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Pulse Phase Conveying — A Review of the First Ten Years

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Die ersten zehn Jahre der pneumatischen Pfropfenförderung

Der Beitrag beschreibt die Entwicklung der pneumatischen Pfropfen- und Schubförderung von den ersten Forschungs- und Entwicklungsarbeiten am Warren Spring Laboratory, England Ende der 60er Jahre bis hin zur heutigen allgemeinen Anwendung dieser Verfahren.

Transport en phase pulsée: Un examen des dix premières années

Cet exposé retrace le développement du concept de transport en phase pulsée depuis les recherches initiales des travaux de développement effectués par Warren Spring Laboratory en Grande-Bretagne, à la fin des années 60, jusqu'à l'application actuelle universelle de ces techniques et principes.

El transporte por fase de impulsos: Una examen de los primeros diez años

Este artículo muestra el desarrollo del concepto de transporte por fase de impulsos desde la labor inicial de investigación y desarrollo emprendida en el Warren Spring Laboratory de Inglaterra a fines de la década de 1960 hasta la aplicación universal de esta tecnologiá en la actualidad.

Summary

This paper traces the development of the pulse phase conveying concept from the initial research and development work undertaken at Warren Spring Laboratory, England in the late 1960s to the present day universal application of the techniques and principles.

1. Historical Background

'Pulse Phase Conveying' will be familiar to those associated with the transport of bulk solids in pipe lines. Much has been written over the last ten years, encouraging the use of the system as an economical method of moving powders and stressing the low energy advantages of this unique form of pneumatic conveying. Certainly the advantages, particularly from the point of view of energy input, are more valid in the 1980s than they were when the system was first launched in the early 1970s and it is interesting to relate what the process was designed to do originally, what progress it has made in the anticipated directions, and where it has exceeded or fallen short of these hopes. Figs. 1 and 2 detail the pulse phase concept.

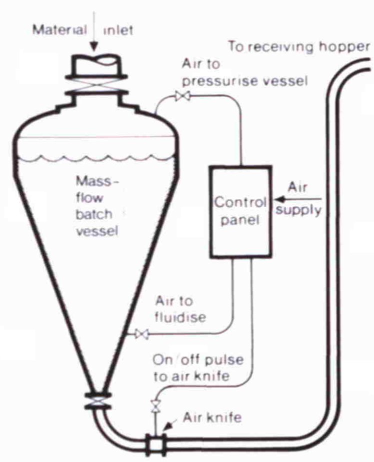

Fig. 1: Pulse phase concept

It was work at the Department of Industry's Warren Spring Laboratory, England in the late 1960s concerned with the design of powder handling and bulk material conveying systems which gave rise to the invention of pulsed dense phase conveying [1, 2]. Existing systems at that time typically involved an auxiliary injection of air, either internally down the conveying pipe line or externally along the complete length and Warren Spring scientists saw the obvious value in having a system which as far as pipe work, valving and control was concerned, terminated at or adjacent to the feed point of the material. Early experiments indicated the now established fact that the pressure required to move plugs of material is approximately proportional to the square of the plug length and the concept really developed from this point. It was found that the total pressure drop required to move a multitude of short length, discrete plugs of material was very much lower than that required for discharge of complete batches of material from even a relatively small pressure vessel.

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The question of operating pressure for the batch type pressure vessel system was fundamental in categorizing the system in relation to other forms of pneumatic transport at that particular time.

Fig. 2: Typical pulse phase unit

A good number of pneumatic conveying systems came under the heading of *lean* or *dilute phase,* often involving centrifugal fans and operating with material to air ratios of up to 5:1, that is 5 kg of material being moved by 1 kg of air at standard atmospheric conditions. A similar number of systems came under the heading of *medium phase,* that is to say operating with material to air ratios, or phase densities as they are nowadays more accurately known, of between 5 and 50:1, although more commonly the 10—20 range. Prime movers for this type of system were frequently Roots type positive displacement blowers which probably still form the back bone of present day pneumatic transport. However, in the *dense phase* area, operating with phase densities in excess of 50:1, there were relatively few systems available and most were somewhat notorious in view of their high operating pressures. Many of these systems were traditionally used on high tonnage transport in cement and quarrying industries, tended to use quite high volumes of expensively produced air, and understandably were not thought to be of very much value to the average 5 t/h pneumatic conveying requirement.

