TECHNICAL PAPER

Pneumatic Conveyors for Foundries

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Presented to:
South African Institute of Foundrymen

SUMMARY
During the past fifteen years, pneumatic conveyors have become increasingly important to the foundry industry. In more recent years, the level of interest has grown more rapidly due to social pressures in the form of new legislation by Governments of industialized countries with the cleanliness of the working environment in the foundry.

Presented to the South African Institute of Foundrymen

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Pneumatic conveyors for foundries

INTRODUCTION

DURING the past 15 years pneumatic conveyors have become increasingly important in the foundry. In more recent years the level of interest has grown more rapidly due to social pressures in the form of new legislation by Governments of industrialised countries concerning the cleanliness of the working environment in the foundry.

The foundry pneumatic conveyor, despite its earlier shortcomings, has increasingly shown that it has a very important contribution to make in this respect. The justification for considering this type of equipment over conventional handling plant, brought about by the need to more closely meet the needs of dust control legislation is becoming increasingly more apparent. As a result of the growing interest, numerous attempts have been made by equipment manufacturers to solve the special problems associated with pneumatically conveying sand. These problems surround the very high wear rates in the conveying pipework and the equipment reliability when operating with this very demanding material.

The common approach to this problem has been through the development of existing pneumatic conveying system designs to meet these needs. Without exception, this approach to the problem has failed and as a consequence some natural market resistance has developed towards equipment that attempts to solve this pressing problem of the foundrymen.

A radical approach, therefore, has been necessary to overcome the component difficulties surrounding the sand handling application in foundries. During the past six years, development work has taken place and has been concluded

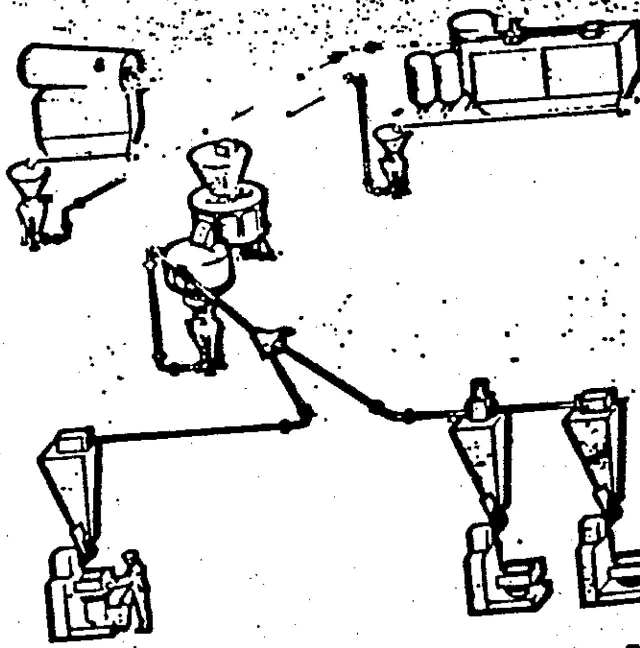


Fig. 1. Schematic view of Green Sand Plant Based on P... matic Conveyors.

Fig. 1 represents a green sand preparation system a...

... has led to general acceptance in the United Kingdom of pneumatic conveyors as a worthwhile alternative to conventional handling equipment.

SPECIAL REQUIREMENTS

Operational Requirements

It is accepted that the foundry industry is the least endowed of any industry with high in-plant maintenance capability and skill. Difficulties in recruiting and keeping skilled maintenance engineers is a symptom of the very problem that pneumatic conveyors are contributing to solve.

Fundamentally, therefore, the requirement of equipment simplicity, coupled with freedom from maintenance attention, is of paramount importance. If, in solving a dust and spillage problem, it becomes necessary to increase the maintenance attention in that area of the foundry by, shall we say, replacing pipes or bends frequently, then the equipment fails to meet its initial operating criteria.

The next operational requirement concerns the ability of the equipment to perform with at least the same, or hopefully better, freedom from supervision. Most mechanical handling plant will today distribute dry sand or prepared moulding sand in an automatic fashion without the need to rely on operators to pull valves and levers. By virtue of the mechanical equipment involved, this requirement can only be met with large valves (ploughs) operating in an exposed way on the belt conveyor. The pneumatic conveyor must match, or improve this capability without adding to equipment sophistication and in a way that satisfies the technical requirements of the foundrymen.

