ARTICLE REPRINT

The Experts and Academics Confirm:
Pipeline Boosters are Unnecessary

Pneumatic Conveying in the 21st Century

by James S. Mason
Solids Handling Unit
Thames Polytechnic / England

SUMMARY

Pipeline boosters were widely used in earlier pneumatic conveying system designs as a means of fluidizing and accelerating material velocity. This additional fluidization using large volumes of air indiscriminately along the pipeline is unnecessary in a correctly designed system in which the batch volume is correctly sized with the pipeline diameter.

In the case of incorrectly designed systems using large batch volumes and small pipelines, boosters have been used, but the effect is to lose control of the material velocity, causing:

- High pipewear
- Material degradation
- Very large air volumes
- Large hopper baghouses

and a generally inefficiently designed pneumatic conveying system.

Third-party endorsement of this statement is provided in the attached two (2) papers which have been marked at the appropriate passages.

PNEUMATIC CONVEYING INTO THE 21st CENTURY

J.S. Mason
Bulk Solids Handling Unit,
Thames Polytechnic,
Wellington Street,
Woolwich, SE18 6PF

Abstract

This paper predicts that the present variety of research programmes centred on modelling gas-solid flows will lead to the widespread use of computer-aided design programmes for both suspension and non-suspension flows by the 21st Century. The application of these programmes will point the way to the sensible limits of pneumatic conveyor applications. The paper then considers both recent developments in system design and in industrial applications of current pneumatic conveying to provide a base knowledge of the technology from which to predict future possibilities for the pneumatic conveying industry. Some indication of possible trends is demonstrated by reference to new product developments. The paper concludes with an outline of Intelligent Knowledge Based Computer Systems and suggests that in the 21st Century Expert Systems will have been developed to answer, quickly and economically, the question "what is the best storage, transport and control system for a particular bulk solids handling plant?"

1. INTRODUCTION

The infinite variety of physical properties of the two phases in gas-solid flows precludes a rigorous description of these complex phenomena by a set of mathematical models which can be used for general pneumatic conveying system design. However, the ue of models developed with the aid of empirical data and careful choice of simplifying decisions has improved the understanding of the dynamics of gas-solid flows. This process of establishing models and assessing their validity through careful experimental work to further refine the models has been a characteristic feature of the work of many researchers during the last thirty years or so. The improved insight into the mechanism of actual two phase flows which has been acquired has facilitated the use of dimensionless groups selected to represent the physical behaviour exhibited by the flows. Once reliable dimensionless groups have been identified then these can be used for scaling-up during the design process. It is reliable models and scale-up procedures which are the heart of computer-aided design programmes. It is true that skill in writing good and efficient software is important to show both the range of design options available to solve a problem and to provide suitable graphics facilities, but good models are essential. At the present time a number of computer-aided design programmes are available for satisfactory design of some suspension flow systems. By the 21st Century the majority of such systems will be designed by computer. This will require considerable extension of the data bases on product characteristics for the wide range of bulk particulate solids.

The position for the many forms of non-suspension or dense phase flows is far more problematical. Research over the next decade will be needed to provide more data about the factors influencing these conveying modes. It is reasonable to expect that the CAD of systems for low velocity flows having high solids concentration will be available in the 21st Century for different groups of products. It is suggested that models will have been established to describe the flow behaviour of groups of particles and much data will have been gathered to provide adequate data bases for design.

It will be the application of CAD programmes that will identify the boundaries for the economic pneumatic conveying of products either over long distances or at very high product flowrates.

The purpose of this paper is to outline what the author believes will be the significant developments in pneumatic conveying technology into the 21st Century. This position is reached through a consideration of current developments in system design, new applications and product developments and Intelligent Knowledge Based Systems.

2. MODERN DEVELOPMENTS IN SYSTEM DESIGN

During the last decade there have been a number of advances which collectively have produced techniques in pneumatic conveying system design which lead to reliable plant operation. The improvements in current system design are a result of some or all of the following developments :-

2.1 an increased understanding of how and which characteristics of bulk particulate solids influence the mode of gas-solid flows, Ref. 7.1. That is, initial characterisation tests can indicate the suitability or otherwise of a product for suspension or non-suspension flows;

2.2 a realisation that the conveying capability of a product can be described knowing the relationship between the product mass flowrate and the gas mass flowrate for a particular pipeline configuration. Such a plot yields the product's conveying characteristics from which the optimum system design parameters can be established Ref. 7.2. Alternatively, information is available from these relationships to assess the potential of an existing system for being uprated;