We therefore have a picture in the early 1970s of two fairly well established areas of pneumatic conveying with a third slightly detached method regarded with some suspicion by many plant and project engineers. What did seem highly attractive, however, about the *dense phase* concept, was the fact that one could move such a high tonnage of material down such a small pipe line and this is really the platform upon which the *pulsed dense phase* principle, later to be generally known as the *pulse phase system,* was launched. It had the advantage of the high pressure dense phase systems, in terms of high tonnages through small pipe lines over relatively long distances, but it could also operate at pressures often as low as the established medium phase systems. In most cases the initial conveying velocity at 3 m/s (Fig. 3) was as low or lower than the high pressure dense phase systems and because of the greatly reduced pressure gradient, the high acceleration of residual material at the end of a conveying batch was eliminated as air expands to final atomospheric pressure.

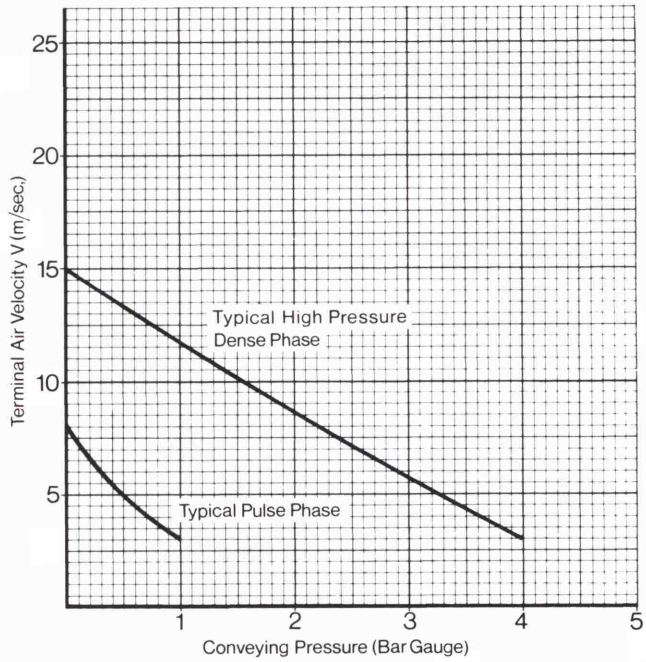

Fig. 3: Velocity gradient in dense phase conveying from initial 3 m/s

2. Introduction of the Pulse Phase System

The pulse phase system was introduced commercially by the National Research Development Corporation, England with the above technical advantages being emphasized and principally aimed at those industries using fine cohesive powders. This loose definition naturally encompassed just about all process industries, with the possible exception of foundries and their use of a particular group of often moist sands; but for the remainder it was clear that the economics of the Pulse Phase System over other means of pneumatic transport would lie with powders that were abrasive or prone to special difficulties within continuous feeding devices. Indeed the early Warren Spring Laboratory work included much test work with whiting, cement, alumina and slate powder as well as some emphasis on the food industry with materials such as milk powder and cocoa powder (Table 1).

3. Early Application of the Process

In the abrasive category, considerable potential was thought to lie in the cement manufacturing and quarrying industries where power intensive continuous conveyors in the medium phase range were well established. Time has proved this assumption to be false for a variety of reasons. As far as cement manufacturing plants are concerned, there have generally been reductions in capacity and few opportunities for existing plant modification where the head room requirement of the pulse phase pressure vessel would normally be more than that of a continuously operating conveyor. In a

Table 1:
Sample Reference List: Pulse Phase Conveying Systems

Material	Distance Plus Lift (m)	Rate (t/h)	Pipe Dia (mm)	Air Consumption (m^3/min)
Plaster	105 + 16	12	75	3
Corvic	101 + 23	1.5	40	1
Clay	7 + 7	10	75	2.3
Glass Batch	223 + 9	3.2	65	1
Alumina Hydrate	158 + 13	12	100	4.8
Milk	11 + 20	2.5	50	1.1
Potato Starch	136 + 15	2	50	1.9
Molecular Sieve Powder	92 + 15	0.2	40	0.85
Silica Flour	7 + 6	12	75	2.4
Limestone	107 + 37	5	65	2
Cement	120 + 5	1.7	25	0.4
Precipitator Dust	200 + 38	5	75	2.6

new plant situation, this can obviously be designed for but when interconnecting existing elements, there are clearly difficulties. Added to this was a basic technical misjudgement in assessing the early applications. As would be expected with any type of pneumatic conveying system which deliberately creates anything up to 100 blockages in a pipe line simultaneoulsy, extreme care has to be taken in the assessment of the material and certain parameters laid down as to its powder properties in terms of particle size analysis, bulk density, shear strength, moisture content etc., all of which will be of increasing significance the longer the distance one is attempting to convey. Early applications in the cement manufacturing industry were unwisely aimed at dusts which could not be adequately defined and which were at times quite coarse in nature, in addition to having varying temperature and flow characteristics. These were to be conveyed over distances between 150—250 m and conveying proved unreliable.