The final operational requirement concerns equipment life. This concerns the handling system as a whole and not just the life of the prime mover. It has been demonstrated that pneumatic conveyors will outlive their mechanical system competitors whose greatest disadvantage involves the need to render hundreds of moving parts wear resistant when concerned with handling the most destructive bulk commodity known to the foundryman.

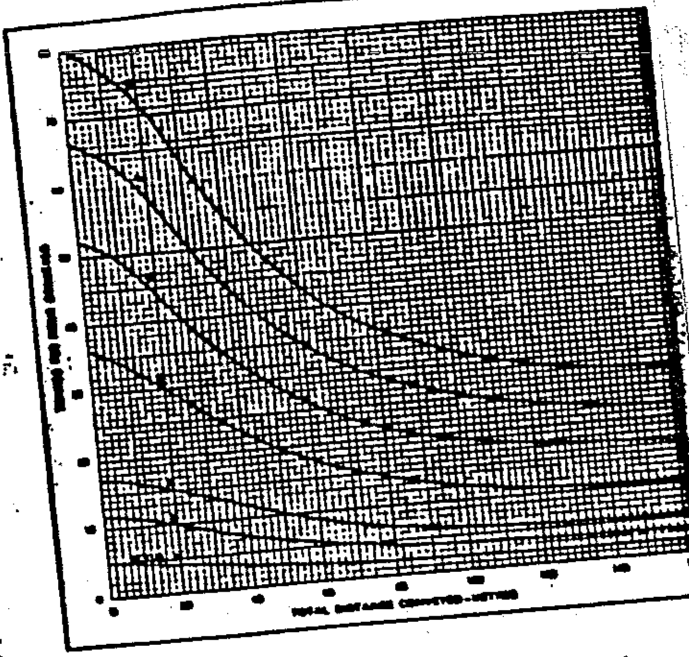
Technical Requirements

The technical requirements and operating capability of the foundry pneumatic conveyor differs from material application to material application. Broadly these may fall into four general categories which, together, embrace the needs of the green sand plant based foundry.

Dry sand technical requirements are most easily met by the pneumatic conveyor. The need to transfer dry sand from one point in a foundry to another without creating dust and spillage and without regularly producing pipes or bends with holes, is the least demanding application for the correct system design. A system is more likely to succeed in this simple, although abundant application area, if it is able to provide the foundry manager with a clear forecast of the capability of the equipment and corresponding power absorbing requirements (fig. 2).

Prepared moulding sand handling requirements concern the need to transfer reliably and regularly a material that, even in the best equipped foundries, will vary in mechanical properties due to variations in additions content and/or moisture content. The operating tolerance due to the mechanical properties variation of sand in a moulding machine may be quite different to the degree of tolerance accepted by the pneumatic conveying system and the pneumatic conveying design that does not take this into consideration is not meeting the operational requirements set out earlier (fig. 3).

The same requirements apply to knock-out sand and return sand applications with the added variation of temperature changes and an uncontrolled moisture condition.



POWER REQUIREMENTS

MODEL NO	Air Consumption at Maximum Pumping Rate M³/Min	Conveying Line Size MM	Air Supply [...] Size (Bor[e]) MM
2	1,58	50	25
3	2,12	75	38
4	3,40	100	38
8	5,95	125	50
12	10,96	150	50
16	11,30	175	63
20	14,15	200	63

NOTES

1. Air supply to be at 5, 6 kg/cm².
2. Allowances included for bends.
3. Conveying distance includes horizontal plus [...] lengths.
4. Reception Hopper dust suppression filters [...] mended.
5. Special conveyor tubing *not* required.