2.3 a capability to scale-up test data to reliable design data for full-scale plant. This position has been reached through a series of research investigations aimed at obtaining correlations for the number of bends, bend geometry, vertical pipe-runs and so on in terms of equivalent horizontal length and conveying air inlet velocity, Ref.7.3;

2.4 a knowledge of the relationship between feeder type and feeder design on the operational conditions. For example, with continuous feed systems using rotary valves it is now possible to predict the influence of the transition section geometry and size, at the interface between the rotary valve and the pipeline, on the performance of the overall conveying system, Ref. 7.4. With batch systems a major break-through is the ability to match the feeding capability of a blow-tank with the conveying capacity of a pipeline. This is achieved by relating a blow-tank's feeding characteristics, when using two air-supplies to control the solids feedrate, with a pipeline's product conveying characteristics, Ref. 7.5.

2.5 an improved understanding of the influence of variables such as velocity, product concentration, product characteristics, nature and geometry of the impact surface, and angle of particle impact on both erosive wear of plant components such as bends and valves, and on particle attrition, Ref. 7.6

Thus, nowadays there is no need for pipelines to become blocked, for bends to wear out prematurely, for excessive product degradation to occur, or for the designed product conveying rate not to be achieved. The technology is available now for a pneumatic conveying system to be optimised to give maximum product throughput for minimum energy consumption.

This position of pneumatic conveying technology is creating an increased confidence in a wider industry that these pipeline transport systems can perform reliably and efficiently which is leading to increased applications as industries expand and diversify.

3. APPLICATIONS RESULTING FROM EXTENDING TODAY'S TECHNOLOGY

3.1 Vacuum pneumatic conveying systems for unloading free flowing products such as grain, alumina and petroleum coke from the holds of ships have been in use for many years, but despite their flexibility in operation, compact size and cleanliness they have been compared unfavourably with mechanical systems on account of the high energy consumption, limitations in respect of maximum unloading rate and the small range of products which they can handle. This situation has changed and will continue to change as a result of technical developments. These developments, Ref. 7.7, have centred mainly on :-

(i) significant changes in the approach to suction nozzle design;

(ii) improved techniques of encouraging non-free-flowing material to flow to the pick-up point;

(iii) an increased understanding of the importance of pick-up velocity in relation to maximising product throughput and minimising erosive wear;

(iv) development of sensing devices for attachment to the suction nozzle to provide automatic control of the nozzle position and so ensure that the nozzle is continually immersed in product during main sinking;

(v) improved designs in filter/separator systems;

(vi) the use of a two-pipe system to one filter so that if one pipe is removed from the product conveying continues in the second pipe - a control system has been designed to increase the efficiency of main sinking operations, however, this can be utilised also for increasing the speed of the clean-up stage.

Present-day maximum throughputs for one pneumatic ship-unloader is about 600 tonnes/hour, but it evident that the technical developments referred to here will lead to the 1000 tonnes/hour single unloader by the 21st Century.

Further developments will involve more applications of computers and programmable logic controllers to improve the overall efficiency of ship-unloading, in fact, there is no reason why the entire operation should not be completely automated.

This position will be reached through research into areas such as surface topography measurement of bulk solid materials in ship's holds, surface stockpiles or very large silos, Ref. 7.8. This work relies on instrumentation involving a laser, beam deflector, microprocessor and TV camera measuring continuously the bulk solid surface profile. The information produced can be used to establish an optimal strategy for, say, main sinking operations during ship-unloading. It will also be useful for determining the contents of large bulk solid silos and stockpiles.

3.2 Research into the conversion of coal to a useful transportation fuel for application to a gas turbine suitable for road vehicles has been pioneered by General Motors, Ref. 7.9. General Motors realised that powdered coal contains more than 80% of its original energy after being processed, compared with 55% for liquid fuels derived from coal. This fact, coupled with the abundance of coal in the United States, motivated General Motors into investigating the powdered coal turbine as an alternative to the internal combustion engine. General Motors installed a coal-powdered gas turbine engine in two production cars. The engines produced a power output similar to a small V-8 engine and the fuel economy was similar, however, the turbine engine weighed considerably less. They used an onboard computer to control the combustion process.

The coal, which was finer than powdered sugar, was stored in a tank in the engine compartment from where the coal was pneumatically conveyed to the combustion chamber. Development work is continuing in areas such as injection of the coal into the engine - another aspect of pneumatic conveying.

If such a vehicle engine is developed the market for storage, distribution and sales outlets for the new fuel will be phenomenal. In the United Kingdom alone the micronised coal needs for road vehicles would be around ten million tonnes per annum. There would also be a need to handle the resulting ash. Thus, the future for pneumatic conveying in this one area alone is quite breath-taking as pneumatic conveying installations will be needed at all existing petrol stations and at the numerous cleaning and coal-preparation plants which will be needed. In fact, it is easy to envisage underground pipeline systems distributing the coal in much the same way as petrol is distributed today. This prospect for the 21st Century means that pneumatic conveying will become as familiar to people as the domestic vacuum cleaner and this is when Pneumatic Conveying will have come of age.