A proven low velocity method of pneumatic conveying, which by established test work (Fig. 4) has shown itself ideally suited for powders produced to specification, such as cement, should be by now the automatic choice for many handling situations in the cement industry. Unhappily, this is not the case, and this is largely the unwelcome consequence of the lack of success shown by the early applications. To prove the point we need only turn to related abrasive materials used in quarrying and roadstone situations where the pulse phase system is firmly established as an alternative to other methods of pneumatic transport and particularly to mechanical conveying elements. Abrasive powders under the limestone heading in addition to granite dust and other fillers feature prominently in the Pulse Phase reference list (Table 1).

Turning now to the food industry, a different picture emerges. Several early successes with installed plants handling milk powder promised much for the future and an installation handling tea satisfied all criteria relating to minimum degradation and blend importance. Regrettably, those more recently responsible for installing tea handling systems seem to have gone back to their established mechanical conveying elements, although the reasons remain obscure. Where the future would seem to lie in the food industry, is with materials normally causing problems in continuous feed devices such as rotary valves, and where the absence of moving parts in the pulse phase system can make a powerful argument. There are now several installed plants handling potato starch with a 20% moisture content and one in particular where the system conveys over a total distance of about 60 m through 40 mm diameter pipe work with a total installed power of 10 HP covering conveying requirements, reverse jet filter cleaining elements, pneumatic control equipment etc. Pneumatic conveying in the food industry favours the use of compression couplings for pipe work connection and the relatively low operating pressures of the pulse phase system make this a practical proposition, using light gauge pipe work. This can show important savings over some currently available high pressure dense phase systems, which in view of their relatively high operating pressure, dictate the use of heavier gauge pipe work with bolted flanged connections.

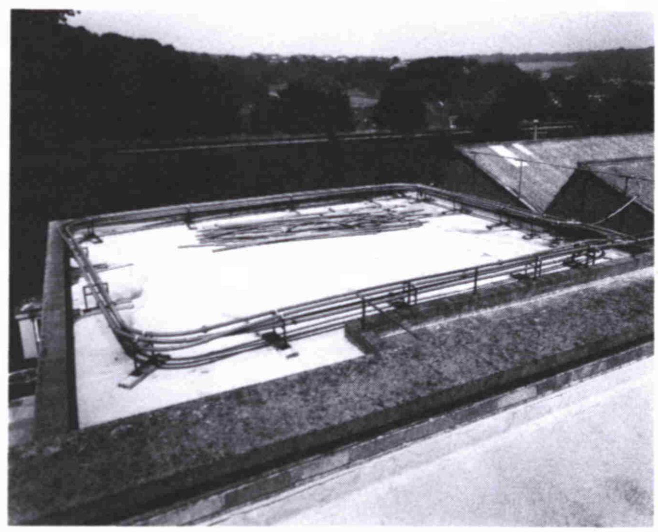

Fig. 4: Sturtevant pulse phase conveying test rig

4. Successful Applications

Two of the many industries within which pulse phase systems were thought to have considerable potential were introduced above, and it was shown, however, that this has only partly been the case.

Therefore one might ask the question: What are the materials which would benefit most from this method of pneumatic transport?

As with any form of materials handling, particularly when assessed over a ten year period, there are many types of materials which have been successfully conveyed and in a variety of applications. It is clear that the plastics industries benefited considerably with particular reference to the conveying of PVC and polyethylene powder. Other successful applications tend to be spread in diverse manufacturing situations, including the conveyance of the following fine powder materials:

— manganese dioxide
— silica flour
— glass batch
— limestone
— quicklime
— magnesium hydroxide
— animal feed vitamins
— alumina tri-hydrate
— china clay
— sugar
— lead oxide

4.1 Case Studies

What continues to be of interest is the different reasons for specifying the pulse phase system, as shown by the following two case studies:

Case history 1 concerns a large manufacturer of biscuits using large quantities of wheat flour, received in storage silos from road delivery tankers. One particular process area had been re-located at the factory and there was some doubt as to the capability of the existing medium phase system using traditional Roots type blower and blowing seal to convey over the distance of approximately 200 m at up to 5 t/h. Flour is not abrasive and can be encouraged to flow reasonably well into pneumatic conveying lines and there is of course a wealth of experience in conveying it by the medium phase solution. A 100 mm pipe line system had been designed and a dust filtration unit sized for the terminal hopper based on the air delivery of the Roots blower. The manufacturer concerned had knowledge of the pulse phase principle and decided to investigate this as an alternative with the hope that energy savings could be achieved with no significant increase of initial capital cost. The comparison proved most interesting and certainly running costs for the pulse phase system were less. The pipe line system could be reduced to 75 mm and the dust filtration for the terminal hopper reduced in size to one sixth of the medium phase system requirement, assuming the same cloth to air ratio. In addition the Roots type blower would have to be positioned reasonably close to the pick-up point and would require acoustic treatment whereas the compressor for the pulse phase system could be sited in a remote compressor house with no such treatment required.