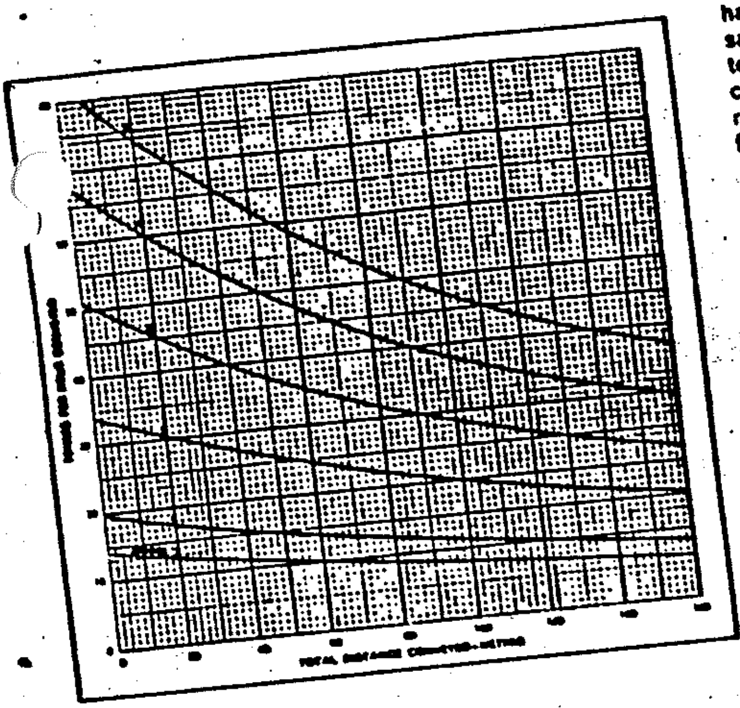
MATERIAL SPECIFICATION

Sand, bulk density: 1520 kg/m³.
Moisture Content: nil – 1%.
Grain Size: 0, 1mm – 3mm any distribution.

Fig. 2. Dry Sand Handling Performance Data.

Both these variables considerably affect the [...] property of the sands and an understanding [...] haviour in the pneumatic conveying system [...] carefully considered by the foundrymen.

A fourth area of technical requirements to be [...] would have particular interest to the foundry [...] committed to the application of pneumatic con[veying] handling pr[...] foundry. This area concerns handling [...] (return sand, new sand and additions) from [...] mill. This application area is of considerable [...] the foundryman contemplating the need f[...] ductivity from his batch mixer since it has b[...]



POWER REQUIREMENTS

MODEL NO	Air Consumption at Maximum Pumping Rate M³/Min	Conveying Line Size MM	Air Supply Line Size (Bore) MM
3	3,56	75	25
4	4,15	100	32
8	6,53	125	38
12	8,90	150	50
16	10,97	175	50
20	13,36	200	50

NOTES

1. Air supply to be at 5, 6 kg/cm².
2. Allowances included for bends.
3. Conveying distance includes horizontal plus vertical lengths.
4. Reception Hopper dust suppression filters not necessary.
5. Special conveyor tubing *not* required.

MATERIAL SPECIFICATION

Material Bulk Density: 1410 kg/m³.
Moisture Content: 10% described as wet sharp coarse sand during washing and grading.

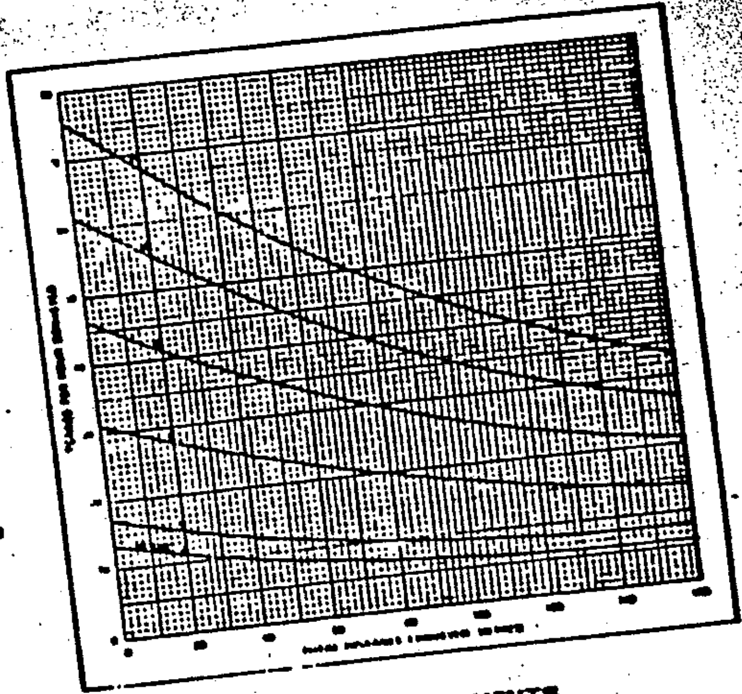
Fig. 3. Prepared Sand Handling Performance Data.

