a recent world symposium on pneumatic conveying, delegates and speakers alike generally agreed that pneumatic conveying continued to appear more of an art than a science. Until it becomes possible to produce a 'foolproof' equation that represents the total activity of materials inside a pneumatic conveying system, the success rate for pneumatic conveying system applications will continue to depend on the accumulated experience of manufacturers and interested engineers. In these circumstances it becomes evident that a heavy responsibility lies with the client engineer to fully investigate system performance claims and be fully aware of the limitations his own material may impose on certain equipment.

The most important aspect of these considerations concerns the performance criteria relating to: (i) velocity of material in the pipeline and (ii) air consumption as expressed by the air/material ratio.

The foregoing has been prepared with the intention of making client engineers more aware of the material and application circumstances that provide the background conditions to form a successful marriage between bulk material and system design or more importantly to avoid an embarrassing association.