3.3 In 1977 at the International Powder and Bulk Solids Handling and Processing Conference in Chicago Ref. 7.10, Professor Soo presented a paper which examined the feasibility of transporting coal economically over hundreds of miles. He proposed two pilot plants - one having a 3.5 mile pipeline and conveying 200 tonnes/hour of 50 mm coal - the second was to be used to evaluate the economics of 100 mile pneumatic conveying applications based on 1000 tonnes/hour of 6 mm coal. These proposals have not been developed further. However, there are applications in Australia, South Africa, India and other countries where products are conveyed over distances of around 2 km and longer distances are being considered. For example, the Central Electricity Generating Board in the United Kingdom are considering the transport of 400 tonnes/hour of pulverised fly ash over 10 km.

It seems that economics, environmental and political factors will determine the future of very long distance pneumatic conveying applications and not the technical problems. However, technical developments will undoubtedly make the economic considerations more attractive.

4. NEW PRODUCT DEVELOPMENTS

4.1 Pneumatic conveying systems for very low velocity flows - it is well known that there are several proprietory conveying systems which transport solid particles at low velocity, say 2 to 5 m/s, by conditioning the material into either plugs or a highly aerated state, and maintaining the conditioned state throughout the conveying line. Also, it is realised that, in many cases, air boosters and similar devices are just not necessary, for the non-suspension slug flow behaviour is a function of the nature of the bulk solid, the air pressure and volume provided, the pipeline configuration and the feeding mechanism at the start of conveying.

Recent research, Ref. 7.11, has identified two types of low velocity flow, namely, "shearing-type flow" and "full plug flow". These flows have been modelled and the models are the basis of reliable computer software for rapid production of good designs. Such systems are capable of conveying products like granulated sugar at velocities of around 1 m/s and so particle degradation is avoided.

4.2 Computer Control Systems for Pneumatic Conveying Plant - reliable instrumentation has been available for some time to measure, say, the speed of a rotary valve, the speed of a blower, the output from load cells fixed to a receiving hopper, the pressure differential across an orifice plate, the pressure and temperature of the conveying air, the system and conveying line pressure drops, and the electrical power absorbed by a blower motor. The information from this type of instrumentation can be fed to a computer control scheme to control a pneumatic conveying plant. If the computer has stored data on the conveying performance characteristics of the product in the pipeline, the computer can be instructed to arrange for a product flowrate of, say 10 tonnes/hour. If the flow reduces to 9.9 tonnes/hour then the computer will decide whether to increase the rotary valve speed and to make other consequent adjustments or to, say, reduce the blower speed. Thus, a pipeline can be controlled to transport product at a closely specified rate.

5. INTELLIGENT KNOWLEDGE BASED SYSTEMS

5.1 Introduction. Whenever people in an organisation consult with an expert, for example, in planning, production, financial management, marketing, engineering design, risk analysis, complex scheduling, or scientific analysis - this is an application for an Expert System.

An Expert System is an Intelligent Knowledge Based System, this requires powerful information processing systems to enable more effective transfer of human intelligence and knowledge to the computer and to computer systems that are easier to build and use - that is a machine which can make decisions more effectively and reliably than a human - hence Artificial Intelligence.

Information Technology is accepted as being associated with new technology - this implies fast access to knowledge and information. Also, it is well known that the rapid advances in microelectronics are providing greater processing power to enable vast amounts of data to be organised quickly to provide solutions to questions which enable decisions to be made.

Thus, Information Technology is the acquisition, production, transformation, storage and transmission of data by electronic means in forms which facilitate the interaction between men and between men and machines. The key words relate to storage of DATA, relationships between PEOPLE and MACHINES, systems APPLICATIONS, and the IMPLICATIONS.

It seems inevitable that fast access to information for purposes of process and system control in Bulk Solids Handling Plant is the developing technology of today, but what does the future hold for Bulk Solids Handling Systems and Pneumatic Conveying in particular? It would give the industry and ourselves increased status to be recognised as part of the "new technology" boom. A goal such as this could be realised through the development of Intelligent Knowledge-Based Systems for the Safe, Economic and Reliable Design of BSH Systems. That is, a computer-based facility which provides an applied artificial intelligence capability. For example, a key decision to be made by a user company is "what is the most appropriate Bulk Solid conveying, storage and control system for my application?"