mixing times may be reduced and at the same time, mixing efficiency improved, by achieving a preblend in the pneumatic conveying system feeding the mixer. This application in the green sand preparation plant forms the link in the series of applications shown in Fig. 1, to provide a very high degree of plant efficiency, cleanliness and space and other accumulated benefits of the pneumatic

handling wet sand since most foundries here dry their own sand. The technical requirements here concern the ability to handle sand with varying moisture contents and the chief benefit arising relates to equipment maintenance reduction and plant design flexibility rather than savings from dust and spillage. (Fig. 4).

PNEUMATIC CONVEYING SYSTEM DESIGN

The foundryman is not expected to be an expert in pneumatic conveying but a general appreciation of the design



POWER REQUIREMENTS

MODEL NO	Air Consumption at Maximum Pumping Rate M³/Min	Conveying Line Size MM	Air Supply Line Size (Bore) MM
3	3,40	75	25
4	3,96	100	32
8	6,23	125	38
12	8,50	150	50
16	10,48	175	50
20	12,75	200	50

NOTES

1. Air supply to be at 5, 6 kg/cm².
2. Allowances included for bends.
3. Conveying distance includes horizontal plus vertical lengths.
4. Reception Hopper dust suppression filters not required.
5. Special conveyor tubing *not* required.

MATERIAL SPECIFICATION

Material Bulk Density: 1202 kg/m³.
Moisture Content: 3 – 4%.
Shatter: 75 – 85%.
Green Compression Strength: 41 – 56 kPa.
Flowability: 70 – 80%.

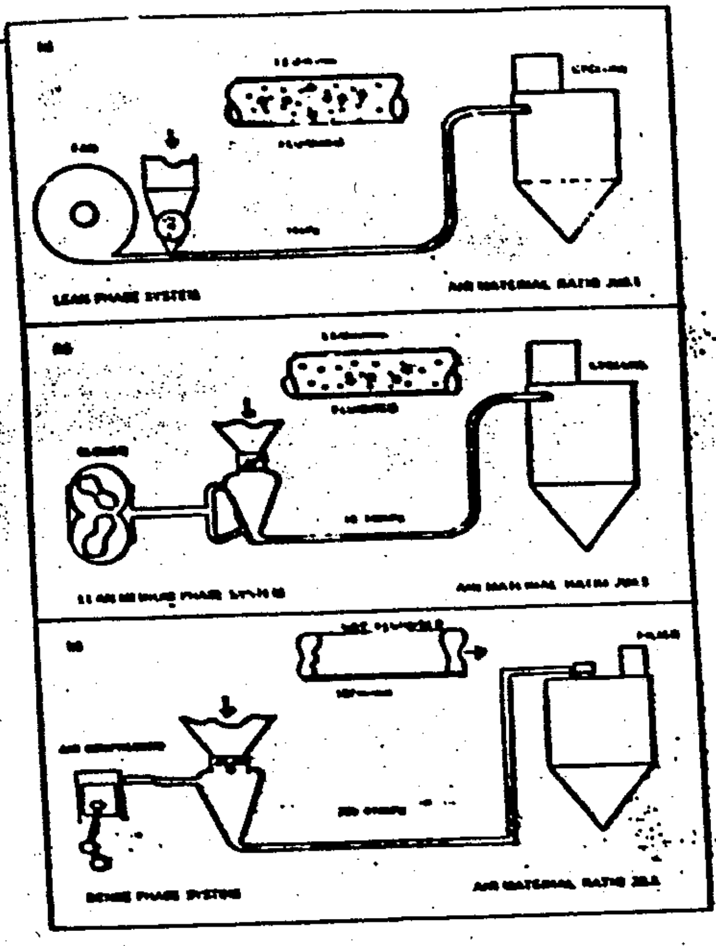


Fig. 5. Schematic of Basic Pneumatic Conveyor Types.

types and general pneumatic conveying theory will considerably help his ability to assess a particular systems capability to meet his needs.