The medium phase system was decided upon and installed due to one important point, the cost of which weighed slightly against the pulse phase system, namely the head room available beneath the existing storage silo which allowed for the installation of a simple blowing seal but not for the greater requirement of a pulse phase pressure vessel. The manufacturer chose a system to line up with others in the factory at a slightly favourable capital cost and he can be considered as having made the right decision on the assumption that his running costs are not going to be worked out too closely. From this example, it is clear that one only has to introduce an additional factor such as a reluctance to feed through rotary valves, or an abrasion problem, or a limited head room above terminal hoppers for filtration elements, to make an irrefutable case for the pulse phase system.

This point is demonstrated in the examination of a second case study for which the pulse phase system was investigated and subsequently installed and commissioned.

Case history 2: The requirement here, also in the food industry, concerned a fine gravy powder mix, flavoured with coarser particles of very different bulk density to the base material. Material was to be taken as a discrete batch from a blender and conveyed over a distance of only 8 m to any one of four receiving hoppers. Other forms of pneumatic conveying were investigated, including negative pressure, and even over the short distance none had met the requirement of maintaining the homogeneous blend and even distribution of the flavouring particles. Extensive tests were carried out and the low velocity advantages of the pulse phase system proven.

Although the pressure vessel was of relatively large size in order to accommodate the complete blending batch, the transfer rate was not critical and small diameter 40 mm stainless steel pipe work was used incorporating a remote operated four-way diverter valve. Pipe work and installation costs were therefore very low and due to the intermittent batch operation, and extremely limited head room over the terminal hoppers, dust filtration was limited on each hopper to a small vent sock which proved adequate for the low air volume.

5. Continuing Development

Development of the system into a convenient range of standard sizes has evolved to produce a nominal vessel capacity range from 0.14 m^3 to 4.2 m^3. The various components of the system including inlet valve and discharge valve have been proven rigorously in terms of abrasion resistance and minimum maintenance attention to produce a packaged unit with electro-pneumatic controls which can be conveniently specified by contracting firms or users alike.

Use of the pressure vessel as a weigh hopper when suspended on load cell equipment is increasing with clear benefits in terms of capital cost and head room and the extension of this concept to include air mixing is likely.

6. The Future

The pulse phase concept, once aimed at fine cohesive powders now extends to decidedly granular materials and recent development work has shown that with minor modifications to discharge valving equipment, materials such as rice, plastic granules and peanuts can be conveyed over considerable distances at relatively low velocities without the need for boosters or other auxillary air injection. The controls of the standard unit have been refined to the point where filters are fitted in the pressure sensing lines and automatic purge sequences are inbuilt to minimise any possible build up of material in the air knife annulus. The definitive procedure to assist in unblocking a pipe line is of course only possible due to the discharge valve on the bottom of the pressure vessel and operates by repeated line pressurization at the air knife connection (Fig. 1) followed by a venting of the conveying line blockage back into the pressure vessel. Dependent on material and distance, this can be a highly effective manual override procedure on the control panel and an important bonus over those high pressure dense phase systems with no discharge valve. Inlet valve specification has also been improved over the years to feature easily replaceable seals, and the pulse phase concept of generally only 10—30 batches/h means many less inlet valve movements as well as less pressure differential requirements than high pressure dense phase systems.

7. Final Comment

In conclusion, the pulse phase system is firmly up to date. Its low energy requirement and the associated advantages of true low air consumption and small diameter pipe lines demand increasing consideration from a wide variety of industries intent on maximizing the benefits of in-plant pneumatic transport.

References

[1] R.J. Flain & R. Farley, "Evolution of the Pulsed Dense Phase Conveyor", Bulk, May/June 1978.

[2] R.J. Flain, "Pneumatic Conveying — How the system is matched to the materials", Process Engineering, June, 1978.

[3] F.G. Lanchester, "Pneumatic Handling — Some problems and their practical solutions", 1973, Inst. Powder Technology and Bulk Solids Conference, England.