To provide a reliable and quick answer to this question needs a consideration of :-

a) The transport system alternatives, for example :-

(i) mechanical conveying - en-masse
belt
screw
vibratory

(ii) pipeline conveying - slurry
capsule
pneumatic
high or low pressure,
batch or continuous,
vacuum or positive pressure,
suspension flow or non suspension
flow, and so on

Then, ENERGY considerations of these;
RELIABILITY aspects (pipeline blockage,
belt/chain failures etc);
ENVIRONMENTAL problems (dust emissions etc);
EXPLOSION hazards and solutions;
EROSIVE WEAR of plant;
DEGRADATION of the product;

The EXPERT SYSTEM must be able to provide quickly a comparative assessment of the suitability of the many alternative transport systems with recommendations backed-up by justification.

(b) Storage System Alternatives, with attention to :-

Reliable flow; product characteristics under various conditions;
Extent of product segregation in hopper;
Forces and pressures generated - safe structural design.

(c) (i) Data base for a wide range of products and applications :-

product properties;
bulk solid characteristics;
conveying characteristics.

(ii) CAD for Pneumatic Conveying Systems - to provide
decisions on pipeline diameter;
stepping pipelines and the consequences;
compressor/blower ratings and so on.

(iii) CAD for Mechanical Handling Systems

(iv) CAE for Storage Applications :-

finite element approach;
flow analysis;
structural analysis;
production of drawings.

The collaborative input of researchers and industrialists to the production of such an IKBS will be :-

(i) interrogation of programs
(ii) creation of user-friendly interactive software
(iii) programs which link the various elements.

These are some different approaches to building EXPERTS SYSTEMS.

6. CONCLUSION

At a recent meeting on Industrial Computer Systems it was forecast that by 1990 Western countries will spend over 10% of their gross national products on software development and maintenance. In Europe, the Information Technology industry is already comparable to the automobile and steel industries in terms of wealth created.

In Europe a 1.5 billion dollar project for Research and Development in Information Technology has been created to develop the necessary software engineering tools and methods - Pneumatic Conveying in the 21st Century will be involved in these new technological developments in order to remain competitive with other transport systems and new markets for pneumatic conveying will emerge through the operation and availability of EXPERT SYSTEMS.

7. REFERENCES

7.1 Dixon C. Plastics Pneumatic Conveying and Bulk Storage. Book edited by G. Butters, pub. Applied Science Publishers 1981, Ch. 2, pp. 39 to 42 and 56 to 62.

7.2 Mills D, Mason J.S., Agarwal V.K. An Analysis of the Dilute Phase Pneumatic Conveying of Sand. Proc. Pneumatech 2 Conf., Powder Advisory Centre, Canterbury, Sept. 1984.

7.3 Mason J.S., Mills, D. Pneumatic Handling Technology. Industrial Awareness Seminar 4, Part 2, Powder and Bulk Solids Conf., Cahners Expo. Group, Chicago, May 1985.

7.4 Kessel S.R., Reed A.R., Mason J.S. Current Research into the Performance of Rotary Valves. Proc. Pneumatech 2 Conf., Powder Advisory Centre, Canterbury, Sept. 1984.

7.5 Mason J.S., Mills D., Reed A.R., Woodcock C.R. Pneumatic Handling of Bulk Materials Part B: Practical System Design. Intensive Short Course Notes, Thames Polytechnic, May 1985.

7.6 Agarwal V.K., Mills D, Mason J.S. Some Aspects of Bend Erosion on Pneumatic Conveying System Pipelines. Proc. 1st Nat. Symp. on Hydraulic Transportation of Solids through Pipelines, Ranchi, India, March 1985.

7.7 Reed A.R., Mason J.S. The Effect of Suction Nozzle Geometry on the Performance of Pneumatic Ship Unloaders. J. of Pipelines, 5 (1985), pp 67-75.

7.8 Barnes R.N. Surface Topography Measurement of Bulk Solid Material Stockpiles. Proc. 10th Int. Conf. on Powder and Bulk Solids, Cahners Exp. Group, Chicago, May 1985.

7.9 Stretter R.J., Bell A.H., Shows E.W. Initial Evaluation of a Coal Burning Turbine Powered Vehicle System. ASME paper 83-GT-183.

7.10 Soo, S.L., Leung S.T. Transportation and Distribution of Coal via Pneumatic Pipelines. Proc. Int. Powder and Bulk Solids Handling and Processing Conf., Chicago, May 1977.

7.11 Hitt R.J. An Investigation into the Low Velocity Pneumatic Conveying of Bulk Solids. PhD Thesis, Thames Polytechnic, January 1985.