Referring to Fig. 5., will show differences in operating method and illustrate the basis of the three main pneumatic conveying system design groups. All three methods and other variations of them, are widely used in various industries to good effect. We are however, fundamentally concerned with the special needs of sand conveying.

Section (a) shows the principle of the lean-phase system which relies on mixing air and sand together to maintain a fluidised condition in the pipeline from the point of introduction to the point of reception. This arrangement is an almost exact replica of much earlier designs used commonly in other industries not concerned with abrasive materials and remains the only method of handling sand from road tanker vehicles into storage hoppers. This method of pneumatic conveying sand causes extremely high material speeds in the pipeline, as well as a very high degree of inter-granular activity. This arrangement does not attempt to overcome very high wear problems and provides an additional problem at the reception hopper where it is necessary to separate the high volumes of air from the sand that is being conveyed.

Section (b) shows a later development of the lean-phase system in which a pressure vessel was applied to transfer batches of material from the point of introduction to the reception hopper. This method attempted to reduce the volume of air used to transfer the material in an attempt to slow the material speed and to reduce the amount of inter-granular activity. However, although higher air pressure vessel designs and vessel filling valve designs, did not achieve the desired handling characteristics of material and the problem of high speed and, therefore, high wear rate remains.

Section (c) is a schematic arrangement which describes the dense-phase pneumatic handling system which has been successfully applied to the special needs of sand and other abrasive materials. With this arrangement, a pressure vessel is employed and a source of high pressure is obtained from an air compressor. A valve filling design has been prepared to incorporate the dual requirements of the filling valve which are:

(i) Material supply shut-off through a static head of sand.
(ii) Creation of air tight seal between the pressure vessel and the material supply.

A method of air supply and modulation has been provided which is arranged to extrude the sand slowly into the pipeline without causing fluidisation and in a way that allows the air to expand behind the material thus providing the motive power at a controlled rate. The control of air supply during conveying prevents uncontrolled sand speed which would lead to fluidisation of the sand developing as the sand moved further along the pipeline. Consequently a controlled sand speed maintains the 'plug' identity of the charge during conveying and prevents high inter-granular activity.

SUITABLE DESIGN FOR FOUNDRIES.

From the preceding section it becomes obvious that the dense-phase pneumatic conveying system goes a long way to satisfy the special requirements outlined earlier. The important features of the dense-phase pneumatic conveying principles are incorporated into one widely used design in the following way:

A carefully prepared vessel design allows the introduction of high pressure air into the material chamber in a way that prevents fluidisation and contains the high pressure air behind the solid 'plug' of material. The speed is controlled by modulating the supply into the material chamber during the conveying period up until the time that the plug of material enters the reception hopper.

The combined action of material supply shut-off through the static head of sand and the formation of an air tight seal between the supply chute above and the pressure vessel are achieved with a purpose designed dome valve, (fig. 6). The dome valve is designed to operate in this way with sand

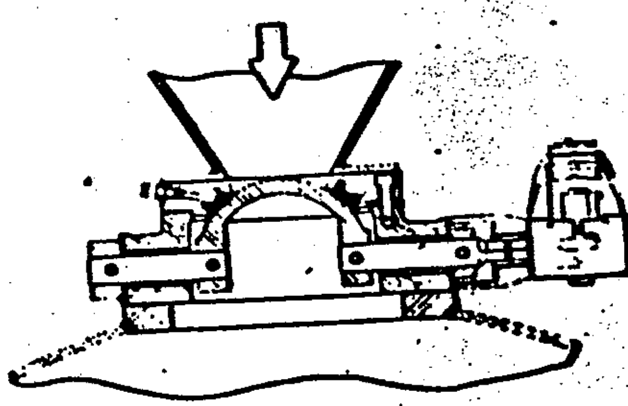


Fig. 6. Cut Away Section of Dome Valve.

and other large granular material of an abrasive nature. Applications, therefore, involving the handling of return sand containing core lumps, are within the capability of the valve. The dome valve seal forms part of a top sealing plate which is easily removable for maintenance inspection.

The seal is rated for 100 000 cycles of operation between maintenance inspections and the seal which is bonded into the top plate metal may be replaced by remoulding without the need to replace the component completely.

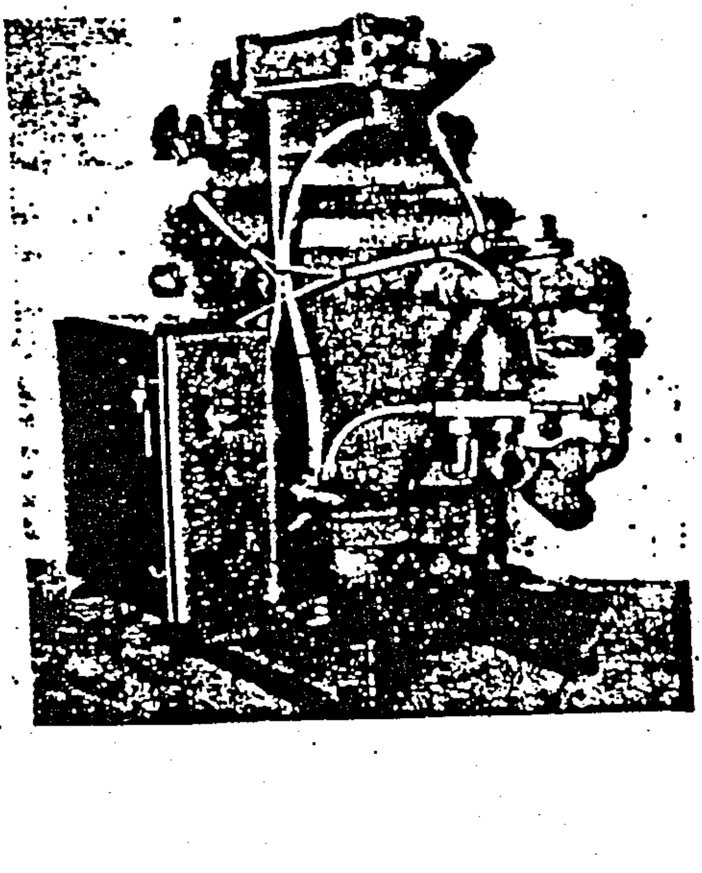
Sand Speed

The design being discussed effectively controls the sand speed to an extent which enables the use of right angle bend fittings in the conveying pipeline in place of the more commonly used long radius reinforced bend. The bend fitting deflects the material through 90° (or other angles) without the need to provide heavy reinforcing pads. The bend fittings are of light fabrication that may be easily handled to make installation of the pipe system simple. The entire pipework distribution system is manufactured from standard mild steel tubing using simple flange connections and without requiring special alignments during erection.

The use of boosters in the conveying pipework, common with fluidising systems are unnecessary since the controlled speed of the material is maintained without using this destructive facility.

The low air material ratio employed in the system overcomes the need for ineffective cyclones and the low volume of conveying air can be effectively filtered into the atmosphere through standard bin vent units. The bin vent units are self contained and maintenance free and are not subject to wear in the way in which the cyclone is effected, since the conveyed material does not pass through the filter as it does with the cyclone.

Use is made of existing air supply services normally available in the foundry. Only one connection to the unit conveyor is required (Fig. 7) from which both conveying air and self contained control air is taken. The unit is equipped with its own system control panel and is a packaged system free standing on its own chassis ready for connection to air supply services and to conveying pipeline.



Time Lapse

One of the most important features of the dense-phase pneumatic conveying system when applied to multi distribution applications concerns the period of time during which conveying in the pipeline is not taking place. During this period the material chamber of the unit is receiving sand by gravity feed from the supply above and the conveying pipeline is at atmospheric pressure. During this period the distribution valves in the pipeline are automatically reset to enable the next supply of material to be routed to the point in the system required. All these systems are automatic in operation and in the distribution of material in multi-hopper reception arrangements.

This distribution system employs a dump valve for the purpose of depositing sand into the reception hopper or allowing its onward movement to subsequent points. The same principle involving use of bonded seals is employed to achieve air tight conveying pipelines and avoid dust entering the valve casings.

Five Hoppers

One successful installation handles prepared moulding sand from the sand mill to five reception hoppers. Each reception hopper is fitted with a single high level probe and each hopper provides a demand signal to the system control when further supplies of sand for moulding are required.

The supply hopper above the dense-phase unit is fe[d] automatically from the Mill above. Located in the supp[ly] hopper are two level probes – one extending to the base o[f] the supply hopper which provides the signal to the unit t[o] stop cycling when sand is no longer available for transfe[r]. The other probe is located towards the top of the supp[ly] hopper and provides the signal to the mill to prevent th[e] mill emptying when there is a danger of overfilling in th[e] hopper occurring.

The control arrangement for the prepared sand distribution system is incorporated in the mill which has be[en] fitted with an automatic cycling control in order to achie[ve] maximum output from the mill and from the distributi[on] system.

The scheme described has, since installation, be[en] extended to feed two further storage hoppers without a[ny] changes to the system or the control arrangement.

ECONOMICS – COST COMPARISONS

The considerable benefits of dense-phase pneumatic co[n]veyors as outlined in the foregoing cannot be achie[ved] without some cost.

The cost of these benefits concern the additional po[wer] that is required to generate the compressed air used in [the] system. The penalty arising from the additional power c[ost] is substantial when considered alone and in compari[son] with the power cost for comparable mechanical hand[ling] plant.

However, despite the fashionable cause surround[ing] power savings at the present time, there are consider[able] benefits to be achieved when all operating costs are t[aken] in together. An analysis of total operating costs are the[re]fore shown in Table 1 on the next page, based on a sys[tem] that has been installed for a period of five years and w[here] records have been made of maintenance costs and po[wer] costs.

We are able to show therefore that despite the penal[ty of] additional power costs there is a nett gain in ave[rage] running costs to the extent, in this example, of more [than] 20% over mechanical plant.

SCOPE AND FUTURE DEVELOPMENT

It is evident that foundry pneumatic conveyors are he[re to] stay. Earlier unsuccessful attempts to provide the d[...]

to good effect, encouraged a healthy scepticism.

However, the fundamental problems of overcoming high wear rates and proving operating reliability have been achieved with the dense-phase pneumatic conveying system. Its general acceptance has opened the way ahead for further development, in handling applications which involve separation between metal, re-useable sand and waste sand. Success in this application area will eliminate one of the most difficult dust producing areas in the foundry at the point of knock-out.

The continuing development and use of automatic moulding machines also encourages the use of green sand pneumatic conveyors, which require a regular supply of sand in good condition received from the mixer automatically.

Social pressures will demand continuous improvements in the foundry working environment and as a consequence in the not too distant future, it is confidently expected that pneumatic conveyors will become the normal method of handling foundry sand at all stages of processing.

TABLE I

Cost* Comparisons with Mechanical Handling

Application: Dry Sand 15 tons/hour to 2 reception hoppers. 2 shift operation 16 hours/day.
Total conveying distance 30m with 90° bend in horizontal. Installed 1970.

1. Capital Cost

Mechanical		Pneumatic	
Bucket Elevator, Belt Conveyor, Supporting Steelwork.	£9800	Model 4 Dense-Phase system with automatic controls and air compressor.	£7000
Installation	£3300		£1500
Total.	£13100	Total.	£8500

2. Power Cost

Mechanical	Pneumatic
2 x 3kW and 1 x 9kW Motors Total 15kW = 15 kW. hrs. Approx. £2.40/day £ 720/year	Air compressor rated at 26 kW = 26 kW. hrs. Approx. £ 4.17/day £ 1251/year

3. Maintenance Cost – Over 5 year period

Mechanical		Pneumatic	
Replaced bearings, belt gearbox and elevator chain		Replaced sealing head and one bend	
Total.	£2100	Total.	£ 250

Average Annual Running Cost:

	Mechanical	Pneumatic
Capital Depreciation	£2620	£1700
Power Cost	£ 720	£1251
Maintenance	£ 420	£ 50
	£3760	£3001

**As this table refers to British practice, the sterling costs have been retained.*